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

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ABSTRACT

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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/height² (kg/m²). 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[®] 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 ± 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

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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

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530 **Statements and Declarations**

531

532 **Conflict of interest**

533 The remaining authors state no conflict of interest.

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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

		Overall	Boys	Girls	P*
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)	<0.001
	<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	<0.005
Height (<i>cm</i>)		148.22 ± 7.80	147.67 ± 7.56	148.89 ± 7.88	<0.005
Body mass Index (<i>kg/m²</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	<0.005
20-m shuttle run test - Prefit (<i>speed, km.h⁻¹</i>)		9.46 ± 1.38	9.82 ± 1.49	9.08 ± 1.21	<0.005
20-m shuttle run test - Original (<i>stages</i>)**		3.0 ± 1.6	3.2 ± 1.7	2.5 ± 1.4	<0.005
Absolute Handgrip strength (<i>kg</i>)		20.02 ± 5.10	20.40 ± 5.00	19.62 ± 4.93	<0.005

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.

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

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).

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