



**HAL**  
open science

## Sport participation, weight status, and physical fitness in French adolescents

Jérémy Vanhelst, Anne Le Cunuder, Luc Léger, Martine Duclos, Daniel  
Mercier, François Carré

► **To cite this version:**

Jérémy Vanhelst, Anne Le Cunuder, Luc Léger, Martine Duclos, Daniel Mercier, et al.. Sport participation, weight status, and physical fitness in French adolescents. 2024. hal-04717606

**HAL Id: hal-04717606**

**<https://hal.science/hal-04717606v1>**

Preprint submitted on 2 Oct 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



## ABSTRACT

30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55

**Background:** The primary objective of this study was to investigate the associations between sport participation and weight status with physical fitness among French adolescents. The secondary aim was to establish sex- and age-specific physical fitness percentiles for French adolescents.

**Methods:** The sample comprised 8084 adolescents (4126 boys, 3958 girls), aged 10–14 years. Participants were tested on cardiorespiratory fitness and muscular strength using the following tests: 20-m shuttle run test and handgrip strength test. A questionnaire on organized sport participation was completed.

**Results:** Physical fitness levels were better in boys ( $P < 0.005$ ). Handgrip strength increased with age whereas 20-m shuttle run performance decreased with age. Overweight and obese adolescents had significantly lower cardiorespiratory fitness levels than their normal-weight peers ( $P < 0.005$ ), whereas normal-weight adolescents had lower cardiorespiratory fitness than thin adolescents ( $P < 0.005$ ). Sport participation was higher for boys (57.2% boys vs. 52.8% girls) ( $P < 0.001$ ). Adolescents who participated in at least one organized sport (either through a club or at school) were fitter than those who did not participate in organized sports ( $P < 0.005$ ).

**Conclusions:** Adolescents who engaged in organized sports were more active and physically fit than those who did not participate. The fitness benefits of club sports are greater than those provided by school-based sports, highlighting the potential of sports clubs as a key setting for promoting health.

**Keywords:** Fitness, youth, sport participation.

## 56 INTRODUCTION

57 Health-related fitness encompasses several components such as cardiorespiratory fitness  
58 (also known as aerobic fitness or cardiorespiratory endurance), musculoskeletal fitness  
59 (muscular strength, power, endurance, and flexibility), and body composition (body mass  
60 index (BMI), and waist circumference) [1]. Given the broad spectrum of health-related fitness  
61 components, understanding their specific contributions to overall health is crucial for effective  
62 monitoring and intervention.

63 Over the years, it has been widely demonstrated that physical fitness is a strong marker of  
64 health in children and adolescents [1, 2]. Indeed, a review study reported that physical fitness  
65 is linked to numerous health benefits, including a reduced risk of chronic diseases and  
66 premature death [2]. Among the different components of physical fitness, cardiorespiratory  
67 fitness and muscular strength have shown the strongest and most consistent associations  
68 with health in children and adolescents, and are also a strong predictor for future health in  
69 adulthood [3, 4]. In addition, studies indicate that a high level of cardiorespiratory fitness and  
70 muscular strength has positive effects on mental health [2, 5]. Recent studies based on large  
71 samples have reinforced earlier findings, indicating that low cardiorespiratory fitness and  
72 muscular strength during childhood and adolescence are associated with increased risks of  
73 early all-cause and cause-specific mortality, including cardiovascular diseases and cancer  
74 [6–9]. These two components of physical fitness in childhood are crucial predictors of future  
75 disability in adulthood, with a study showing that muscular weakness and a combination of  
76 poor muscular strength with low cardiorespiratory fitness during adolescence are strongly  
77 associated with an increased risk of disability later in life [10]. Because cardiorespiratory  
78 fitness and muscular strength are important indicators of current and future health, it is  
79 important to assess them regularly in children and adolescents.

80 The last French Report Card on Physical Activity and Sedentary Behaviors in Children and  
81 Youth (2022) emphasized a lack of fitness data and the need to develop nationwide  
82 programmes to measure the physical fitness levels of youths [11]. In addition, a recent study  
83 showed a large decline in cardiorespiratory fitness levels among French children and  
84 adolescents since 1999 [12]. In this context, improving our understanding of factors  
85 associated with physical fitness outcomes is much needed for designing present and future  
86 national health improvement policies. The primary objective of this study was to investigate  
87 the associations between sport participation and weight status with physical fitness among  
88 French adolescents. The secondary aim was to establish sex- and age-specific physical  
89 fitness percentiles for French adolescents.

90

## 91 **METHODS**

### 92 **Study design**

93 The study was conducted between September and October 2022 in three regions of France  
94 (Hauts-de-France, Brittany, Auvergne-Rhône-Alpes). All schools in these regions were  
95 invited to participate. The decision to join the study was made by each school's principal and  
96 Physical Education (PE) teacher. If both agreed, the adolescents were invited to take part in  
97 the study. Written informed consent was obtained from both the adolescents and their  
98 parents. The study received approval from the local ethics committee (Centre Hospitalier  
99 Universitaire de Rennes, n° 21.115), and all procedures adhered to the ethical standards of  
100 the 1975 Helsinki Declaration, as revised in 2008.

101

### 102 **Measures**

#### 103 *Participant characteristics*

104 Sex (male/female) was self-reported. Body weight was measured to the nearest 0.1 kg using  
105 an electronic scale, with participants wearing light clothing and no shoes. Height was  
106 recorded without shoes to the nearest 0.1 cm using a standard physician's scale. Then, the  
107 BMI was calculated as weight/height<sup>2</sup> (kg/m<sup>2</sup>). Nutritional status was evaluated using the  
108 International Obesity Task Force scale [13].

109

#### 110 *Physical fitness*

111 The health-related physical fitness components were assessed using two tests from two  
112 batteries of well-validated physical fitness tests, which assessed cardiorespiratory fitness and  
113 upper limbs muscular strength [14, 15]. To ensure strict standardization in physical fitness  
114 measurements across different schools, several web-based training sessions were  
115 conducted by a study investigator for the PE teachers. These sessions were recorded,  
116 allowing PE teachers to review the material as needed. The instructions provided to the  
117 adolescents for each test were standardized across all schools. In addition, a smartphone  
118 application (METs-Up Pro Navette®) was developed to reinforce the testing procedures and  
119 guide data collection. Each PE teacher received a unique account for this application,  
120 through which they recorded the data. The entire dataset was audited, and aberrant data  
121 were excluded.

122

#### 123 *Cardiorespiratory fitness (CRF)*

124 CRF was assessed using a modified version of the original 20-m shuttle run test (20-m SRT)  
125 developed by Leger et al. [16], the PREFIT (FITness testing in PREschool children) [17]. In  
126 this test, adolescents continuously ran back and forth between two lines set 20 metres apart,

127 following the pace set by audio signals from a pre-recorded CD. The test started at a speed  
128 of 6.5 km/h, increasing by 0.5 km/h every minute. Adolescents were instructed to run in a  
129 straight line, pivot on reaching each line, and maintain their pace in sync with the audio  
130 signals. They were verbally encouraged to run as long as possible. The test finished when  
131 adolescents failed to reach the line in sync with the audio signals on two consecutive  
132 attempts, or when they voluntarily stopped due to fatigue. The last fully or half-completed  
133 stage was recorded, with the corresponding speed used for statistical analysis. The PREFIT  
134 allows a feasible, reliable, and valid assessment of CRF among pre-schoolers aged 5–6  
135 years [14, 18]. To estimate the number of shuttles for the 20-m SRT using the original  
136 protocol, we applied a linear regression as recommended by Mora-Gonzalez [18]. The  
137 formula used was  $Y = 0.535X - 1.685$ , where Y represents the shuttles of the original  
138 protocol and X represents the shuttles from the PREFIT protocol [18].

139

#### 140 *Muscular strength*

141 Upper body muscular strength was assessed using the handgrip test [15]. The Camry digital  
142 handgrip dynamometer with an adjustable grip to account for varying hand sizes (EH101;  
143 Zhongshan Camry Electronic Co. Ltd., Zhongshan, China) was used. This digital  
144 dynamometer is a cost-effective and valid alternative to the gold standard Jamar<sup>®</sup> hydraulic  
145 handgrip dynamometer [19, 20]. It measures isometric grip strength ranging from 0 to 90 kg.  
146 During the test, adolescents stood with the arm fully extended at a 30° angle from their trunk  
147 to prevent any other body part from contacting the dynamometer, except the hand being  
148 measured. The radioulnar and wrist joints were maintained in a neutral position to ensure  
149 accurate and consistent measurements. They were instructed to squeeze the dynamometer  
150 gradually and continuously for 2 to 3 seconds. Each hand was tested twice, with a one-  
151 minute rest between trials, and the order of testing each hand was randomized. For each  
152 hand, the maximum score expressed in kilograms (absolute value) was recorded. No verbal  
153 encouragement was provided during the test to avoid any external influence on the  
154 participants' performance. The handgrip test shows a high-to-very-high construct validity and  
155 reliability, and negligible test–retest learning and fatigue effects in adolescents [15, 21–23].

156

#### 157 *Sport participation*

158 Data on sport participation were collected through two questions asked of the adolescents.  
159 Before physical fitness tests, PE teachers asked the following questions to adolescents: 'Are  
160 you a member of an organized sports club outside of school?' and 'Are you a member of an  
161 organized sports club at school?'

162

#### 163 **Statistical analysis**

164 Continuous variables are presented as mean (standard deviation, SD), whereas categorical  
165 variables are expressed as frequency (percentage). The normality of distributions was  
166 evaluated using histograms and the Shapiro–Wilk test. Sex differences in participant  
167 characteristics were analysed using a *t* test for continuous variables and a chi-squared test  
168 for categorical variables. Comparisons of physical fitness, weight status, and sports  
169 participation were conducted using a one-way analysis of variance. Pairwise post hoc  
170 comparisons were carried out using linear contrasts, with a Bonferroni correction applied for  
171 multiple comparisons. Percentile values, including the 5th, 10th, 20th, 30th, 40th, 50th, 60th,  
172 70th, 80th, 90th, and 95th percentiles of physical fitness measures for French adolescents,  
173 were calculated by age and stratified by sex using the generalized additive model for  
174 location, scale, and shape (GAMLSS). The GAMLSS package (version 4.2-7) within the R  
175 statistical software (version 3.2.1) was used for these analyses.

176

## 177 **RESULTS**

178 In total, 9022 adolescents (4428 girls and 4593 boys, mean age  $11.25 \pm 0.42$  years)  
179 participated in the study. From the total population, 938 adolescents (467 boys and 471 girls)  
180 with missing or incomplete data on anthropometric measurements, age, or non-physical  
181 fitness measurements were excluded, resulting in a study sample of 8084 participants  
182 (Figure S1). Because of the small sample size for 13-year-old subjects ( $n = 62$ ), the  
183 percentile values were reported only for 10–12-year-old subjects ( $n = 8022$ ). Physical fitness  
184 measurements are displayed by sex in Table 1. Overall, physical fitness performances were  
185 better in boys ( $P < 0.005$ , Table 1). Handgrip strength increased with age whereas 20-m  
186 shuttle run performance decreased with age. Sport participation was higher for boys (57.2%  
187 boys vs. 52.8% girls) ( $P < 0.001$ ; Table 1).

188

189 *Insert Table 1.*

190

191 Physical fitness according to weight status in boys and girls is presented in Table 2. Scores  
192 in the 20-m SRT were better for adolescents with a normal weight than for overweight and  
193 obese adolescents ( $P < 0.005$ ; Table 2). By contrast, normal-weight adolescents had  
194 significantly lower performance in 20-m SRT than thin adolescents ( $P < 0.005$ ; Table 2).  
195 Overweight and obese adolescents had significantly better results in handgrip strength than  
196 their normal or thin counterparts ( $P < 0.005$ ; Table 2) whereas the normal-weight adolescents  
197 had better scores than thin adolescents ( $P < 0.005$ ; Table 2). Results are similar when  
198 stratified by sex.

199

200 *Insert Table 2.*

201

202 As shown by the data in Table 3, adolescents with at least one organized sport participation  
203 (club or in school) had better performances in 20-m SRT than non-organized sport  
204 participation participants ( $P < 0.005$ ; Table 3). In other terms, on average, adolescents  
205 participating in organized school and club sport ran two stages more on the SRT than  
206 adolescents reporting no organized sport participation. Results are similar when stratified by  
207 sex. No difference was found for upper muscular strength (Table 3).

208

209

*Insert Table 3.*

210

211 Sex- and age-specific percentile values (P5, P10, P20, P30, P40, P50, P60, P70, P80, P90,  
212 P95) for physical fitness measures are described in Tables 4, 5.

213

214

*Insert Tables 4, 5.*

215

216

## 217 **DISCUSSION**

218 Beyond the well-established health benefits of high physical fitness, the decline in physical  
219 fitness among youth is well documented [12, 24, 25]. A meta-analysis has shown that  
220 cardiorespiratory fitness levels in French children and adolescents have declined over recent  
221 decades, with a decrease of  $2.7 \text{ ml.kg}^{-1}.\text{min}^{-1}$ , or 5.7% per decade [24]. A recent study has  
222 further corroborated this decline over the past two decades [12]. Therefore, it is crucial to  
223 continue monitoring physical fitness levels in French youth and to investigate the role of  
224 individual and environmental factors in relation to physical fitness.

225 Our first finding showed differences in physical fitness levels according to sex. Boys showed  
226 better performances for 20-m SRT and handgrip strength than girls. These data concur with  
227 previous studies conducted in France and other countries in Europe or on other continents  
228 [26–30]. Indeed, two previous large French cohort studies showed that physical fitness levels  
229 were better in boys than in girls, except for agility and flexibility [26, 31]. From these two  
230 studies, one study showed a difference of 1.4 stages completed (6.3 vs. 4.9 for boys and  
231 girls, respectively), using the original 20-m shuttle run [26]). In our present study, the mean  
232 difference is similar (7.7 vs. 6.4). The differences between boys and girls are associated with  
233 developmental changes in body composition during adolescence, driven by puberty and  
234 related hormonal changes, generally beginning around age 11 years for girls and 12 years  
235 for boys, with significant individual variations [32]. Daily physical activity is also a factor that



236 could explain this difference in physical fitness levels. Previous studies have shown that a  
237 high daily physical activity or meeting physical activity guidelines in youth was associated  
238 with better physical fitness levels [33–35]. It is widely acknowledged that physical activity  
239 levels are lower in girls than in boys [36, 37]. Recently, Verdot et al. (2022) demonstrated, in  
240 a large sample of French youth, a substantial and significant disparity between boys and girls  
241 in meeting physical activity guidelines, with 51% and 33%, respectively [38]. Hence, the  
242 lower level of physical activity among girls, along with a decreased percentage of French  
243 girls meeting physical activity guidelines, might account for the discrepancy in physical  
244 fitness between boys and girls in our study.

245 Regarding weight status differences, normal-weight adolescents (both boys and girls) have  
246 significantly higher performances in 20-m SRT than their overweight and obese counterparts  
247 ( $P < 0.005$ ). This has been extensively studied and our data support previous findings on the  
248 relationship between weight excess and low physical fitness levels [39–41]. However, our  
249 results should be interpreted with caution because the data are only presented with body  
250 weight, without considering body composition (i.e. fat-free mass). Indeed, Goran et al.  
251 demonstrated that cardiorespiratory fitness expressed relative to fat-free mass was not  
252 significantly different between normal-weight and obese children [42]. As we found in our  
253 study, several studies have reported a positive association between BMI and muscular  
254 strength assessed using the handgrip test [39, 43]. However, the relationship is reversed  
255 when expressed relative to body weight. Our study also showed that performances in 20-m  
256 SRT are better among thin adolescents than among those with a normal weight status ( $P <$   
257  $0.005$ ). The SRT may be considered weight dependent. Indeed, thin adolescents with a low  
258 weight may have a lower energy expenditure at the same speed than adolescents with  
259 normal weight status. Therefore, thin adolescents might have an advantage in this type of  
260 test over normal-weight adolescents, which could explain their better performance in  
261 cardiorespiratory fitness tests.

262 Another outcome found from our study was the positive association between organized sport  
263 club participation (club or school sport) and physical fitness levels. Our results are consistent  
264 with previous studies performed in other countries [44–46]. In addition to the benefits of  
265 physical fitness, studies have also shown that sport participation was associated with lower  
266 fat mass and BMI, higher daily physical activity levels and a lower time spent in sedentary  
267 activities [47–49]. However, participation in organized sports does not ensure that  
268 adolescents meet physical activity guidelines (60 minutes daily of moderate to vigorous  
269 activity) [50]. Sports participation can also substantially influence weight status. Drake et al.  
270 showed that the prevalence of obesity would decrease by approximately 26% if all

271 adolescents played on at least two sports teams per year [51]. Unfortunately, the 2022  
272 French Report Card on Physical Activity and Sedentary Behaviors in Children and Youth  
273 highlighted a 4% decrease between 2019 and 2022 in the enrolment of French youth in  
274 sports clubs [11]. This highlights the need to persist and enhance ongoing policy initiatives  
275 aimed at broadening access to and participation in sports clubs/associations.

276 In the present study, French adolescents demonstrated lower performance in the 20-m SRT  
277 than recently published international and European norms [27, 52]. Both boys and girls have  
278 had 20-m SRT performance around the 30th percentile when compared with these  
279 international and European standards. By contrast, their results for muscular strength were  
280 better, with both boys and girls scoring around the 60th percentile of the European norms,  
281 indicating above-average muscular strength for both sexes. In light of these findings,  
282 targeted actions are necessary to improve physical fitness among adolescents in France.  
283 Public health strategies should be implemented to address these gaps and promote better  
284 overall fitness among the youth.

285 Given the absence of reference standards of upper muscular strength in French adolescents,  
286 results from our study showing sex- and age-specific normative values for using the handgrip  
287 test are relevant [4, 8, 10, 53]. These references are necessary for screening, monitoring,  
288 and making a national standard or surveillance in comparison with their counterparts [54, 55].  
289 We encourage French investigators (e.g. healthcare practitioners, PE teachers, researchers,  
290 and sport coaches) to use these new normative data when they assess the physical fitness  
291 levels of adolescents to identify those with a low physical fitness status.

292 The main strengths include data analysis in a large sample of adolescents derived from three  
293 administrative regions in France with sex-specific information, with the use of standardized  
294 procedures and the rigorous methodology to assess physical fitness (web-based training  
295 sessions and smartphone application for the procedures of tests and how to collect data).  
296 These strengths improve the applicability and implementation of our findings and the  
297 statistical robustness of the results. Another strength is establishing sex and age percentiles  
298 for both sexes due to the widely known impact of age and sex on physical fitness levels. The  
299 last strength recognized is the use of two validated tests to assess cardiorespiratory and  
300 muscular fitness, widely used at the European/international level. Our study also presents  
301 some limitations. The main limitation concerns the design of the study. Indeed, our cross-  
302 sectional data are likely to underestimate within-individual age-related changes. Although the  
303 present data were derived from a large sample, this study did not use a stratified sample  
304 design with a narrow age demographic. Therefore, it is not possible to assume that the  
305 studied cohort is fully representative of the French adolescent population. Lastly, the use of

306 the 20-m shuttle run from the PREFIT battery proposed for children aged 5–6 years, thus not  
307 appropriate for the age range of our study sample.

308 In conclusion, our findings suggest that adolescents in France who engaged in organized  
309 sport were more physically fit than those who did not participate. While these results highlight  
310 the potential benefits of club sports over school-based sports in promoting physical fitness,  
311 the cross-sectional nature of this study limits the ability to establish causality. Therefore,  
312 these findings should be interpreted with caution, and further longitudinal research is needed  
313 to confirm the causal relationships. Nevertheless, our result suggests that sports clubs may  
314 serve as a valuable setting for promoting adolescent health. Developing policies aimed at  
315 increasing physical education and sports in schools and colleges, as well as promoting  
316 access to organized sports clubs, could significantly enhance the cardiorespiratory fitness of  
317 adolescents, thereby improving their overall health. However, to achieve these goals,  
318 targeted strategies are essential, particularly for increasing the participation of overweight or  
319 obese adolescents and girls in organized sports. These strategies should be tailored to meet  
320 the specific needs of these groups to ensure broader participation and better health  
321 outcomes.

322

### 323 **Acknowledgments**

324 The authors sincerely thank every teachers and children involved in this study.

325

### 326 **Conflict of interest**

327 The remaining authors state no conflict of interest.

328

### 329 **Authors contributions**

330 Jérémy Vanhelst, Daniel Mercier, Martine Duclos, Luc Léger and François Carré conducted  
331 the initial analyses and drafted the initial manuscript. Anne Le Cunuder conducted statistical  
332 analysis and drafted the initial manuscript. François Carré and Daniel Mercier designed data  
333 collection instruments, coordinated and supervised data collection and reviewed the  
334 manuscript. All authors approved the final manuscript as submitted and agree to be  
335 accountable for all aspects of the work.

336

### 337 **Funding**

338 There is no funding for this study.

339 **References**

- 340 1. Ruiz JR, Castro-Piñero J, Artero EG, et al (2009) Predictive validity of health-related  
341 fitness in youth: a systematic review. *Br J Sports Med* 43:909–923.  
342 <https://doi.org/10.1136/bjism.2008.056499>
- 343 2. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M (2008) Physical fitness in childhood and  
344 adolescence: a powerful marker of health. *Int J Obes (Lond)* 32:1–11.  
345 <https://doi.org/10.1038/sj.ijo.0803774>
- 346 3. García-Hermoso A, Ramírez-Vélez R, García-Alonso Y, et al (2020) Association of  
347 Cardiorespiratory Fitness Levels During Youth With Health Risk Later in Life: A  
348 Systematic Review and Meta-analysis. *JAMA Pediatr* 174:952–960.  
349 <https://doi.org/10.1001/jamapediatrics.2020.2400>
- 350 4. García-Hermoso A, Ramírez-Campillo R, Izquierdo M (2019) Is Muscular Fitness  
351 Associated with Future Health Benefits in Children and Adolescents? A Systematic  
352 Review and Meta-Analysis of Longitudinal Studies. *Sports Med* 49:1079–1094.  
353 <https://doi.org/10.1007/s40279-019-01098-6>
- 354 5. Smith JJ, Eather N, Morgan PJ, et al (2014) The Health Benefits of Muscular Fitness for  
355 Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med*  
356 44:1209–1223. <https://doi.org/10.1007/s40279-014-0196-4>
- 357 6. Ballin M, Nordström A, Nordström P (2020) Cardiovascular Disease and All-Cause  
358 Mortality in Male Twins With Discordant Cardiorespiratory Fitness: A Nationwide Cohort  
359 Study. *Am J Epidemiol* 189:1114–1123. <https://doi.org/10.1093/aje/kwaa060>
- 360 7. Crump C, Sundquist J, Winkleby MA, Sundquist K (2017) Interactive Effects of Aerobic  
361 Fitness, Strength, and Obesity on Mortality in Men. *Am J Prev Med* 52:353–361.  
362 <https://doi.org/10.1016/j.amepre.2016.10.002>
- 363 8. Ortega FB, Silventoinen K, Tynelius P, Rasmussen F (2012) Muscular strength in male  
364 adolescents and premature death: cohort study of one million participants. *BMJ*  
365 345:e7279. <https://doi.org/10.1136/bmj.e7279>
- 366 9. Högström G, Ohlsson H, Crump C, et al (2019) Aerobic fitness in late adolescence and  
367 the risk of cancer and cancer-associated mortality in adulthood: A prospective  
368 nationwide study of 1.2 million Swedish men. *Cancer Epidemiology* 59:58–63.  
369 <https://doi.org/10.1016/j.canep.2019.01.012>
- 370 10. Henriksson H, Henriksson P, Tynelius P, Ortega FB (2019) Muscular weakness in  
371 adolescence is associated with disability 30 years later: a population-based cohort  
372 study of 1.2 million men. *Br J Sports Med* 53:1221–1230.  
373 <https://doi.org/10.1136/bjsports-2017-098723>
- 374 11. Fillon A, Vanhelst J, Genin P, et al (2023) 2022 French Report Card on Physical Activity  
375 and Sedentary Behaviors in Children and Youth: From Continuous Alarming  
376 Conclusions to Encouraging Initiatives. *J Phys Act Health* 1–10.  
377 <https://doi.org/10.1123/jpah.2022-0660>
- 378 12. Vanhelst J, Lang JJ, Matelot D, et al (2024) Cardiorespiratory fitness has declined  
379 among French children since 1999, although the decline appears to be getting smaller.  
380 *Scandinavian Med Sci Sports* 34:e14641. <https://doi.org/10.1111/sms.14641>

- 381 13. Cole TJ, Lobstein T (2012) Extended international (IOTF) body mass index cut-offs for  
382 thinness, overweight and obesity. *Pediatr Obes* 7:284–294.  
383 <https://doi.org/10.1111/j.2047-6310.2012.00064.x>
- 384 14. Cadenas-Sanchez C, Martinez-Tellez B, Sanchez-Delgado G, et al (2016) Assessing  
385 physical fitness in preschool children: Feasibility, reliability and practical  
386 recommendations for the PREFIT battery. *Journal of Science and Medicine in Sport*  
387 19:910–915. <https://doi.org/10.1016/j.jsams.2016.02.003>
- 388 15. Ruiz J, Castro-Piñero J, Vanesa E-R, et al (2010) Field-based fitness assessment in  
389 young people: The ALPHA health-related fitness test battery for children and  
390 adolescents. *British journal of sports medicine* 45:518–24.  
391 <https://doi.org/10.1136/bjism.2010.075341>
- 392 16. Léger LA, Mercier D, Gadoury C, Lambert J (1988) The multistage 20 metre shuttle run  
393 test for aerobic fitness. *J Sports Sci* 6:93–101.  
394 <https://doi.org/10.1080/02640418808729800>
- 395 17. Ortega FB, Cadenas-Sánchez C, Sánchez-Delgado G, et al (2015) Systematic review  
396 and proposal of a field-based physical fitness-test battery in preschool children: the  
397 PREFIT battery. *Sports Med* 45:533–555. <https://doi.org/10.1007/s40279-014-0281-8>
- 398 18. Mora-Gonzalez J, Cadenas-Sanchez C, Martinez-Tellez B, et al (2017) Estimating  
399 VO<sub>2</sub>max in children aged 5–6 years through the preschool-adapted 20-m shuttle-run  
400 test (PREFIT). *Eur J Appl Physiol* 117:2295–2307. <https://doi.org/10.1007/s00421-017-3717-7>  
401
- 402 19. Lupton-Smith A, Fourie K, Mazinyo A, et al (2022) Measurement of hand grip strength:  
403 A cross-sectional study of two dynamometry devices. *S Afr J Physiother* 78:1768.  
404 <https://doi.org/10.4102/sajp.v78i1.1768>
- 405 20. Andrade MS, Honorato MP, Vargas JP, et al (2023) Comparison of two handgrip  
406 dynamometers in older adults before elective surgery. *Perioper Med (Lond)* 12:46.  
407 <https://doi.org/10.1186/s13741-023-00334-y>
- 408 21. Castro-Piñero J, Artero EG, España-Romero V, et al (2010) Criterion-related validity of  
409 field-based fitness tests in youth: a systematic review. *Br J Sports Med* 44:934–943.  
410 <https://doi.org/10.1136/bjism.2009.058321>
- 411 22. Artero EG, España-Romero V, Castro-Piñero J, et al (2011) Reliability of field-based  
412 fitness tests in youth. *Int J Sports Med* 32:159–169. <https://doi.org/10.1055/s-0030-1268488>  
413
- 414 23. Ortega FB, Artero EG, Ruiz JR, et al (2008) Reliability of health-related physical fitness  
415 tests in European adolescents. The HELENA Study. *Int J Obes (Lond)* 32 Suppl 5:S49-  
416 57. <https://doi.org/10.1038/ijo.2008.183>
- 417 24. Tomkinson GR, Lang JJ, Tremblay MS (2019) Temporal trends in the cardiorespiratory  
418 fitness of children and adolescents representing 19 high-income and upper middle-  
419 income countries between 1981 and 2014. *Br J Sports Med* 53:478–486.  
420 <https://doi.org/10.1136/bjsports-2017-097982>
- 421 25. Dooley FL, Kaster T, Fitzgerald JS, et al (2020) A Systematic Analysis of Temporal  
422 Trends in the Handgrip Strength of 2,216,320 Children and Adolescents Between 1967  
423 and 2017. *Sports Med* 50:1129–1144. <https://doi.org/10.1007/s40279-020-01265-0>

- 424 26. Vanhelst J, Labreuche J, Béghin L, et al (2017) Physical Fitness Reference Standards  
425 in French Youth: The BOUGE Program. *J Strength Cond Res* 31:1709–1718.  
426 <https://doi.org/10.1519/JSC.0000000000001640>
- 427 27. Ortega FB, Leskošek B, Blagus R, et al (2023) European fitness landscape for children  
428 and adolescents: updated reference values, fitness maps and country rankings based  
429 on nearly 8 million test results from 34 countries gathered by the FitBack network. *Br J*  
430 *Sports Med* 57:299–310. <https://doi.org/10.1136/bjsports-2022-106176>
- 431 28. Tuan S-H, Chen G-B, Chen C-H, et al (2021) Comparison of Peak Oxygen  
432 Consumption During Exercise Testing Between Sexes Among Children and  
433 Adolescents in Taiwan. *Front Pediatr* 9:657551.  
434 <https://doi.org/10.3389/fped.2021.657551>
- 435 29. Ramos-Sepúlveda JA, Ramírez-Vélez R, Correa-Bautista JE, et al (2016) Physical  
436 fitness and anthropometric normative values among Colombian-Indian schoolchildren.  
437 *BMC Public Health* 16:962. <https://doi.org/10.1186/s12889-016-3652-2>
- 438 30. Ramírez-Vélez R, Correa-Bautista JE, Ramos-Sepúlveda JA, et al (2017) Aerobic  
439 capacity and future cardiovascular risk in Indian community from a low-income area in  
440 Cauca, Colombia. *Ital J Pediatr* 43:28. <https://doi.org/10.1186/s13052-017-0347-y>
- 441 31. Vanhelst J, Ternynck C, Ovigneur H, Deschamps T (2020) Normative health-related  
442 fitness values for French children: The Diagnoform Programme. *Scand J Med Sci*  
443 *Sports* 30:690–699. <https://doi.org/10.1111/sms.13607>
- 444 32. Malina RM, Katzmarzyk PT (2006) Physical activity and fitness in an international  
445 growth standard for preadolescent and adolescent children. *Food Nutr Bull* 27:S295-  
446 313. <https://doi.org/10.1177/15648265060274S511>
- 447 33. Migueles JH, Delisle Nyström C, Dumuid D, et al (2023) Longitudinal associations of  
448 movement behaviours with body composition and physical fitness from 4 to 9 years of  
449 age: structural equation and mediation analysis with compositional data. *Int J Behav*  
450 *Nutr Phys Act* 20:11. <https://doi.org/10.1186/s12966-023-01417-1>
- 451 34. Migueles JH, Delisle Nyström C, Leppänen MH, et al (2022) Revisiting the cross-  
452 sectional and prospective association of physical activity with body composition and  
453 physical fitness in preschoolers: A compositional data approach. *Pediatr Obes*  
454 17:e12909. <https://doi.org/10.1111/ijpo.12909>
- 455 35. Martinez-Gomez D, Ruiz JR, Ortega FB, et al (2010) Recommended levels and  
456 intensities of physical activity to avoid low-cardiorespiratory fitness in European  
457 adolescents: The HELENA study. *Am J Hum Biol* 22:750–756.  
458 <https://doi.org/10.1002/ajhb.21076>
- 459 36. Downing KL, Hinkley T, Timperio A, et al (2021) Volume and accumulation patterns of  
460 physical activity and sedentary time: longitudinal changes and tracking from early to late  
461 childhood. *Int J Behav Nutr Phys Act* 18:39. [https://doi.org/10.1186/s12966-021-01105-](https://doi.org/10.1186/s12966-021-01105-y)  
462 [y](https://doi.org/10.1186/s12966-021-01105-y)
- 463 37. Corder K, Sharp SJ, Atkin AJ, et al (2015) Change in objectively measured physical  
464 activity during the transition to adolescence. *Br J Sports Med* 49:730–736.  
465 <https://doi.org/10.1136/bjsports-2013-093190>

- 466 38. Verdot C, Salanave B, Aubert S, et al (2022) Prevalence of Physical Activity and  
467 Sedentary Behaviors in the French Population: Results and Evolution between Two  
468 Cross-Sectional Population-Based Studies, 2006 and 2016. *Int J Environ Res Public*  
469 *Health* 19:2164. <https://doi.org/10.3390/ijerph19042164>
- 470 39. Manzano-Carrasco S, Garcia-Unanue J, Haapala EA, et al (2023) Relationships of BMI,  
471 muscle-to-fat ratio, and handgrip strength-to-BMI ratio to physical fitness in Spanish  
472 children and adolescents. *Eur J Pediatr* 182:2345–2357.  
473 <https://doi.org/10.1007/s00431-023-04887-4>
- 474 40. de Lima TR, Martins PC, Moreno YMF, et al (2022) Muscular Fitness and  
475 Cardiometabolic Variables in Children and Adolescents: A Systematic Review. *Sports*  
476 *Med* 52:1555–1575. <https://doi.org/10.1007/s40279-021-01631-6>
- 477 41. Santaliestra-Pasías AM, Moreno LA, Gracia-Marco L, et al (2021) Prospective physical  
478 fitness status and development of cardiometabolic risk in children according to body fat  
479 and lifestyle behaviours: The IDEFICS study. *Pediatr Obes* 16:e12819.  
480 <https://doi.org/10.1111/ijpo.12819>
- 481 42. Goran M, Fields DA, Hunter GR, et al (2000) Total body fat does not influence maximal  
482 aerobic capacity. *Int J Obes Relat Metab Disord* 24:841–848.  
483 <https://doi.org/10.1038/sj.ijo.0801241>
- 484 43. Godoy-Cumillaf A, Fuentes-Merino P, Farías-Valenzuela C, et al (2023) The  
485 Association between Sedentary Behavior, Physical Activity, and Physical Fitness with  
486 Body Mass Index and Sleep Time in Chilean Girls and Boys: A Cross-Sectional Study.  
487 *Children (Basel)* 10:981. <https://doi.org/10.3390/children10060981>
- 488 44. Zahner L, Muehlbauer T, Schmid M, et al (2009) Association of sports club participation  
489 with fitness and fatness in children. *Med Sci Sports Exerc* 41:344–350.  
490 <https://doi.org/10.1249/MSS.0b013e318186d843>
- 491 45. Mäkituomas L, Heikkilä L, Nurkkala M, et al (2022) Factors associated with body size  
492 perception among adolescent goal-oriented sports participants and non-participants: a  
493 cross-sectional Finnish study. *BMC Public Health* 22:2188.  
494 <https://doi.org/10.1186/s12889-022-14511-z>
- 495 46. Telford RM, Telford RD, Cochrane T, et al (2016) The influence of sport club  
496 participation on physical activity, fitness and body fat during childhood and  
497 adolescence: The LOOK Longitudinal Study. *J Sci Med Sport* 19:400–406.  
498 <https://doi.org/10.1016/j.jsams.2015.04.008>
- 499 47. Pate RR, Trost SG, Levin S, Dowda M (2000) Sports participation and health-related  
500 behaviors among US youth. *Arch Pediatr Adolesc Med* 154:904–911.  
501 <https://doi.org/10.1001/archpedi.154.9.904>
- 502 48. Ara I, Vicente-Rodríguez G, Jimenez-Ramirez J, et al (2004) Regular participation in  
503 sports is associated with enhanced physical fitness and lower fat mass in prepubertal  
504 boys. *Int J Obes Relat Metab Disord* 28:1585–1593.  
505 <https://doi.org/10.1038/sj.ijo.0802754>
- 506 49. Sirard JR, Pfeiffer KA, Dowda M, Pate RR (2008) Race differences in activity, fitness,  
507 and BMI in female eighth graders categorized by sports participation status. *Pediatr*  
508 *Exerc Sci* 20:198–210. <https://doi.org/10.1123/pes.20.2.198>

- 509 50. Leek D, Carlson JA, Cain KL, et al (2011) Physical activity during youth sports  
510 practices. *Arch Pediatr Adolesc Med* 165:294–299.  
511 <https://doi.org/10.1001/archpediatrics.2010.252>
- 512 51. Drake KM, Beach ML, Longacre MR, et al (2012) Influence of sports, physical  
513 education, and active commuting to school on adolescent weight status. *Pediatrics*  
514 130:e296-304. <https://doi.org/10.1542/peds.2011-2898>
- 515 52. Tomkinson GR, Lang JJ, Tremblay MS, et al (2017) International normative 20 m  
516 shuttle run values from 1 142 026 children and youth representing 50 countries. *Br J*  
517 *Sports Med* 51:1545–1554. <https://doi.org/10.1136/bjsports-2016-095987>
- 518 53. Herraiz-Adillo Á, Ahlqvist VH, Higuera-Fresnillo S, et al (2024) Physical fitness in male  
519 adolescents and atherosclerosis in middle age: a population-based cohort study. *Br J*  
520 *Sports Med* [bjsports-2023-107663](https://doi.org/10.1136/bjsports-2023-107663). <https://doi.org/10.1136/bjsports-2023-107663>
- 521 54. Tomkinson GR, Carver KD, Atkinson F, et al (2018) European normative values for  
522 physical fitness in children and adolescents aged 9–17 years: results from 2 779 165  
523 Eurofit performances representing 30 countries. *Br J Sports Med* 52:1445–1456.  
524 <https://doi.org/10.1136/bjsports-2017-098253>
- 525 55. Kułaga Z, Świąder-Leśniak A, Kotowska A, Litwin M (2023) Population-based  
526 references for waist and hip circumferences, waist-to-hip and waist-to-height ratios for  
527 children and adolescents, and evaluation of their predictive ability. *Eur J Pediatr*  
528 182:3217–3229. <https://doi.org/10.1007/s00431-023-05001-4>

529



530 **Statements and Declarations**

531

532 **Conflict of interest**

533 The remaining authors state no conflict of interest.

534 **Funding**

535 There is not support for this research.

536 **Authors contributions**

537 Jérémy Vanhelst, Daniel Mercier, Martine Duclos, Luc Léger and François Carré conducted  
538 the initial analyses and drafted the initial manuscript. Anne Le Cunuder conducted statistical  
539 analysis and drafted the initial manuscript. François Carré and Daniel Mercier designed data  
540 collection instruments, coordinated and supervised data collection and reviewed the  
541 manuscript. All authors approved the final manuscript as submitted and agree to be  
542 accountable for all aspects of the work.

543 **Ethics approval**

544 The study was approved by the local ethics committee (Centre Hospitalier Universitaire de  
545 Rennes, n° 21.115), and all procedures were following the ethical standards of the Helsinki  
546 Declaration of 1975 as revised in 2008.

547 **Consent to participate**

548 Written, informed consent was obtained from the adolescents and the parents.

549 **Consent for publication**

550 NA

551

**Table 1.** Subjects characteristics studied according to the sex

		<b>Overall</b>	<b>Boys</b>	<b>Girls</b>	<b>P*</b>
N		8084	4126	3958	
Age		11.2 ± 0.4	11.3 ± 0.4	11.2 ± 0.4	0.36
	<i>10-10.9 years</i>	1611 (19.9)	796 (19.3)	815 (20.7)	
	<i>11-11.9 years</i>	6062 (75.0)	3108 (75.3)	2954 (74.6)	-
	<i>12-12.9 years</i>	349 (4.3)	193 (4.7)	156 (3.9)	
	<i>13-13.9 years</i>	62 (0.8)	29 (0.7)	33 (0.8)	
Sport participation					
	<i>No</i>	3287 (45.0)	1594 (42.8)	1693 (47.2)	
	<i>Outdoor (club)</i>	2583 (35.4)	1303 (35.0)	1280 (35.7)	
	<i>School</i>	455 (6.2)	231 (6.2)	224 (6.2)	<b>&lt;0.001</b>
	<i>Both</i>	976 (13.4)	595 (16.0)	391 (10.9)	
Weight ( <i>kg</i> )		40.17 ± 10.55	39.70 ± 9.76	40.63 ± 11.07	<b>&lt;0.005</b>
Height ( <i>cm</i> )		148.22 ± 7.80	147.67 ± 7.56	148.89 ± 7.88	<b>&lt;0.005</b>
Body mass Index ( <i>kg/m<sup>2</sup></i> )		18.11 ± 3.66	18.08 ± 3.51	18.14 ± 3.80	0.42
20-m shuttle run test - Prefit ( <i>stages</i> )		7.08 ± 2.66	7.70 ± 2.82	6.44 ± 2.34	<b>&lt;0.005</b>
20-m shuttle run test - Prefit ( <i>speed, km.h<sup>-1</sup></i> )		9.46 ± 1.38	9.82 ± 1.49	9.08 ± 1.21	<b>&lt;0.005</b>
20-m shuttle run test - Original ( <i>stages</i> )**		3.0 ± 1.6	3.2 ± 1.7	2.5 ± 1.4	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )		20.02 ± 5.10	20.40 ± 5.00	19.62 ± 4.93	<b>&lt;0.005</b>

553 Values are mean ± standard deviation or number (%)

554 \* For comparison between boys and girls, a *t*-test for continuous variables and chi-squared test for categorial variables were used.

556 \*\* 20-m SRT original stages were estimated with the PREFIT speeds as recommended by Mora-Gonzalez et al. [18]

**Table 2.** Physical fitness according to weight status.

<b>Total</b>	<b>Thin</b> N = 920	<b>Normal</b> N = 3586	<b>Overweight</b> N = 770	<b>Obesity</b> N = 273	<b>P*</b>
20-m shuttle run test - Prefit ( <i>stage</i> )	7.88 ± 2.52 <sup>b,c,d</sup>	7.43 ± 2.55 <sup>c,d</sup>	5.48 ± 2.00 <sup>d</sup>	4.08 ± 1.80	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )	17.60 ± 4.37 <sup>b,c,d</sup>	19.94 ± 4.84 <sup>c,d</sup>	21.23 ± 4.67 <sup>d</sup>	23.89 ± 5.01	<b>&lt;0.005</b>
<b>Girls</b>	<b>Thin</b> N = 486	<b>Normal</b> N = 1738	<b>Overweight</b> N = 378	<b>Obesity</b> N = 128	
20-m shuttle run test - Prefit ( <i>stage</i> )	7.22 ± 2.23 <sup>b,c,d</sup>	6.67 ± 2.29 <sup>c,d</sup>	5.11 ± 1.71 <sup>d</sup>	3.98 ± 1.57	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )	17.16 ± 4.12 <sup>b,c,d</sup>	19.52 ± 4.84 <sup>c,d</sup>	21.04 ± 4.58 <sup>d</sup>	23.88 ± 4.84	<b>&lt;0.005</b>
<b>Boys</b>	<b>Thin</b> N = 434	<b>Normal</b> N = 1848	<b>Overweight</b> N = 392	<b>Obesity</b> N = 145	
20-m shuttle run test - Prefit ( <i>stage</i> )	8.62 ± 2.62 <sup>b,c,d</sup>	8.16 ± 2.57 <sup>c,d</sup>	5.84 ± 2.20 <sup>d</sup>	4.17 ± 1.97	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )	18.13 ± 4.12 <sup>b,c,d</sup>	20.34 ± 4.84 <sup>c,d</sup>	21.41 ± 4.5 <sup>d</sup>	22.69 ± 5.25	<b>&lt;0.005</b>

Values are mean ± standard deviation

\* One-way ANOVA test. Pairwise Post-hoc comparisons were performed using linear contrasts, after applying a Bonferroni correction for multiple comparisons (a = thin; b = normal; c = overweight; d = obesity).

1

**Table 3.** Physical fitness according to organized sport participation (club and school).

<b>Total</b>	<b>No</b> N = 3287	<b>School only</b> N = 455	<b>Club only</b> N = 2583	<b>Club and school</b> N = 976	<b>P*</b>
20-m shuttle run test - Prefit ( <i>stage</i> )	6.22 ± 2.46 <sup>b,c,d</sup>	7.05 ± 2.59 <sup>c,d</sup>	7.34 ± 2.55 <sup>d</sup>	8.14 ± 2.61	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )	19.95 ± 5.22	19.92 ± 5.68	20.05 ± 4.82	20.19 ± 4.29	0.60
<b>Girls</b>	<b>No</b> N = 1693	<b>School only</b> N = 224	<b>Club Only</b> N = 1280	<b>Club and school</b> N = 391	
20-m shuttle run test - Prefit ( <i>stage</i> )	5.86 ± 2.23 <sup>b,c,d</sup>	6.47 ± 2.31 <sup>c,d</sup>	6.69 ± 2.20 <sup>d</sup>	7.40 ± 2.51	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )	19.56 ± 4.89	19.40 ± 6.09	19.71 ± 4.93	19.74 ± 4.38	0.73
<b>Boys</b>	<b>No</b> N = 1594	<b>School only</b> N = 231	<b>Club Only</b> N = 1303	<b>Club and school</b> N = 595	
20-m shuttle run test - Prefit ( <i>stage</i> )	6.61 ± 2.81 <sup>b,c,d</sup>	7.92 ± 2.80 <sup>c,d</sup>	7.59 ± 2.62 <sup>d</sup>	8.73 ± 2.53	<b>&lt;0.005</b>
Absolute Handgrip strength ( <i>kg</i> )	20.38 ± 5.49	20.44 ± 5.14	20.37 ± 4.69	20.48 ± 4.36	0.97

2

Values are mean ± standard deviation

3

\* One-way ANOVA test. Pairwise Post-hoc comparisons were performed using linear contrasts, after applying a Bonferroni correction for multiple comparisons (a = no; b = school only; c = club only; d = club and school).

4

5

**Table 4.** Centiles estimation for cardiorespiratory fitness (20-m shuttle run test - PREFIT, stages) by sex and age based on 8022 test performances of French adolescents aged 10-12 years.

	Mean $\pm$ SD	Percentiles										
		5	10	20	30	40	50	60	70	80	90	95
<b><i>PREFIT protocol</i></b>												
<i>Boys</i>												
10-10.9 years	7.7 $\pm$ 2.8	3.5	4.0	5.5	6.0	7.0	8.0	8.5	9.5	10.0	11.0	12.0
11-11.9 years	7.7 $\pm$ 3.2	3.3	4.0	5.0	6.0	7.0	7.5	8.5	9.5	10.5	11.5	12.5
12-12.9 years	6.5 $\pm$ 2.9	2.5	3.0	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0
<i>Girls</i>												
10-10.9 years	6.4 $\pm$ 2.4	3.0	3.5	4.5	5.0	5.5	6.0	7.0	7.5	8.5	9.5	10.5
11-11.9 years	6.4 $\pm$ 2.6	3.0	3.5	4.5	5.0	5.5	6.5	7.0	7.5	8.5	9.5	10.5
12-12.9 years	5.2 $\pm$ 2.2	2.0	2.7	3.0	4.0	4.5	5.0	5.5	6.0	7.0	8.5	9.5

7 Centile values were estimated by using GAMLSS model (Box–Cox power exponential distribution) for exact ages. SD indicates standard deviation.

**Table 5.** Centiles estimation for handgrip strength (absolute values) by sex and age based on 8022 test performances of French children aged 10-12 years.

	Mean $\pm$ SD	Percentiles										
		5	10	20	30	40	50	60	70	80	90	95
<i>Boys</i>												
10-10.9 years	19.33 $\pm$ 4.64	13.38	14.50	15.60	16.80	17.96	18.80	19.80	20.90	22.26	24.50	26.80
11-11.9 years	20.66 $\pm$ 4.90	14.10	15.40	16.90	18.00	19.10	20.10	21.10	22.40	23.90	26.20	28.34
12-12.9 years	22.28 $\pm$ 7.32	12.50	13.90	16.60	18.20	19.90	21.00	22.60	24.60	27.50	30.40	35.80
<i>Girls</i>												
10-10.9 years	18.65 $\pm$ 4.49	12.90	14.00	15.60	16.51	17.30	18.00	18.70	19.80	21.10	23.70	26.75
11-11.9 years	19.89 $\pm$ 4.91	13.20	14.60	16.00	17.36	18.40	19.30	20.20	21.40	23.10	25.70	28.20
12-12.9 years	21.76 $\pm$ 6.85	12.50	14.80	16.52	18.00	20.00	21.50	22.10	24.04	25.86	28.44	32.36

10 Centile values were estimated by using GAMLSS model (Box–Cox power exponential distribution) for exact ages. SD indicates standard deviation.