European Fitness Landscape in Children and Adolescents: updated reference values, fitness maps, and country rankings based on nearly 8 million data points from 34 countries gathered by the FitBack network

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ABSTRACT

Objectives: (1) To develop reference values for health-related fitness European children and adolescents aged 6–18 years that are the foundation for the web-based, open-access and multi-language 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 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 GAMLSS method.

Results: A total of 7,966,693 data points from 34 countries (106 datasets) were used to develop sex- 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 at www.fitbackeurope.eu.

Conclusions: This study discusses the major implications of fitness assessment in youth from a health, educational and sport perspective, 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.

What is already known on this topic

- Fitness testing in youth is important from a health, educational and sport point of view.
- The EU-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 6-to 18-year-old Europeans.
- This study introduces the first web-based, open-access, and multi-lingual 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 the individual and group level (e.g., school, 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 the 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.

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 health-related [3,4]. Other fitness components include muscular endurance, 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- 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. 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 whole brain size, as well as total gray and white matter volumes, is larger in fit compared to unfit children with overweight/obesity [30]. This is important because brain size is positively associated with intelligence [31].

This evidence begs the question: what are the best methods to assess health-related fitness among children and adolescents? The EU-funded ALPHA project was designed to answer this question. By conducting a set of systematic reviews [2,32,33] and methodological papers, the ALPHA consortium aimed to identify which field-based fitness tests demonstrated the highest test-retest reliability, criterion/construct validity, and health-related predictive validity (see ALPHA summary article [34]). Anthropometry and body composition were 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. A year later and after following a similar systematic review process, the U.S. Institute of Medicine (now the National Academy of Medicine) recommended these tests for the assessment of youth physical fitness [35,36], strengthening the recommendation of using these selected tests.

The EU-funded the FitBack consortium (www.fitbackeurope.eu) titled 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]. 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"[38]. 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 physical activity and physical fitness levels of their students not only in the short term, but also by instilling values and skills that will help children throughout their lives.

The final output of the FitBack project has been the development of a web-based, open-access, and multi-language fitness platform, which allows the results of fitness testing to be automatically and interactively interpreted based on sex- 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, accumulating 8 million data points to create reference values for European children and adolescents aged 6 to 18 years.

The aim of this article is to present the most comprehensive and up-to-date health-related fitness reference values for European children and adolescents. Additionally, we provide European fitness maps for the main health-related fitness components. Since pediatric obesity is being comprehensively monitored by other organizations (e.g., 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 supplementary material.

METHODS

Data search and pooling

A systematic review of existing data sets including fitness tests in children and adolescents was previously performed by Tomkinson et al. and details of the search have been published [39]. These data were included in the FitBack dataset, with Monte Carlo simulation used to produce pseudodata (from reported means and SDs) when raw data were unavailable. In addition to this, the authors of the FitBack network conducted a narrative search based on fitness terms to identify new datasets not included in the Tomkinson et al. review [39]. 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-to 17-year-olds, whereas in this study we widened the age demographic to include 6-to 18-year-olds. It is important to note that our search strategy was fitness focused, and specific searches on adiposity, BMI, or waist circumference were not conducted for pragmatic reasons (e.g., 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 organizations are comprehensively monitoring pediatric 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 supplementary material.

The FitBack network involved many experienced researchers working in pediatric fitness across Europe, which helped to identify unpublished fitness datasets that were pooled with the gathered data. Moreover, massive data from existing surveillance systems in Europe 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 Supplementary Table 1**. The entire Fitback procedures for pooling together existing fitness data were evaluated and approved by the Ethics Committee in Sports Science at the University of Ljubljana, Slovenia (the University coordinator the FitBack project).

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 [40], NETFIT [41], and Fitescoula [42]. Specifically, CRF was assessed using the 20-m shuttle run test [43]. 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 [44]. All data were converted and harmonized into completed stages according to the original Léger's protocol [43], as described elsewhere [44]. Muscular strength was assessed by the handgrip strength (i.e., upper-limb muscular strength) and standing long jump tests (i.e., lower-limb muscular strength). Total and abdominal adiposity were assessed by BMI and waist circumference, respectively, following standardized procedures. For handgrip, most studies collected data from both hands, with the average of the maxima for 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 to the non-dominant hand. Exploratory analyses on Spanish data in children [45] 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), sex, and their interaction as independent variables was fitted. Studentized residuals were obtained and then 0.01% subjects with the smallest and largest studentized residuals were removed from further analysis. Weights were computed via iterative post-stratification (aka iterative proportional fitting) [46] 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 [46].

Centile curves and reference values were developed using Generalized Additive Models for Location, Scale and Shape (GAMLSS) [47]. Several continuous (Box-Cox Cole and Green (BCCG), Box-Cox power exponential – BCPE, Box-Cox-*t* – BCT, generalized inverse Gaussian) distributions were fitted to the data, optimizing the degrees of freedom (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 [48]. 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 version 3.6.3) [49]; GAMLSS were fitted using R package GAMLSS [50]; post-stratification weights were obtained using R package survey [50]. The best fitting model for each test is presented in **Online Supplementary Table 2.**

RESULTS

After cleaning and removing outliers, 7,966,693 data points 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 representing 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 data points) 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 to 3**) and corresponding percentile curves (**Figure 1**). Reference values for body height, body mass, BMI, and waist circumference are presented in **Online Supplementary Tables 3 to 6**, and **Online Supplementary Figures 1 and 2**. Percentile curves for CRF and muscular strength are higher for boys compared to girls across all ages, with differences increasing with age. The age-related increase in fitness-performance tends to stabilize from age 14 to 15 years onwards. Variation between the fittest (e.g., percentiles 90–99) and least fit (e.g., percentiles 1–10) is larger for boys compared to 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 Supplementary 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 color 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 Supplementary 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 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

Summary of findings

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 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, children with higher CRF levels generally had higher muscular strength levels. A major contribution of our study is that it comes together with the FitBack 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. The FitBack platform provides individual and group-based fitness reports supported by educational materials for implementation of fitness monitoring to support fitness education (i.e., 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 best available fitness reference values for a large sample of European children and adolescents were those published by Tomkinson et al. in 2018 [39]. Our study updates such work, by expanding the Tomkinson et al. data set [39] and updating the CRF and muscular strength reference values with more recent and representative data for each country.

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 [51]. 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 insight 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 (e.g. the 20m 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 pediatricians and school doctors/nurses. Such practice has been implemented at the regional level in Galicia, Spain [52], and at the national level in Slovenia [40] and Finland [53]. 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 level. For instance, policy makers at education, sport, and health institutions can obtain valuable information about regional differences or temporal trends by monitoring fitness levels over time and use these reference values and the FitBack tool for proper sex- and age-specific interpretation.

In fact, fitness monitoring could 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 [54,55]. Thus, timely interventions for specific target groups can be implemented.

Second, fitness monitoring is part of physical education curricula in many European countries, but most European physical education teachers do not currently have access to an easy-to-use and automatic tool for interpreting sex- 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. Enhancing physical fitness through goal setting and an appropriate physical activity program, and tracking changes through fitness monitoring, may improve students' physical literacy journey. Those with better fitness education may be more attuned with their body and what is required to function well, 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 [42,56]. Youth who have fitness levels above the 90thpercentiles 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- and age-specific percentile bands to identify expected, better than expected, or worse than expected developmental changes.

Limitation and strengths

While the FitBack network gathered 8 million data points 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-age youth. Other countries such as Greece [57] and Poland [58] 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. Important contributions from our study and the FitBack network include: (1) increased awareness around the importance of fitness surveillance and monitoring, (2) the identification of countries that have access to large fitness databases, and (3) to facilitate fitness testing and interpretation through the FitBack platform, which we hope will improve the amount, quality, and availability of future fitness data. Unfortunately, included fitness data were collected at different times and temporal trends in fitness may have biased our results. To minimize the potential for bias, old data collected in 1980s were excluded from our analyses, with 95% of our data points collected since 2000 (see

Online Supplementary Table 1). Only harmonized cross-country testing at the same time will provide the most accurate comparisons. While not nationally representative, the HELENA study collected harmonized fitness data in 2005–08 across 10 European cities, and the results suggested that adolescents living in Southern Europe (Spain, Italy, Greece) had lower levels of CRF and muscular strength, as well as more total and central adiposity, than their peers living in Central-Northern Europe [59]. These findings are consistent with the FitBack results hereby presented, and are in line with previous reports[60,61]. 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.

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, videos) needed to evaluate youth health-related fitness levels in a standardized 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- 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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Table 1. Reference values (centiles) 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=1,063,591)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources

Table 2. Reference values (centiles) 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=827,585)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

Table 3. Reference values (centiles) for muscular strength as assessed by the standing long jump test (expressed in cm) in European children and adolescents (N=1,384,856)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	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 yrs	118.	149.	162.	177.	187.	195.	203.	210.	218.	227.	240.	251.	274.

	6	1	8	7	7	9	4	8	6	8	7	8	4
17.0-17.9 yrs	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 yrs	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 Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

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

20m Shuttle run test

		Both		Girls		Boys	
	N	Centile	Rank	Centile	Rank	Centile	Rank
ISL	6127	81.3	1	85.2	1	77.7	1
NOR	2302	75.3	2	76.5	2	74.2	2
SVN	4752	73.0	3	75.9	3	70.2	4
DEN	9178	68.9	4	67.7	5	70.8	3
FIN	2077	66.5	5	68.8	4	63.8	5
FRA	11627	61.4	6	61.0	8	61.9	7
CYP	1058	61.0	7	63.7	6	58.6	10
SLO	4709	60.8	8	59.1	11	62.1	6
CZE	1561	60.7	9	63.2	7	58.4	11
GER	1968	59.3	10	60.5	9	58.2	13
IRE	1055	59.0	11	59.8	10	58.2	12
BEL	19623	57.8	12	54.8	14	60.5	8
SWI	3699	56.7	13	54.7	15	58.7	9
LIT	8397	56.3	14	57.6	12	55.0	16
UK	40841	55.7	15	53.5	17	57.7	15
CRO	595	55.5	16	52.5	18	58.1	14
SWE	950	52.3	17	54.8	13	49.4	19
EST	4647	51.1	18	53.7	16	48.6	20
SPA	25877	48.3	19	46.4	22	50.2	17
POR	30265	47.1	20	44.3	23	50.0	18
POL	45925	46.9	21	48.1	20	45.8	22
AUS	270	46.4	22	49.1	19	43.7	24
ITA	4084	44.6	23	43.1	24	45.9	21
HUN	593803	44.6	24	47.6	21	41.7	25
GRE	176056	44.1	25	42.7	25	45.4	23
KOS	741	39.1	26	41.3	26	37.2	27
MCD	1011	38.0	27	36.2	28	39.7	26
SRB	18772	36.4	28	36.5	27	36.4	28
LAT	3264	30.1	29	28.6	29	31.4	29
BIH	843	26.3	30	24.2	30	28.3	30
ALB	-	-	-	-	-	-	-
BUL	-	-	-	-	-	-	-
LUX	-	-	-	-	-	-	-
NET	-	-	-	-	-	-	-
N	1026077						

Handgrip strength

		Both		Girls		Boys	
	N	Centile	Rank	Centile	Rank	Centile	Rank
SLO	4648	75.4	1	74.8	1	75.8	1
DEN	5938	64.7	2	64.2	3	65.2	2
NET	1713	64.6	3	68.3	2	60.8	6
BEL	18012	61.2	4	60.6	4	61.9	4
LIT	3188	60.1	5	56.4	6	64.4	3
KOS	742	57.6	6	52.9	10	61.7	5
GER	1399	55.9	7	59.9	5	52.0	11
POL	47061	55.8	8	53.2	9	58.2	7
HUN	614569	54.4	9	55.2	7	53.7	9
SVN	4828	54.1	10	54.3	8	54.0	8
BUL	497	51.5	11	49.3	13	53.6	10
EST	1681	51.4	12	52.5	11	50.3	14
AUS	389	50.6	13	49.6	12	51.6	12
MCD	7177	48.8	14	46.0	18	51.4	13
CYP	1204	47.8	15	47.6	15	48.0	15
SWE	2719	46.1	16	45.0	19	47.2	16
POR	7199	45.8	17	47.8	14	43.7	18
GRE	688	45.4	18	46.7	16	43.9	17
ISL	387	44.1	19	46.4	17	42.2	19
LAT	7743	42.3	20	42.5	21	42.1	20
UK	23373	42.3	21	42.9	20	41.6	21
IRE	1149	40.3	22	40.6	22	40.0	24
FRA	813	40.1	23	38.8	25	41.5	22
ITA	5768	39.9	24	39.3	24	40.4	23
SPA	23097	39.3	25	39.6	23	39.0	25
ALB	1984	17.7	26	16.4	26	18.8	26
BIH	-	-	-	-	-	-	-
CRO	-	-	-	-	-	-	-
CZE	-	-	-	-	-	-	-
FIN	-	-	-	-	-	-	-
LUX	-	-	-	-	-	-	-
NOR	-	-	-	-	-	-	-
SRB	-	-	-	-	-	-	-
SWI	-	-	-	-	-	-	-
N	787966						

Standing long jump

		Both		Girls		Boys	
	N	Centile	Rank	Centile	Rank	Centile	Rank
ISL	6589	72.4	1	74.7	1	70.2	1
CZE	439	69.1	2	72.0	2	66.2	3
BUL	497	68.0	3	67.1	5	68.9	2
SVN	211629	66.5	4	68.4	4	64.7	5
FIN	1393	66.0	5	67.1	6	64.9	4
CRO	22135	65.9	6	70.1	3	60.7	8
SLO	5163	65.2	7	66.3	7	64.4	6
SWI	2982	64.4	8	64.6	8	64.2	7
EST	4997	61.5	9	62.8	9	60.2	9
LIT	12158	58.6	10	58.5	11	58.7	10
NOR	2490	58.5	11	61.2	10	55.9	11
AUS	595	56.2	12	57.5	12	54.8	12
BEL	19161	55.5	13	56.7	13	54.3	14
LAT	7743	54.6	14	54.5	15	54.7	13
SWE	1076	53.4	15	53.4	16	53.4	15
GER	5999	53.4	16	54.6	14	52.2	18
POL	47326	52.3	17	51.2	20	53.3	16
LUX	1128	51.5	18	52.9	18	50.4	21
HUN	604114	51.4	19	53.1	17	49.8	22
ITA	21448	51.4	20	51.8	19	50.9	19
FRA	32943	51.3	21	50.3	21	52.3	17
CYP	1193	49.5	22	48.1	23	50.8	20
ALB	2114	47.4	23	49.4	22	45.7	25
GRE	256826	44.7	24	42.9	26	46.5	23
SRB	20341	44.4	25	43.0	25	45.9	24
SPA	27218	42.9	26	42.3	28	43.4	27
POR	7715	42.5	27	40.2	30	44.9	26
IRE	1158	41.8	28	43.5	24	40.1	30
UK	13981	41.3	29	40.8	29	41.9	28
KOS	742	40.8	30	42.9	27	39.0	31
BIH	843	39.2	31	36.5	31	41.6	29
MCD	1023	34.6	32	32.8	32	36.3	32
DEN	-	-	-	-	-	-	-
NET	-	-	-	-	-	-	-
N	1345159						

Overall

	Avg. Rank MS	Avg. Rank CRF	Rank MS &CRF	Overall Fitness Ranking
DEN	2.0	4.0	3.0	1
NET	3.0	-	3.0	1
FIN	5.0	5.0	5.0	2
SVN	7.0	3.0	5.0	2
CZE	2.0	9.0	5.5	3
ISL	10.0	1.0	5.5	3
SLO	4.0	8.0	6.0	4
NOR	11.0	2.0	6.5	5
BUL	7.0	-	7.0	6
BEL	8.5	12.0	10.3	7
SWI	8.0	13.0	10.5	8
GER	11.5	10.0	10.8	9
LIT	7.5	14.0	10.8	9
CRO	6.0	16.0	11.0	10
CYP	18.5	7.0	12.8	11
FRA	22.0	6.0	14.0	12
EST	10.5	18.0	14.3	13
SWE	15.5	17.0	16.3	14
POL	12.5	21.0	16.8	15
AUS	12.5	22.0	17.3	16
IRE	25.0	11.0	18.0	17
LUX	18.0	-	18.0	17
HUN	14.0	24.0	19.0	18
UK	25.0	15.0	20.0	19
POR	22.0	20.0	21.0	20
KOS	18.0	26.0	22.0	21
SPA	25.5	19.0	22.3	22
ITA	22.0	23.0	22.5	23
GRE	21.0	25.0	23.0	24
LAT	17.0	29.0	23.0	24
ALB	24.5	-	24.5	25
MCD	23.0	27.0	25.0	26
SRB	25.0	28.0	26.5	27
BIH	31.0	30.0	30.5	28

MS, muscular strength; CRF, cardiorespiratory fitness; N, sample size and total sample size at the bottom of the table. The 3-digit country codes were used to abbreviate the full country names https://en.wikipedia.org/wiki/List_of_UNDP_country_codes as follows: ALB, Albania;

AUS, Austria; BEL, Belgium; BIH, Bosnia and Herzegovina; BUL, Bulgaria; CRO, Croatia; CYP, Cyprus; CZE, Czech Republic; DEN, Denmark; EST, Estonia; FIN, Finland; FRA, France; GER, Germany; GRE, Greece; HUN, Hungary; ISL, Iceland; IRE, Ireland; ITA, Italy; KOS, Kosovo; LAT, Latvia; LIT, Lithuania; LUX, Luxembourg; NET, Netherlands; MCD, North Macedonia; NOR, Norway; POL, Poland; POR, Portugal; SRB, Serbia; SLO, Slovakia; SVN, Slovenia; SPA, Spain; SWE, Sweden; SWI, Switzerland; UK, United Kingdom.

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- 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 EU reference values. Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

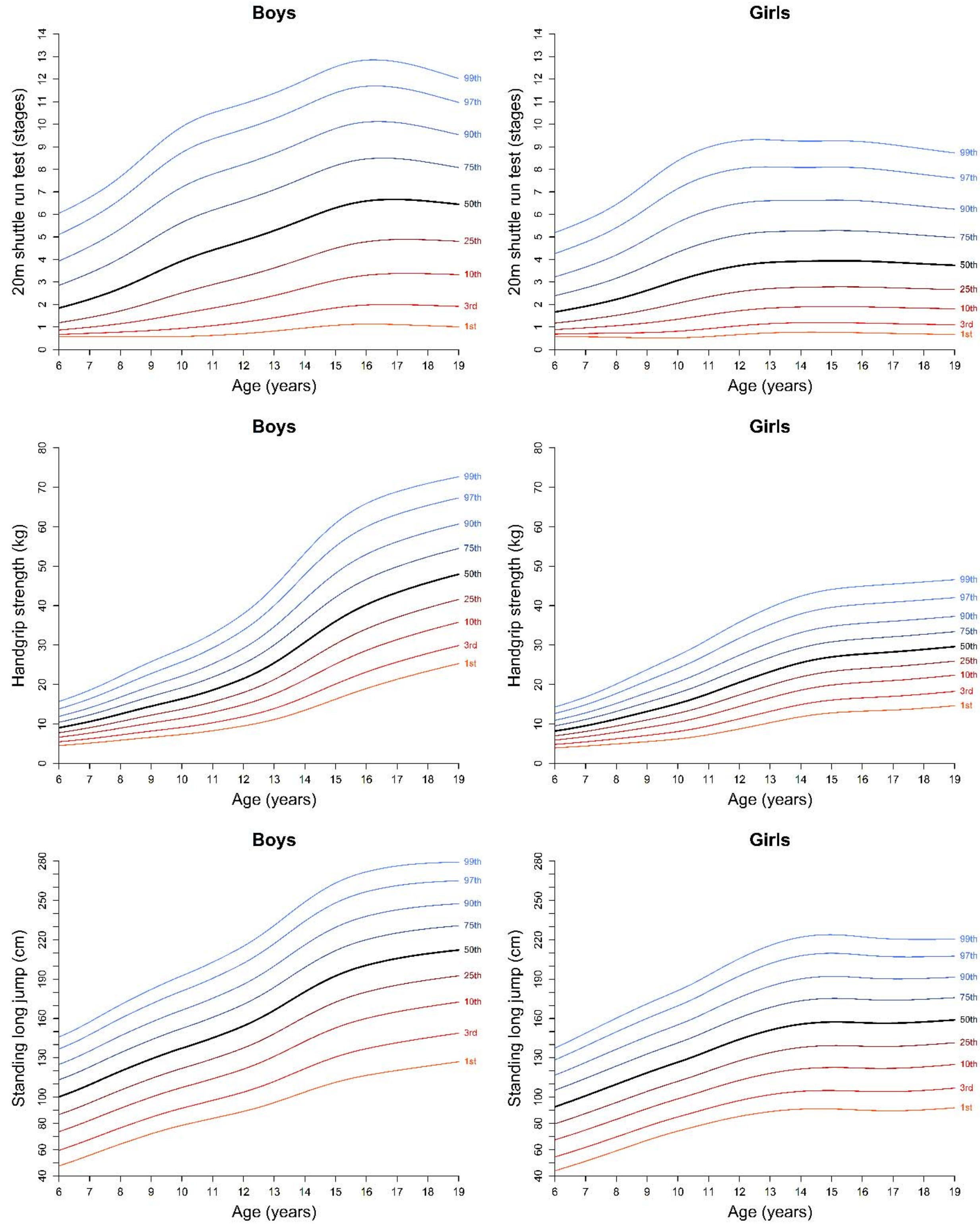


Figure 1. Percentile curves for cardiorespiratory and muscular strength tests among European children and adolescents.

Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) method and weights were applied according to country population. Data sources are available at: https://www.fitbackeurope.eu/en-us/fitness-map/sources.

EU cardiorespiratory fitness landscape (20-m shuttle run test) | EU muscular strength landscape (Handgrip test) | EU muscular strength landscape (Standing long jump test)

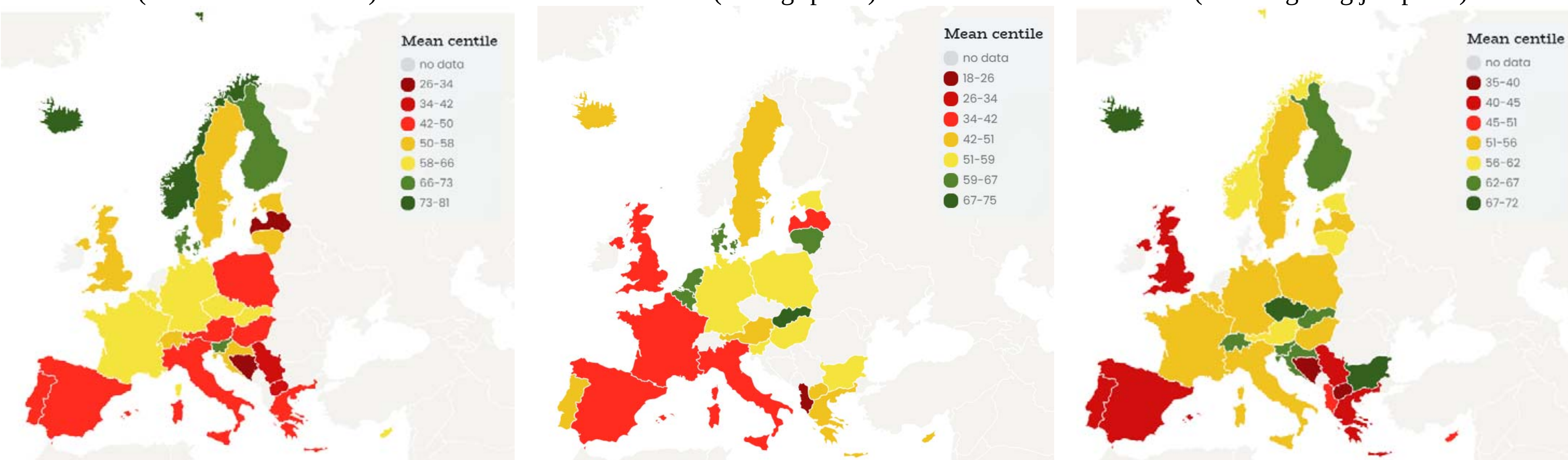


Figure 2. European fitness maps for cardiorespiratory and muscular strength in children and adolescents.

Sex- 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 EU reference values. Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: 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 this study and in the platform. Data sources are available at: www.fitbackeurope.eu/en-us/fitness-map/sources.

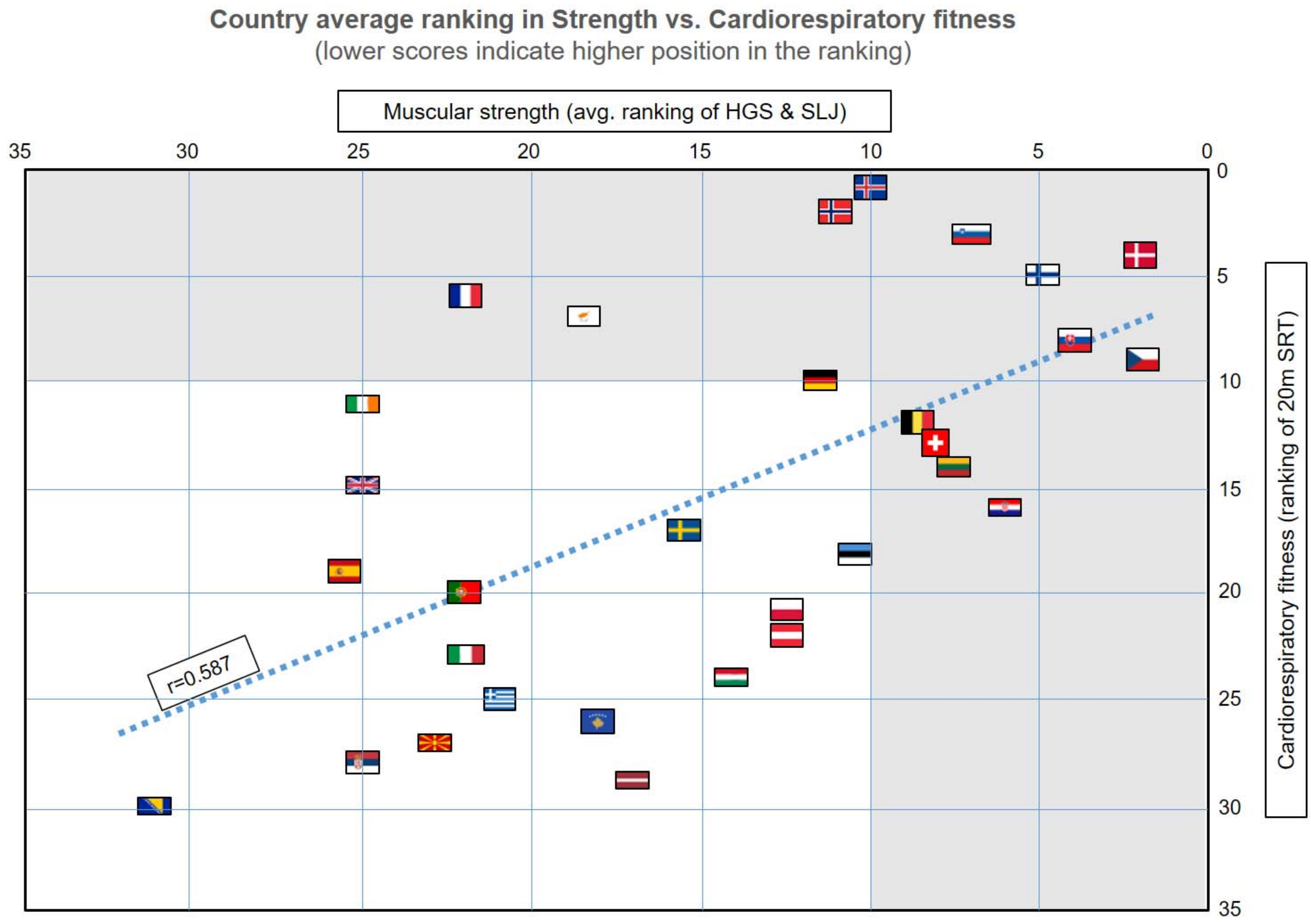


Figure 3. Country average ranking in muscular strength and cardiorespiratory fitness in European children and adolescents. HGS indicates handgrip strength test; SLJ, standing long jump test; 20mSRT, 20-m shuttle run test.

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.
Gray shaded areas indicate countries ranked in the top-10 for either muscular strength, cardiorespiratory fitness, 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 in either missing muscular strength or cardiorespiratory fitness data. 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

ONLINE SUPPLEMENTARY MATERIAL

Online Supplementary Table 1. Summary of the sources used for generating the FitBack reference values and centiles.

				Sample size					
Country	**Year of testing**	**% male**	**Age (years)**	**BMI**	**WC**	**20mSRT**	**SLJ**	**HGS**	**Reference**
Albania	1994-95	53.7%	10–18	2,115			2,114	1,984	Markola et al. 1997 *
Austria	2006-08	48.9%	13–18	425	415	269	390	388	Ortega et al. 2011
Austria	2015-17	48.0%	8–10	204			204		Greier et al. 2019
Belgium	2006-08	46.4%	13–18	343	337	332	334	337	Ortega et al. 2011
Belgium	2007	53.0%	6–14	2,893	2,689	2,373	2,795	2,800	Vandendriessche et al. 2012
Belgium	2007-08	48.5%	6–10			650	707	705	De Miguel-Etayo et al. 2014
Belgium	1997	58.0%	13–18	515		554	561	262	Baquet et al. 2000 *
Belgium	2002?	48.9%	10–11	591		591	591	591	Cardon et al. 2004 *
Belgium	1994-04	51.9%	11–18	6,493		6,418	6,526	6,537	Heyters & Marique 2004 *
Belgium	1993-97	49.9%	13–18	5,683		5,535	5,660	5,690	Lefèvre et al. 1998 *
Belgium	2005	44.8%	13–18	3,135					Matton et al. 2007 *
Belgium	1994-95	52.5%	13–16	2,225		2,225	895		Telama et al. 2002 *
Belgium	2002-04	49.1%	10–13	1,055		1,055	1,055	1,055	Verstraete et al. 2007 *
Bosnia and Herzegovina	2015-16	52.3%	12–15	843		843	843		Budimlic et al. 2016
Bulgaria	1998-99	52.5%	10–18	497			497	497	Dimitrova, 2001 *
Crete	2006-08	47.4%	12–18	336	324	192	319	327	Ortega et al. 2011
Croatia	2015	50.5%	15–18	794	820	596	505		Štefan et al. 2017
Croatia	2015-18	51.6%	6–8	1200			349		Šalaj et al. 2018
Croatia	2019	44.6%	16–18	1,036	1,033		1,036		Zvonar et al. 2019
Croatia	2008-09	44.8%	11–18	20,616			20,594		Štefan et al. 2021
Cyprus	2007-08	51.3%	6–10			1,111	1,173	1,184	De Miguel-Etayo et al. 2014
Czechia	2013-16	51.3%	12–18	1,154		1,086			Rubín et al. 2018 *
Czechia	1994-95	51.0%	13–16	439		439	439		Telama et al. 2002 *
Denmark	2008	47.5%	6–16	1,009	1,010			5,904	Hébert et al. 2020

Denmark	1996-97	39.6%	16–18			9,342			Nielsen & Andersen, 2003 *
Estonia	2017	47.0%	13–14			142	155	158	Sepp et al. 2017
Estonia	2018-	49.9%	8–11	212			215		10.23736/S0022-4707.20.10550-4
Estonia	2016-	51.7%	7–9	256	256	222	226	226	Riso et al. 2019
Estonia	2016	50.9%	8–9	145	146	136	137	137	Reisberg et al. 2020
Estonia	2018-	56.4%	13–17	413	413	413	413	413	Galan-Lopez et al. 2019
Estonia	2017	51.5%	12–18	3,052		3,056	3,103		https://www.sportest.eu/
Estonia	2007-08	47.5%	6–9			725	745	745	De Miguel-Etayo et al. 2014
Finland	2013	47.6%	9–15	970	970				Joensuu et al. 2020
Finland	2007-09	51.3%	9–11	374	374		374		Lintu et al. 2015
Finland	1995	46.6%	13–16	1,109		1,109	1,019		Telama et al. 2002 *
France	2006-08	42.2%	12–17	307	308	258	304	306	Ortega et al. 2011
France	2009-13	49.8%	9–16	9,669		10,862			Vanhelst et al. 2016
France	2010-18	51.0%	6–18	31,748			31,748		Vanhelst et al. 2020
France	1997	50.7%	12–15	507		507	507	507	Baquet et al. 2001 *
Germany	2006-08	58.9%	12–18	495	473	392	433	445	Ortega et al. 2011
Germany	2009-12	50.0%	6–18	3,039	3,023		3,043		Niessner et al. 2020
Germany	2007-08	48.3%	6–10			638	944	952	De Miguel-Etayo et al. 2014
Germany	1994-95	51.0%	13–16	977		977	863		Telama et al. 2002 *
Greece	2014	51.5%	6–18	306,217	304,619	176,844	256,026		Tambalis et al. 2015
Greece	2006-08	48.6%	12–18	369	366	346	359	361	Ortega et al. 2011
Hungary	2006-08	49.5%	13–17	397	393	393	394	395	Ortega et al. 2011
Hungary	2013	51.1%	10–18	580,056		574,375	581,464	591,669	Csányi et al. 2014
Hungary	2007-08	49.6%	6–10			548	1,230	1,228	De Miguel-Etayo et al. 2014
Hungary	1994-95	48.7%	13–16	439		439	434		Telama et al. 2002 *
Iceland	2017	54.0%	12–16	387	387	387	387	387	Galan-Lopez et al. 2018
Iceland	1998	51.8%	10–16			6,130	6,202		Gunnarsson & Sigríksson 1999 *
Ireland	2018-19	49.9%	12–16	1,147		1,002	1,158	1,149	O'Keeffe et al. 2020
Italy	2006-08	38.8%	13–18	321	320	263	266	268	Ortega et al. 2011
Italy	2001-02	55.2%	6–18	4,456					Lovecchio & Zago, 2019

	2004-05 2007-08 2009-10 2010-11 2011-12								
Italy	2001-02 2004-05 2007-08 2009-10 2010-11 2011-12	48.7%	12–14	6,197			5,898		Lovecchio & Zago, 2019
Italy	2001-02 2004-05 2007-08 2009-10 2010-11 2011-12	50.9%	12–14	558					Lovecchio & Zago, 2019
Italy	2004-13	53.0%	12–16	3,331			3,331		Lovecchio et al. 2019
Italy	2004-13	51.5%	6–18	4,376			3,705		Lovecchio et al. 2019
Italy	2004-13	48.4%	6–18	629			510		Lovecchio et al. 2020
Italy	2013	62.5%	13–18	789	722	634	738	770	Jemni et al. 2017
Italy	2013-14	49.5%	8–10	99			99	99	Colella et al. 2019
Italy	2007-08	50.2%	6–9				1,160	1,147	De Miguel-Etayo et al. 2014
Italy	1997	52.9%	13–18	3,638		3,203	3,740	3,415	Cilia et al. 1997 *
Kosovo	2016-17	52.8%	12–18	742		742	742	742	Berisha & Çilli, 2018 *
Latvia	2004-09	53.6%	10–18	7,743		3,400	7,743	7,743	Sauka et al. 2010 *
Lithuania	2002, 2012	53.6%	11–18	5,339		5,228	5,600		Venckunas et al. 2018
Lithuania	2016	49.8%	7–11	3,214			3,368		Emeljanovas et al. 2020
Lithuania	1992	46.4%	12–18	3,188		3,188	3,188	3,188	Jürimäe & Volbekiene, 2006 *
Luxembourg	2003-06	55.1%	9–18				1,128		Woll et al. 2011
Montenegro	2018-19	51.5%	6–18	5,877	3,601				NCD-RisC, 2020
Netherlands	2017-19	48.9%	8–14					1,713	Anselma et al., 2021
North Macedonia	2012	51.4%	6–11	1,156	1,153	1,159	1,159	1,157	Gontarev et al. 2018

North Macedonia	2012	51.1%	10–15					6,156	Gontarev & Ruzdija, 2014 *
Norway	2004	51.9%	14–16	2,604		2,305	2,490		Haugen et al. 2013 *
Poland	2009-10	51.7%	6–18	47,404		45,925	47,326	47,061	Dobosz et al. 2015
Portugal	2008	48.4%	10–18	22,004	21,982	22,004			Santos et al. 2014
Portugal	2018	48.6%	10–18	8,700	8,635	8,289	7,714	7,198	Unpublished data
Serbia	2012-13	48.1%	9–18	20,677		18,778	20,341		Milanovic et al. 2019
Slovakia	1993	49.9%	15–15	689		689	689	689	Belej et al.1995 *
Slovakia	1996	52.0%	12–15	368		287	323	329	Kasa & Majherová, 1997 *
Slovakia	1993-95	0.0%	16–16	95		111	95		Kyselovicová O. 2000 *
Slovakia	1993	59.7%	10–18	3,630		3,630	3,630	3,630	Moravec et al. 1996 *
Slovakia	2014-15	51.9%	10–12	426			426		Krska et al. 2015 *
Slovenia	2013-14	50.6%	6–18	4,745	4,688	4,598	4,670	4,673	Morrison et al. 2021
Slovenia	2018	50.9%	6–18	210,037			206,804		Sorić et al. 2020
Spain	2006-08	48.2%	12–17	413	414	308	397	398	Ortega et al. 2011
Spain	2012-20	49.5%	6–18	14,645	13,952	13,450	14,129	14,155	Iglesias-Soler et al. 2021
Spain	2018	49.4%	9–11	173	173	171	171	173	Cadenas-Sánchez et al. 2021
Spain	2017	48.1%	9–12	558	557	551	554	555	Martínez-Vizcaíno et al. 2022
Spain	2013-14	46.5%	6–7	518	519	522	519		Martínez-Vizcaíno et al. 2020
Spain	2010	50.5%	8–12	1,122		1,061	1,116	1,118	Torrijos-Niño et al. 2014
Spain	2019	52.0%	8–16	284	284	284	289	289	Medrano et al. 2020
Spain	2010-11	51.5%	10–18	905	774	889	879		Unpublished data
Spain	2011-12	51.9%	6–18	2,179	2,178	2,128	2,172	2,173	Castro-Piñero et al., 2014
Spain	2000-02	48.4%	12–18	2,474	2,468	2,087	2,431	2,427	Ortega et al. 2005
Spain	2007-08	47.9%	6–10			38	689	712	De Miguel-Etayo et al. 2014
Sweden	2006-08	39.8%	12–18	361	356	255	306	310	Ortega et al. 2011
Sweden	2007-08	48.8%	6–10			677	750	659	De Miguel-Etayo et al. 2014
Sweden	2001	51.6%	11–17	1,726				1,739	Örjan et al. 2005 *
Switzerland	2004	48.3%	6–13	496	491	501			Meyer et al. 2014
Switzerland	1996-97	49.5%	10–18			2,959	2,982		Cauderay et al. 2000 *
Switzerland	2005	47.9%	12–12	265		265			Shmid et al. 2007

United Kingdom	2006-10	53.4%	9–18	9,642	9,619	9,162		9,397	Sandercock et al. 2012
United Kingdom	1999-10	51.0%	10–11			27,954			Boddy et al. 2012 *
United Kingdom	2000-03	46.5%	10–13	13,152		3,466	13,152	13,152	Ridgers et al. 2006 *
United Kingdom	2009-10	51.3%	10–12			821	829	824	Ranson et al. 2015 *

20mSRT indicates the 20-m shuttle run test; HGS, handgrip strength; SLJ, standing long jump; BMI, body mass index; WC, waist circumference

*Pseudodata generated from Tomkinson et al. [39].

Online Supplementary Table 2. Generalized Additive Model for Location, Scale and Shape (GAMLSS) models used to calculate the physical fitness smoothed percentiles.

Test	Sex	Distribution	n	λ	μ	σ	ν	τ	SBC
20mSRT	Girls	BCPE	516811	1/3	6.16	5.30	3.94	3.39	99786154
20mSRT	Boys	BCPE	546274	1/2	6.67	5.68	4.13	3.43	123204436
HGS	Girls	BCT	404897	1/2	8.26	5.01	2.94	2.66	158351826
HGS	Boys	BCT	422230	1/2	8.32	5.22	3.05	2.41	181302718
SLJ	Girls	BCT	677639	1/2	9.60	5.42	2.84	2.19	269865621
SLJ	Boys	BCT	706134	1/2	9.97	5.42	2.77	2.30	286593503
BH	Girls	BCT	717911	1/2	15.37	5.54	2.10	2.17	211746507
BH	Boys	BCT	741823	1/2	15.28	5.61	2.12	2.12	229117658
BM	Girls	BCT	717526	1/2	9.66	5.52	2.88	2.13	225657454
BM	Boys	BCPE	741678	1/2	9.61	5.61	2.95	3.73	245281509
BMI	Girls	BCT	716750	1/2	10.54	5.57	2.69	2.08	160587571
BMI	Boys	BCT	740973	1/2	10.69	5.63	2.71	2.06	170674420
WC	Girls	BCPE	197832	1/2	10.62	5.20	2.38	3.37	150768194
WC	Boys	BCPE	205870	1/2	10.75	5.15	2.37	3.43	159088298

20mSRT indicates 20-m shuttle run test; HGS, handgrip strength; SLJ, standing long jump; BH, body height; BM, body mass; BMI, body mass index; WC, waist circumference; BCT, Box-Cox t distribution; BCPE, Box-Cox power exponential; SBC, Schwarz Bayesian criterion. Parameters of the fitted distribution are lambda (**λ)**, mu (μ), sigma (σ), nu (ν) and tau (τ)

Online Supplementary Table 3. Reference values (centiles) for body height (cm) in European children and adolescents (N=1,466,821)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	107.6	111.5	113.4	115.7	117.3	118.7	120.0	121.3	122.7	124.4	127.0	129.2	133.9
7.0-7.9 yrs	112.7	116.9	119.0	121.4	123.2	124.7	126.1	127.5	129.0	130.9	133.5	135.9	140.8
8.0-8.9 yrs	117.5	122.0	124.3	127.0	128.9	130.5	132.1	133.6	135.3	137.3	140.2	142.7	147.9
9.0-9.9 yrs	121.7	126.6	129.1	132.0	134.1	135.9	137.6	139.3	141.1	143.3	146.4	149.1	154.6
10.0-10.9 yrs	125.9	131.2	133.9	137.0	139.3	141.2	143.0	144.8	146.7	149.0	152.4	155.2	161.0
11.0-11.9 yrs	132.4	137.9	140.7	144.0	146.3	148.3	150.2	152.1	154.1	156.5	159.9	162.8	168.7
12.0-12.9 yrs	137.9	143.4	146.1	149.4	151.7	153.7	155.5	157.4	159.4	161.7	165.0	167.9	173.5
13.0-13.9 yrs	143.0	148.2	150.9	154.1	156.3	158.2	159.9	161.7	163.6	165.9	169.0	171.8	177.1
14.0-14.9 yrs	146.1	151.2	153.8	156.8	158.9	160.8	162.5	164.2	166.0	168.1	171.2	173.8	178.8
15.0-15.9 yrs	148.0	152.9	155.4	158.4	160.5	162.3	163.9	165.6	167.4	169.5	172.4	174.9	179.8
16.0-16.9 yrs	148.7	153.5	156.0	158.9	161.0	162.8	164.4	166.0	167.8	169.9	172.8	175.2	179.9
17.0-17.9 yrs	149.2	154.0	156.5	159.4	161.5	163.2	164.8	166.5	168.2	170.2	173.1	175.5	180.1
18.0-18.9 yrs	150.0	154.8	157.2	160.1	162.2	163.9	165.5	167.1	168.8	170.8	173.6	176.0	180.6

Boys Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	108.5	112.4	114.4	116.7	118.3	119.7	121.0	122.4	123.8	125.6	128.1	130.4	135.3
7.0-7.9 yrs	113.8	117.9	120.0	122.4	124.2	125.7	127.1	128.5	130.0	131.9	134.6	137.0	141.9
8.0-8.9 yrs	118.7	123.1	125.4	128.0	129.9	131.5	133.1	134.6	136.2	138.2	141.1	143.6	148.7
9.0-9.9 yrs	122.8	127.5	129.9	132.8	134.9	136.6	138.3	139.9	141.7	143.8	146.9	149.5	154.8
10.0-10.9 yrs	125.8	131.0	133.6	136.7	138.9	140.8	142.6	144.4	146.3	148.6	151.8	154.6	160.1
11.0-11.9 yrs	130.5	136.2	139.0	142.5	144.9	147.0	148.9	150.9	153.0	155.5	159.0	161.9	167.8
12.0-12.9 yrs	135.0	141.1	144.3	148.0	150.6	152.9	154.9	157.0	159.3	161.9	165.6	168.7	174.9
13.0-13.9 yrs	141.4	147.8	151.1	155.0	157.7	160.0	162.2	164.4	166.7	169.4	173.2	176.4	182.5
14.0-14.9 yrs	148.3	154.7	157.9	161.7	164.4	166.7	168.8	170.9	173.2	175.8	179.5	182.6	188.6
15.0-15.9 yrs	154.0	160.1	163.2	166.8	169.4	171.5	173.6	175.6	177.7	180.2	183.7	186.6	192.1
16.0-16.9 yrs	157.6	163.3	166.3	169.7	172.2	174.2	176.1	178.0	180.0	182.4	185.6	188.3	193.5
17.0-17.9 yrs	159.6	165.2	168.0	171.3	173.7	175.6	177.5	179.3	181.2	183.4	186.6	189.1	194.0
18.0-18.9 yrs	161.0	166.5	169.3	172.5	174.8	176.7	178.5	180.3	182.1	184.3	187.3	189.8	194.5

Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

Online Supplementary Table 4. Reference values (centiles) for body mass (kg) in European children and adolescents (N=1,466,295)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	16.3	17.8	18.7	19.9	20.9	21.9	22.8	23.8	25.0	26.6	29.2	31.7	38.0
7.0-7.9 yrs	17.8	19.7	20.8	22.3	23.5	24.6	25.8	27.1	28.6	30.5	33.7	36.8	44.6
8.0-8.9 yrs	19.6	21.9	23.3	25.1	26.6	28.0	29.4	30.9	32.7	35.1	39.0	42.8	52.3
9.0-9.9 yrs	21.5	24.2	25.8	28.0	29.8	31.4	33.1	34.9	37.1	39.9	44.4	49.0	60.2
10.0-10.9 yrs	23.5	26.7	28.6	31.2	33.2	35.1	37.0	39.1	41.6	44.8	50.1	55.3	68.3
11.0-11.9 yrs	26.2	29.9	32.1	35.1	37.4	39.5	41.7	44.1	46.9	50.5	56.4	62.3	77.0
12.0-12.9 yrs	29.6	33.8	36.2	39.4	42.0	44.3	46.6	49.2	52.1	56.0	62.2	68.4	84.0
13.0-13.9 yrs	33.5	38.0	40.5	43.9	46.5	48.9	51.2	53.8	56.8	60.7	66.9	73.2	88.8
14.0-14.9 yrs	36.7	41.4	44.0	47.4	49.9	52.3	54.6	57.1	60.0	63.8	69.9	75.9	91.2
15.0-15.9 yrs	38.9	43.6	46.2	49.5	52.0	54.3	56.5	59.0	61.7	65.4	71.2	77.1	92.4
16.0-16.9 yrs	40.0	44.9	47.5	50.7	53.2	55.4	57.6	59.9	62.6	66.2	72.0	77.9	93.7
17.0-17.9 yrs	40.6	45.5	48.1	51.4	53.8	56.0	58.1	60.4	63.1	66.6	72.5	78.5	95.5
18.0-18.9 yrs	40.8	45.9	48.5	51.8	54.2	56.3	58.4	60.7	63.4	66.9	72.8	79.2	97.9

Boys Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	16.7	18.3	19.2	20.5	21.5	22.4	23.3	24.2	25.4	27.0	29.6	32.3	39.5
7.0-7.9 yrs	18.4	20.3	21.4	22.9	24.1	25.2	26.3	27.5	29.0	30.9	34.1	37.4	45.8
8.0-8.9 yrs	20.3	22.5	23.8	25.6	27.1	28.5	29.8	31.3	33.1	35.5	39.4	43.3	53.1
9.0-9.9 yrs	22.1	24.6	26.2	28.3	30.1	31.7	33.4	35.2	37.3	40.1	44.7	49.3	60.4
10.0-10.9 yrs	23.7	26.7	28.5	31.0	33.0	34.9	36.8	39.0	41.5	44.8	50.1	55.3	68.0
11.0-11.9 yrs	25.8	29.3	31.4	34.3	36.7	38.9	41.1	43.6	46.5	50.3	56.5	62.5	77.0
12.0-12.9 yrs	28.6	32.6	35.0	38.4	41.1	43.6	46.1	48.9	52.1	56.4	63.3	70.1	86.4
13.0-13.9 yrs	32.4	37.0	39.8	43.6	46.6	49.3	52.0	55.0	58.5	63.1	70.6	78.0	95.7
14.0-14.9 yrs	36.9	42.1	45.3	49.4	52.5	55.4	58.2	61.3	64.9	69.7	77.5	85.1	103.5
15.0-15.9 yrs	41.4	47.0	50.3	54.6	57.8	60.8	63.6	66.6	70.2	75.0	82.8	90.5	109.0
16.0-16.9 yrs	44.8	50.6	54.0	58.4	61.7	64.6	67.3	70.3	73.8	78.5	86.2	93.9	112.3
17.0-17.9 yrs	47.1	53.0	56.5	60.8	64.1	67.0	69.7	72.6	76.1	80.7	88.4	95.9	114.3
18.0-18.9 yrs	48.8	54.8	58.2	62.6	65.8	68.7	71.4	74.3	77.7	82.3	89.9	97.5	116.0

Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

Online Supplementary Table 5. Reference values (centiles) for body mass index (kg/m^2) in European children and adolescents (N=1,464,795)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	12.3	13.2	13.7	14.3	14.9	15.4	15.8	16.4	17.0	17.8	19.1	20.4	23.4
7.0-7.9 yrs	12.4	13.3	13.8	14.6	15.2	15.7	16.3	16.8	17.5	18.5	19.9	21.4	25.1
8.0-8.9 yrs	12.6	13.6	14.2	15.0	15.7	16.3	16.9	17.5	18.3	19.4	21.0	22.7	27.0
9.0-9.9 yrs	12.9	14.0	14.6	15.5	16.2	16.8	17.5	18.2	19.1	20.2	22.0	23.9	28.7
10.0-10.9 yrs	13.1	14.2	14.9	15.9	16.6	17.3	18.0	18.8	19.7	20.9	22.8	24.8	30.0
11.0-11.9 yrs	13.4	14.6	15.4	16.3	17.1	17.8	18.5	19.3	20.3	21.5	23.6	25.7	31.3
12.0-12.9 yrs	13.9	15.2	15.9	16.9	17.7	18.5	19.2	20.0	21.0	22.3	24.4	26.6	32.3
13.0-13.9 yrs	14.6	15.9	16.7	17.7	18.5	19.2	20.0	20.8	21.8	23.1	25.2	27.4	33.2
14.0-14.9 yrs	15.2	16.5	17.3	18.3	19.1	19.8	20.6	21.4	22.4	23.6	25.7	27.9	33.8
15.0-15.9 yrs	15.5	16.9	17.7	18.7	19.5	20.2	21.0	21.8	22.7	24.0	26.0	28.2	34.1
16.0-16.9 yrs	15.8	17.2	18.0	19.0	19.8	20.5	21.2	22.0	22.9	24.2	26.2	28.4	34.5
17.0-17.9 yrs	15.9	17.3	18.1	19.1	19.9	20.6	21.3	22.1	23.0	24.3	26.3	28.5	35.0
18.0-18.9 yrs	15.9	17.4	18.1	19.1	19.9	20.6	21.3	22.1	23.0	24.2	26.3	28.6	35.4

Boys Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	12.7	13.5	13.9	14.5	15.0	15.5	15.9	16.4	17.0	17.8	19.1	20.4	23.7
7.0-7.9 yrs	12.7	13.6	14.1	14.7	15.3	15.8	16.3	16.8	17.5	18.4	19.9	21.4	25.4
8.0-8.9 yrs	12.9	13.8	14.4	15.1	15.7	16.3	16.9	17.5	18.2	19.2	20.9	22.7	27.4
9.0-9.9 yrs	13.2	14.2	14.8	15.6	16.2	16.8	17.5	18.2	19.0	20.1	22.0	23.9	29.3
10.0-10.9 yrs	13.4	14.4	15.1	15.9	16.6	17.3	18.0	18.7	19.6	20.8	22.9	25.0	31.1
11.0-11.9 yrs	13.6	14.7	15.4	16.3	17.1	17.8	18.5	19.3	20.3	21.6	23.8	26.1	32.7
12.0-12.9 yrs	14.0	15.1	15.9	16.8	17.6	18.3	19.1	19.9	20.9	22.3	24.5	26.9	33.8
13.0-13.9 yrs	14.4	15.7	16.4	17.4	18.2	19.0	19.7	20.6	21.6	23.0	25.3	27.7	34.5
14.0-14.9 yrs	15.0	16.3	17.0	18.1	18.9	19.6	20.4	21.3	22.3	23.6	25.9	28.3	35.1
15.0-15.9 yrs	15.5	16.9	17.7	18.7	19.5	20.3	21.1	21.9	23.0	24.3	26.6	29.0	35.7
16.0-16.9 yrs	16.0	17.4	18.2	19.3	20.1	20.9	21.7	22.5	23.5	24.9	27.2	29.5	36.2
17.0-17.9 yrs	16.3	17.7	18.6	19.6	20.5	21.3	22.1	22.9	23.9	25.3	27.5	29.9	36.6
18.0-18.9 yrs	16.5	18.0	18.9	20.0	20.8	21.6	22.4	23.2	24.2	25.6	27.8	30.2	37.0

Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 at: www.fitbackeurope.eu/en-us/fitness-map/sources.

Online Supplementary Table 6. Reference values (centiles) for waist circumference (cm) in European children and adolescents (N=409,580)

Girls Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	45.2	47.9	49.5	51.6	53.2	54.7	56.1	57.7	59.4	61.7	65.2	68.5	76.0
7.0-7.9 yrs	46.5	49.4	51.1	53.4	55.2	56.9	58.6	60.5	62.5	65.2	69.3	73.1	81.5
8.0-8.9 yrs	48.0	51.0	52.8	55.3	57.4	59.3	61.3	63.4	65.8	68.8	73.5	77.8	87.2
9.0-9.9 yrs	49.0	52.2	54.1	56.8	59.0	61.0	63.2	65.5	68.2	71.5	76.6	81.3	91.6
10.0-10.9 yrs	50.2	53.4	55.4	58.2	60.5	62.7	64.9	67.4	70.2	73.7	79.1	84.1	95.3
11.0-11.9 yrs	51.6	55.0	57.1	59.9	62.3	64.5	66.8	69.2	72.1	75.7	81.2	86.5	98.3
12.0-12.9 yrs	53.0	56.4	58.5	61.4	63.7	65.8	68.1	70.5	73.2	76.7	82.2	87.5	99.4
13.0-13.9 yrs	54.3	57.7	59.8	62.6	64.8	66.9	69.0	71.3	73.9	77.2	82.5	87.6	99.4
14.0-14.9 yrs	55.5	58.9	61.0	63.7	65.9	67.9	69.8	72.0	74.4	77.6	82.7	87.6	99.2
15.0-15.9 yrs	56.5	59.9	62.0	64.6	66.7	68.6	70.5	72.5	74.9	77.9	82.8	87.6	99.1
16.0-16.9 yrs	57.3	60.8	62.8	65.4	67.5	69.3	71.1	73.1	75.3	78.3	83.2	87.9	99.5
17.0-17.9 yrs	57.8	61.2	63.2	65.8	67.8	69.6	71.4	73.3	75.5	78.5	83.3	88.1	100.0
18.0-18.9 yrs	57.8	61.3	63.3	65.9	67.9	69.6	71.4	73.2	75.4	78.3	83.1	88.0	100.3

Boys Age (yr.)	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
6.0-6.9 yrs	45.9	48.8	50.5	52.6	54.2	55.6	56.9	58.3	59.9	62.1	65.7	69.3	78.3
7.0-7.9 yrs	47.3	50.3	52.1	54.4	56.1	57.7	59.3	61.0	63.0	65.5	69.7	73.7	83.4
8.0-8.9 yrs	49.0	52.1	53.9	56.4	58.4	60.2	62.1	64.1	66.4	69.4	74.2	78.7	89.3
9.0-9.9 yrs	50.4	53.5	55.4	58.0	60.2	62.2	64.3	66.6	69.2	72.6	77.9	82.8	94.3
10.0-10.9 yrs	51.6	54.8	56.8	59.6	61.9	64.0	66.3	68.8	71.7	75.3	81.0	86.4	98.8
11.0-11.9 yrs	53.0	56.3	58.4	61.3	63.6	65.9	68.3	70.9	73.9	77.7	83.7	89.4	102.6
12.0-12.9 yrs	54.4	57.8	60.0	62.9	65.3	67.6	69.9	72.5	75.5	79.3	85.3	91.1	104.8
13.0-13.9 yrs	56.2	59.7	61.9	64.8	67.2	69.4	71.7	74.1	77.0	80.7	86.6	92.4	106.1
14.0-14.9 yrs	58.0	61.7	63.9	66.9	69.2	71.3	73.4	75.8	78.5	82.0	87.7	93.3	107.1
15.0-15.9 yrs	59.7	63.5	65.8	68.7	71.0	73.1	75.1	77.2	79.8	83.2	88.7	94.3	108.2
16.0-16.9 yrs	61.2	65.2	67.5	70.5	72.7	74.7	76.6	78.7	81.1	84.4	90.0	95.6	110.1
17.0-17.9 yrs	62.1	66.4	68.8	71.8	74.0	75.9	77.7	79.7	82.1	85.3	90.8	96.6	112.0
18.0-18.9 yrs	62.5	66.9	69.3	72.3	74.5	76.4	78.1	80.0	82.3	85.4	90.9	96.8	113.2

Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) 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 10^{th} percentile; other percentiles are abbreviated accordingly. Data sources are available at: www.fitbackeurope.eu/en-us/fitness-map/sources.

Online Supplementary Table 7. Mean percentile and ranking position of each country according to the pooled EU reference values for body height and weight.

Body height

		Both		Girls		Boys	
	N	Centile	Rank	Centile	Rank	Centile	Rank
MNE	6551	67.4	1	67.2	1	67.6	1
EST	4113	62.9	2	62.3	3	63.4	2
CRO	23651	60.3	3	62.8	2	57.4	6
CZE	1637	58.9	4	59.6	5	58.3	3
SVN	215493	58.2	5	58.2	6	58.3	4
NOR	2659	57.1	6	59.7	4	54.7	10
SRB	20683	57.0	7	56.5	7	57.6	5
DEN	1041	55.6	8	54.2	14	57.2	7
ISL	387	54.7	9	54.4	11	54.9	9
GRE	325078	54.6	10	54.3	13	55.0	8
POL	49550	54.0	11	53.4	15	54.6	11
GER	5229	53.6	12	54.3	12	53.0	13
HUN	601537	53.5	13	53.0	16	54.0	12
LIT	11854	52.9	14	54.9	10	51.0	18
LAT	7743	52.6	15	54.9	9	50.5	19
SLO	5209	52.5	16	55.2	8	50.4	20
FIN	2453	51.8	17	52.1	17	51.5	16
AUS	630	51.5	18	50.4	18	52.6	15
BUL	497	51.4	19	49.8	21	52.8	14
MCD	1022	50.6	20	50.0	19	51.3	17
IRE	1161	49.5	21	49.3	23	49.7	21
ITA	26568	49.0	22	49.8	20	48.2	22
BEL	22973	48.8	23	49.6	22	48.0	23
BIH	843	47.2	24	49.1	24	45.5	25
SPA	26144	45.8	25	45.0	28	46.6	24
FRA	42700	45.4	26	46.0	26	44.8	26

Body mass

		Both		Girls		Boys	
	N	Centile	Rank	Centile	Rank	Centile	Rank
CRO	23646	58.2	1	58.9	1	57.3	3
MNE	6460	57.6	2	55.4	3	59.7	1
MCD	1022	56.2	3	53.6	8	58.7	2
GRE	325357	55.7	4	54.9	4	56.5	4
ISL	387	55.3	5	55.8	2	54.9	6
EST	4091	54.9	6	54.2	6	55.6	5
SVN	215211	53.9	7	53.7	7	54.2	8
SRB	20695	53.4	8	52.5	11	54.3	7
HUN	601487	53.3	9	53.3	9	53.3	10
SPA	26129	53.2	10	53.1	10	53.3	9
CZE	1636	52.0	11	52.3	12	51.7	12
NOR	2608	51.8	12	54.3	5	49.6	17
AUS	630	51.3	13	50.2	15	52.5	11
IRE	1149	50.2	14	50.1	16	50.3	14
GER	5224	50.0	15	50.3	14	49.7	15
POL	49525	49.4	16	47.8	21	50.9	13
ITA	26467	49.2	17	48.7	18	49.7	16
BEL	23019	48.1	18	50.7	13	45.5	19
POR	30731	47.9	19	49.0	17	46.6	18
SWE	2098	46.7	20	48.2	19	45.0	22
UK	22810	46.1	21	47.0	24	45.2	20
DEN	1042	46.0	22	46.7	25	45.2	21
FIN	2453	46.0	23	47.4	23	44.4	25
LAT	7743	45.8	24	47.5	22	44.4	26
BIH	843	45.6	25	48.1	20	43.3	28
LIT	11885	44.7	26	44.9	26	44.4	24

KOS	742	45.3	27	47.4	25	43.4	28	SLO	5208	44.4	27	43.8	29	44.8	23
SWE	2089	44.0	28	45.6	27	42.5	30	FRA	42623	44.2	28	44.9	27	43.6	27
SWI	762	42.4	29	40.7	30	44.3	27	SWI	762	42.5	29	42.3	30	42.8	29
POR	30740	42.4	30	42.0	29	42.7	29	BUL	497	41.2	30	40.4	31	41.9	30
UK	22969	39.1	31	38.2	31	40.1	31	KOS	742	40.8	31	44.2	28	37.8	31
ALB	2113	21.5	32	22.2	32	21.0	32	ALB	2115	30.0	32	31.2	32	28.9	32
N	1466821							N	1466295						

N, sample size and total sample size at the bottom of the table. The 3-digit country codes were used to abbreviate the full country names https://en.wikipedia.org/wiki/List_of_UNDP_country_codes as follows: ALB, Albania; AUS, Austria; BEL, Belgium; BIH, Bosnia and Herzegovina; BUL, Bulgaria; CRO, Croatia; CYP, Cyprus; CZE, Czech Republic; DEN, Denmark; EST, Estonia; FIN, Finland; FRA, France; GER, Germany; GRE, Greece; HUN, Hungary; ISL, Iceland; IRE, Ireland; ITA, Italy; KOS, Kosovo; AT, Latvia; LIT, Lithuania; LUX, Luxembourg; NET, Netherlands; MCD, North Macedonia; MNE, Montenegro; NOR, Norway; POL, Poland; POR, Portugal; SRB, Serbia; SLO, Slovakia; SVN, Slovenia; SPA, Spain; SWE, Sweden; SWI, Switzerland; UK, United Kingdom.

For each test, the countries were sorted according to their rank position in the Both (girls and boys) column. Sex- 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 EU reference values. Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) method and weights were applied according to country population.

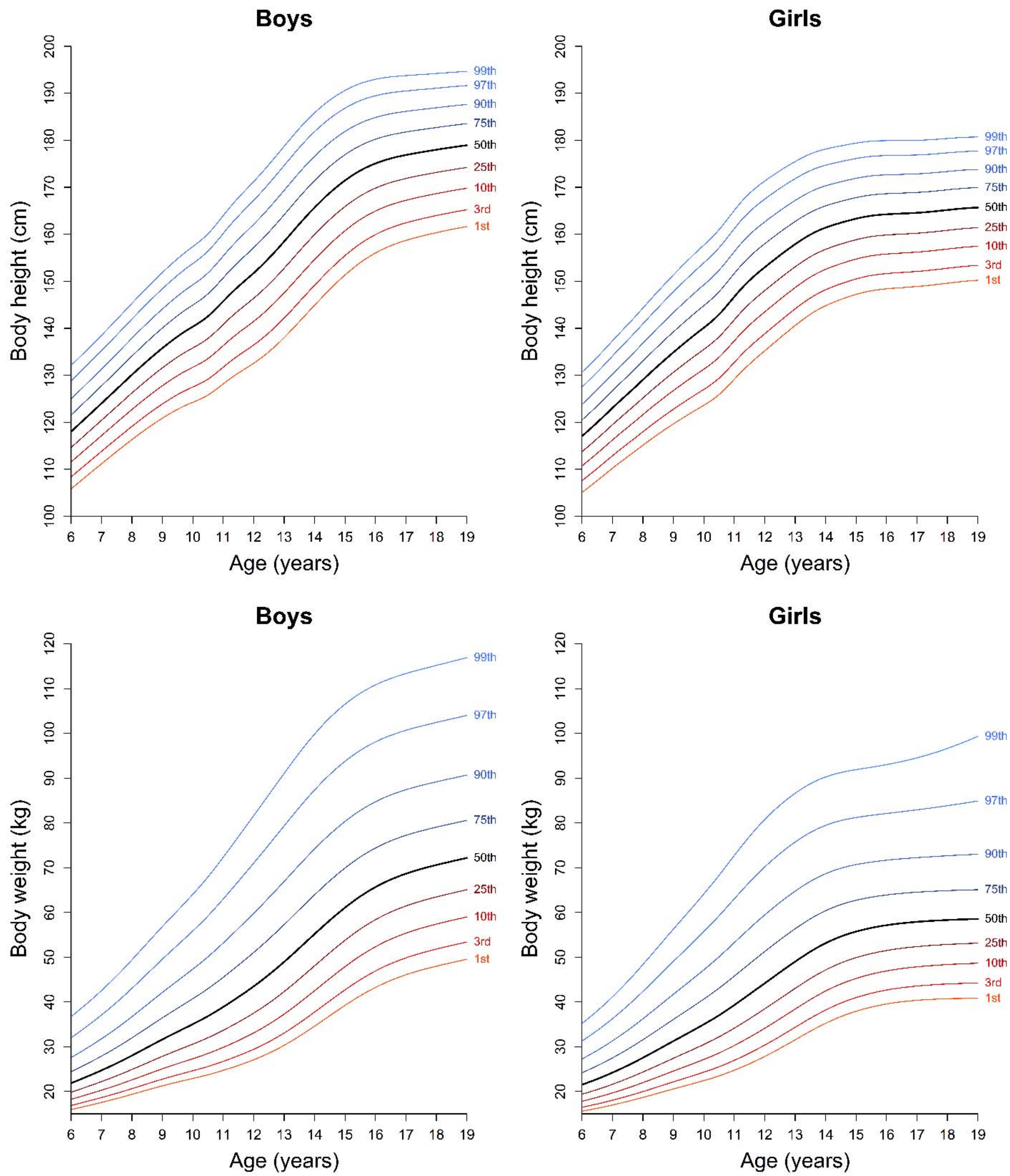
Online Supplementary Table 8. Mean percentile and ranking position of each country according to the pooled EU reference values for body mass index and waist circumference.

Body mass index								Waist circumference							
		Both		Girls		Boys				Both		Girls		Boys	
	N	Centile	Rank	Centile	Rank	Centile	Rank		N	Centile	Rank	Centile	Rank	Centile	Rank
MCD	1021	58.3	1	55.1	2	61.4	1	MNE	3914	59.3	1	59.3	1	59.3	1
SPA	26024	56.3	2	56.7	1	56.0	2	GRE	322480	55.8	2	55.6	2	55.9	2
GRE	324462	54.5	3	53.7	5	55.2	3	ITA	1061	52.6	3	48.5	6	55.9	3
CRO	23645	53.3	4	52.6	7	54.1	4	AUS	416	50.6	4	50.1	4	51.2	4
ISL	387	53.2	5	54.1	3	52.3	5	POR	30620	50.6	5	54.1	3	46.9	7
UK	22794	52.1	6	53.8	4	50.5	10	SPA	21356	49.2	6	49.1	5	49.3	5
POR	30707	51.8	7	53.4	6	50.1	13	ISL	387	47.6	7	47.7	8	47.6	6
HUN	601480	51.6	8	51.9	8	51.2	7	SWE	356	44.4	8	47.8	7	39.1	16
SWE	2087	50.4	9	50.6	9	50.3	12	UK	9619	43.7	9	44.2	9	43.3	11
IRE	1147	50.2	10	50.4	10	49.9	15	MCD	1020	42.4	10	39.1	14	45.6	8
AUS	630	50.0	11	49.4	13	50.6	9	EST	815	42.2	11	39.1	13	44.8	9
SVN	214944	49.8	12	49.6	12	50.0	14	CRO	1853	41.7	12	39.0	15	44.7	10
SRB	20677	49.7	13	49.0	14	50.4	11	FIN	1344	40.7	13	41.4	10	40.1	13
ITA	26462	49.7	14	48.6	16	50.7	8	GER	4197	40.7	14	39.5	12	41.8	12
MNE	6550	48.6	15	45.7	21	51.5	6	SVN	4848	39.6	15	39.8	11	39.4	15
BEL	22966	48.5	16	50.1	11	47.0	21	HUN	393	37.9	16	36.4	18	39.5	14
EST	4079	48.3	17	47.8	18	48.8	16	FRA	308	36.5	17	36.4	17	36.5	17
NOR	2604	48.3	18	48.8	15	47.9	18	DEN	1042	35.2	18	37.4	16	32.7	19
GER	5223	47.7	19	47.6	20	47.8	19	BEL	3059	33.7	19	34.4	19	33.1	18
CZE	1634	47.6	20	47.8	19	47.4	20	SWI	492	27.6	20	27.9	20	27.2	20
POL	49510	47.0	21	45.7	23	48.3	17		-	-	-	-	-	-	-
BIH	843	45.8	22	48.0	17	43.8	23		-	-	-	-	-	-	-
FRA	42615	45.3	23	45.7	22	44.8	22		-	-	-	-	-	-	-
FIN	2453	44.0	24	45.7	24	42.1	28		-	-	-	-	-	-	-
ALB	2115	43.9	25	44.8	27	43.1	26		-	-	-	-	-	-	-
SWI	762	43.7	26	45.2	25	42.1	29		-	-	-	-	-	-	-

KOS	742	43.1	27	45.0	26	41.4	30			-	-	-	-	-	-	-
LAT	7743	43.1	28	42.9	28	43.3	25			-	-	-	-	-	-	-
SLO	5208	41.8	29	39.6	32	43.4	24			-	-	-	-	-	-	-
LIT	11743	41.5	30	40.5	30	42.4	27			-	-	-	-	-	-	-
DEN	1041	40.7	31	42.9	29	38.3	32			-	-	-	-	-	-	-
BUL	497	39.7	32	40.3	31	39.1	31			-	-	-	-	-	-	-
N	1464795							N	409580							

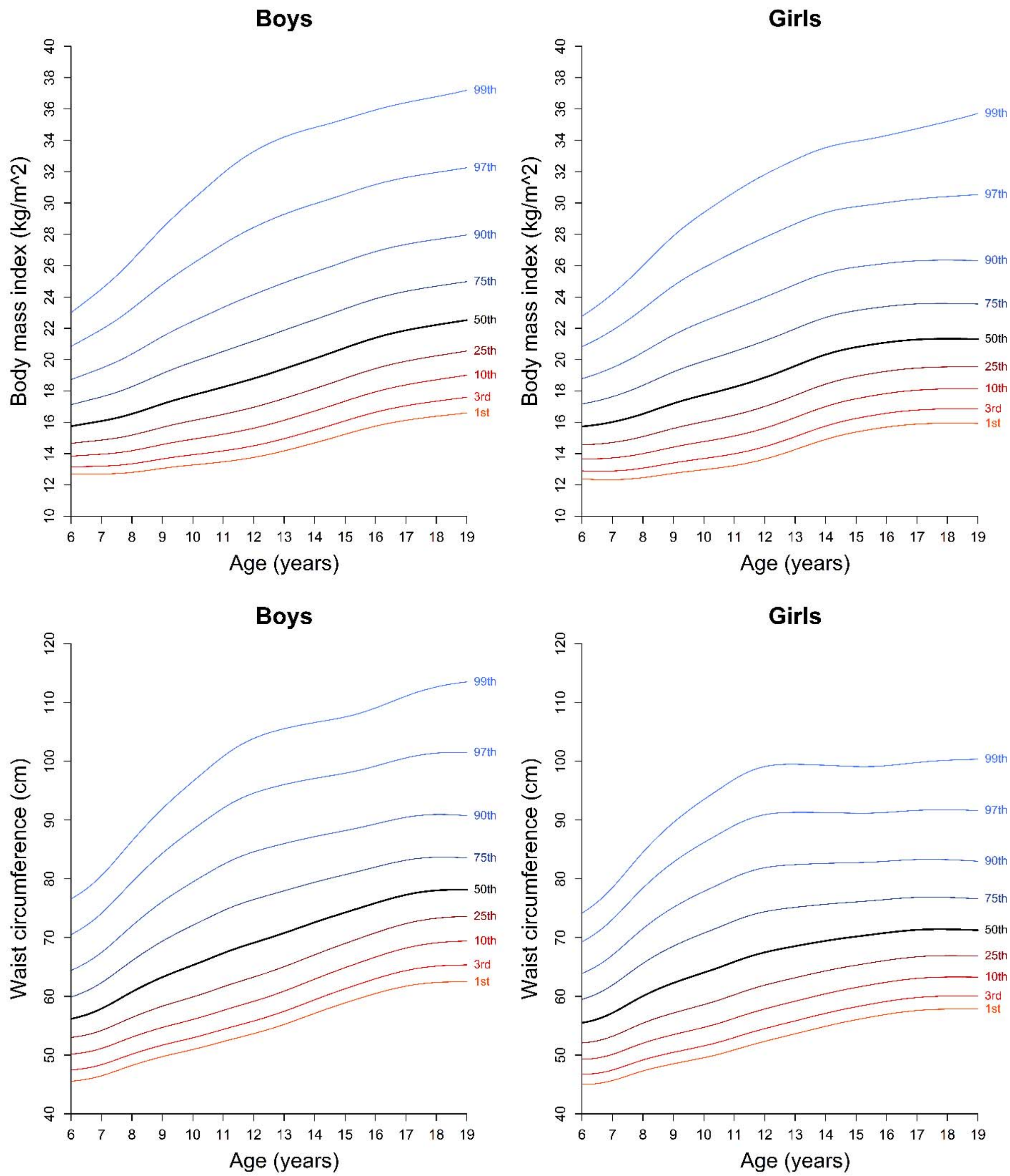
N, sample size and total sample size at the bottom of the table. The 3-digit country codes were used to abbreviate the full country names https://en.wikipedia.org/wiki/List_of_UNDP_country_codes as follows: ALB, Albania; AUS, Austria; BEL, Belgium; BIH, Bosnia and Herzegovina; BUL, Bulgaria; CRO, Croatia; CYP, Cyprus; CZE, Czech Republic; DEN, Denmark; EST, Estonia; FIN, Finland; FRA, France; GER, Germany; GRE, Greece; HUN, Hungary; ISL, Iceland; IRE, Ireland; ITA, Italy; KOS, Kosovo; AT, Latvia; LIT, Lithuania; LUX, Luxembourg; NET, Netherlands; MCD, North Macedonia; MNE, Montenegro; NOR, Norway; POL, Poland; POR, Portugal; SRB, Serbia; SLO, Slovakia; SVN, Slovenia; SPA, Spain; SWE, Sweden; SWI, Switzerland; UK, United Kingdom.

For each test, the countries were sorted according to their rank position in the Both (girls and boys) column. Sex- 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 EU reference values. Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) method and weights were applied according to country population.



Online Supplementary Figure 1. Percentile curves for body height and body mass in European children and adolescents.

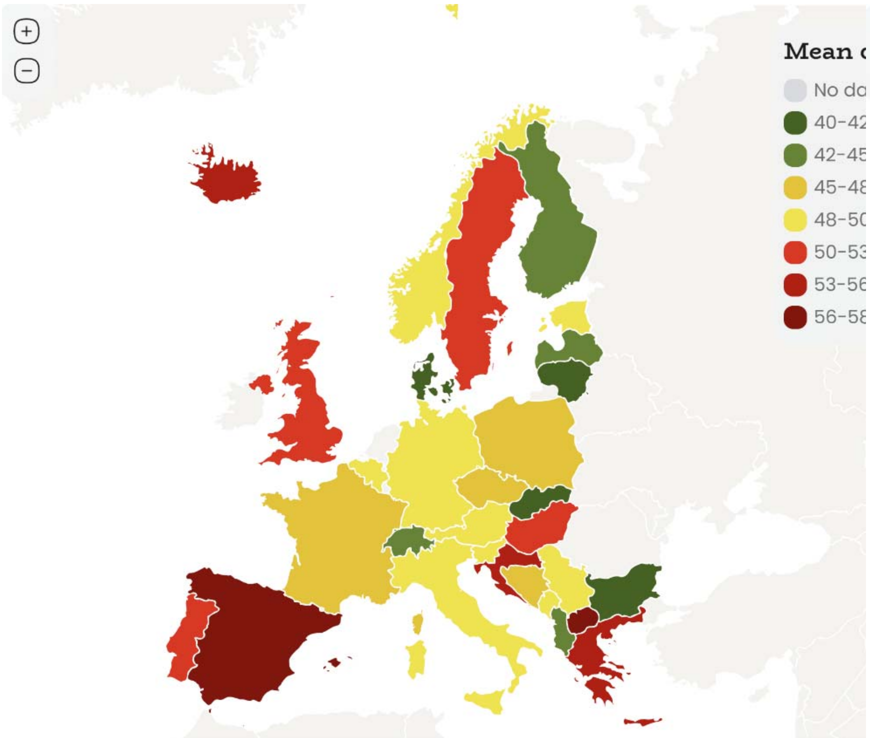
Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) method and weights were applied according to country population. Data sources are available at: https://www.fitbackeurope.eu/en-us/fitness-map/sources.



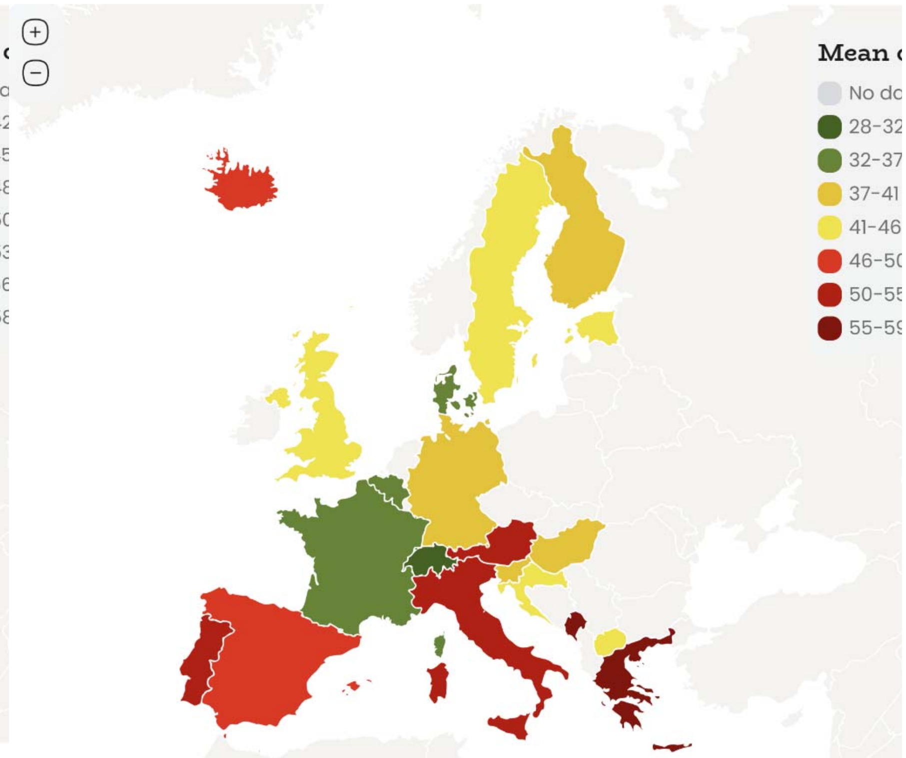
Online Supplementary Figure 2. Percentile curves for body mass index and waist circumference in European children and adolescents.

Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) method and weights were applied according to country population. Data sources are available at: https://www.fitbackeurope.eu/en-us/fitness-map/sources.

EU body mass index landscape



EU waist circumference landscape



Online Supplementary Figure 3. European maps for body mass index and waist circumference in children and adolescents.

Sex- 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 EU reference values. Smoothed percentiles were calculated using the Generalized Additive Model for Location, Scale and Shape (GAMLSS) method and weights were applied according to country population.

Separate European fitness maps for girls and boys are available at: 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 this study and in the platform. Data sources are available at: www.fitbackeurope.eu/en-us/fitness-map/sources.