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27

ABSTRACT

28 We assessed the association between school time and physical fitness in adolescents.
29 The study included 2,024 adolescents, aged 12.5–17.5 years, who participated in the
30 Healthy Lifestyle in Europe by Nutrition in Adolescence study. Health-related
31 physical fitness components were assessed using the physical fitness tests battery.
32 Cardiovascular risk was categorized using the sex-specific cutoffs for a healthy
33 cardiorespiratory fitness level in adolescents proposed by FitnessGram[®]. School time
34 was classified as short or long. Multivariate analysis accounted for confounding
35 factors such age, sex, body mass index, time spent in moderate to vigorous physical
36 activity, pubertal status, and parents' educational level. Cardiorespiratory fitness was
37 higher in adolescents with a long school time than in those with a short school time
38 (42.0 ± 7.6 vs 40.7 ± 7.2 mL.kg⁻¹.min⁻¹, respectively; $p < 0.05$). The percentage of
39 adolescents at cardiovascular risk in adulthood was higher in the short than in the
40 long time group (45.2% vs 31.7%, respectively) ($p < 0.05$). These findings suggest
41 that a long school day is associated with higher cardiorespiratory fitness in
42 adolescents and that school time should be considered in interventions and health
43 promotion strategies.

44

45 **Introduction**

46 Cardiovascular diseases in adulthood have their genesis in childhood, even if the
47 clinical symptoms may not become apparent until later in life. Physical fitness plays
48 an important role in adolescent cardiometabolic health (Högström, Nordström, &
49 Nordström, 2016; Ortega, Ruiz, Castillo, & Sjöström, M, 2008). Health-related
50 physical fitness includes muscular strength and endurance, flexibility, speed/agility,
51 and cardiorespiratory fitness (Caspersen, Powell, & Christenson, 1985; Ortega et al.,
52 2008). Two prospective cohort studies of Swedish male adolescents showed that low
53 cardiorespiratory fitness and muscular strength were strongly associated with risk
54 factors for major causes of death in young adulthood (more widely for cardiovascular
55 diseases) and were equivalent to other risk factors such as elevated body mass index
56 (BMI) or blood pressure (Högström et al., 2016; Ortega et al., 2012). In addition,
57 good physical fitness is associated with numerous health benefits in adolescents,
58 such as a healthier body composition and fewer cardiovascular disease risk factors
59 (García-Hermoso, Ramírez-Campillo, & Izquierdo, 2019; Ortega et al., 2008; Smith
60 et al., 2014). However, physical fitness levels during childhood and adolescence
61 have decreased markedly in the four past decades, especially for cardiorespiratory
62 fitness, which is recognized as the main physiological marker of cardiovascular
63 health (Fühner, Kliegl, Arntz, Kriemler, & Granacher, 2020; Tomkinson et al.,
64 2017). Identifying the factors that influence physical fitness has become an important
65 research issue in the field of public health, and attention has focused on effective
66 methods for improving the physical fitness levels of children and adolescents.

67 School-aged children spend a significant proportion of their waking hours either
68 in transit to and from or in the school setting. However, school time may vary widely
69 between several European countries, and this difference may affect physical fitness
70 in European adolescents. School time was defined as a specific organization of time

71 spend in the school environment. Several parameters have to be taken into account in
72 a school rhythm such as beginning and finishing hours of the class, number and
73 duration of recesses, the time for the lunch break, number of school days per week
74 and total time spent at school. Each European country has his proper policies
75 concerning the school times leading to differences throughout these parameters
76 mentioned above (especially on finishing hours of the class and by consequent time
77 spent in the school environment, daily time spent in recess and time for the lunch
78 break). In short school time, adolescents finished earlier (before 3:00 PM) have less
79 time in recess and lunch break (in average 50 min per day less time). In addition,
80 adolescents spent 9 h per week less time in the school environment compared with
81 those in the long time group (Vanhelst et al., 2017). We hypothesized that these
82 differences of policies may have an impact on lifestyle behaviors of adolescents and
83 consequently on their physical fitness. We therefore hypothesized that adolescents
84 having a long school time had a lower physical fitness compared to those more
85 physically active in short school time. Therefore, the aim of this study was to assess
86 the associations between school time and physical fitness in a large sample of
87 European adolescents.

88

89 **Materials and Methods**

90 ***Study design***

91 The present study was performed under the framework of the Healthy Lifestyle in
92 Europe by Nutrition in Adolescence (HELENA) study. The aim of the HELENA
93 study was to obtain a broad range of standardized, reliable, and comparable nutrition
94 and health-related data from a random sample of European adolescents aged 12.5–
95 17.5 years. The HELENA study was performed from 2006 to 2008 in 10 European

96 cities. Details of the recruitment, sampling, standardization, and harmonization
97 processes were published elsewhere (Béghin et al., 2012; Moreno et al., 2008).
98 Written, informed consent was obtained from the adolescent and the parents. The
99 HELENA study was approved by the local ethics committee for each country, and all
100 procedures were performed in accordance with the ethical standards of the Helsinki
101 Declaration of 1975 as revised in 2008.

102 From the total population of 3,528 adolescents, a subsample of 2,024 (57.4%) was
103 included in the present analysis because the database had complete and valid data
104 about their school schedules.

105

106 ***Measurements***

107 *Physical fitness*

108 The health-related physical fitness components were assessed using a battery of
109 physical fitness tests, which assessed cardiorespiratory fitness, muscular strength
110 (upper and lower limbs), flexibility, and speed/agility (Ortega et al., 2011). All tests
111 were performed twice, and the best score was recorded, except for the
112 cardiorespiratory fitness and the bent arm hang tests, which were performed only
113 once each. Good reliability in young people has been reported for all tests used in the
114 study (Ortega et al., 2008).

115 *Cardiorespiratory fitness* was assessed with a 20-m shuttle run test (Leger,
116 Mercier, Gadoury, & Lambert, 1988). Participants were required to run between two
117 lines 20 m apart while keeping pace with audio signals. The initial speed of 8.5 km/h,
118 was increased by 0.5 km/h for each stage, which lasted 1 min. The participants were
119 instructed to run in a straight line, to pivot on completing each shuttle run, and to
120 pace themselves in accordance with the audio signals. The test was finished when the

121 participant failed to reach the end lines concurrent with the audio signals on two
122 consecutive occasions or stopped because of fatigue. Participants were encouraged to
123 keep running throughout the test. The last completed stage or half-stage was
124 recorded and used to estimate VO_{2max} (Leger et al., 1988).

125 *Muscular strength* of the lower limbs was assessed using the standing broad
126 jump test. From a starting position immediately behind a line and standing with the
127 feet approximately shoulder-width apart, the adolescents were instructed to jump as
128 far as possible with the feet together. The hand grip test was used to assess upper
129 limb muscular strength. The digital Takei TKK 5101 dynamometer (range, 5–100
130 kg) was used to measure the maximum grip strength for both hands.

131 *Flexibility* was assessed by the back-saver sit-and-reach test. A standard box
132 with a small bar, which the participant must push, was used to perform the test. The
133 adolescents were instructed to bend the trunk and reach forward as far as possible
134 from a seated position. In the first test, one leg was straight and the other bent at the
135 knee, and the test was then performed a second time with the opposite leg pattern.
136 The farthest position of the bar reached for each leg was scored in centimeters, and
137 the average of the distances reached by both legs was used in the analysis.

138 *Speed/agility* was assessed using the 4 × 10-m shuttle run test. The participant
139 performed four shuttle runs as fast as possible between two lines spaced 10 m apart.
140 Every time the participants crossed a line, they were instructed to pick up (the first
141 time) or exchange (second and third times) a sponge that had earlier been placed
142 behind the lines. The time taken to complete the test was recorded to the nearest
143 tenth of a second.

144

145 *School time*

146 A detailed description of school time definitions has been published elsewhere
147 (Vanhelst et al., 2017). Briefly, school time was divided into two groups (short
148 school time and long school time) using the information contained in the school
149 schedule. A short school rhythm was defined as finishing school at 3:00 p.m. or
150 earlier and with shorter recess(es) during the school day. A long school time was
151 defined as finishing school after 3:00 p.m. with long recess(es) during the day. The
152 characteristics of school diaries for these two categories are shown in Table 1.

153

154 *Participants' characteristics*

155 Each participant underwent a detailed medical examination. Pubertal status was
156 assessed by direct observation according to method of Tanner and Whitehouse
157 (Tanner & Whitehouse, 1976). Body weight was measured to the nearest 0.1 kg
158 using an electronic scale (SECA 871; SECA, Hamburg, Germany) with the
159 participant wearing shorts and a T-shirt without shoes. Height was measured without
160 shoes to the nearest 0.1 cm using a standard physician's scale (SECA 225; SECA,
161 Hamburg, Germany). BMI was calculated as weight/height squared (kg/m^2). Weight
162 status was classified according to the International Obesity Task Force cutoff (Cole
163 & Lobstein, 2012).

164 Parental educational level (PEL) was classified into one of three categories using
165 a specific questionnaire adapted from the International Standard Classification of
166 Education (ISCED) (<http://www.uis.unesco.org/Library/Documents/isced97-en.pdf>).
167 PEL was scored as 1, primary and lower education (levels 0, 1, and 2 in the ISCED
168 classification); 2, higher secondary (levels 3 and 4 in the ISCED classification); and
169 3, tertiary (levels 5 and 6 in the ISCED classification).

170

171 *Physical activity*

172 PA patterns were assessed using a uniaxial accelerometer (ActiGraph[®] MTI GT1M
173 model, Pensacola, FL, USA). Participants were instructed to attach the accelerometer
174 device on their lower back with an elastic band and adjustable buckle, and to wear it
175 for 1 week (7 consecutive days). They were also asked to follow their normal daily
176 routine and to remove the device only during water-based activities (such as
177 swimming, showering, and bathing) and at night. The sampling interval (epoch) was
178 set at 15 seconds and the output was expressed as counts per min. The GT1M
179 sampling frequency was set to 30 Hertz, and the monitor measures 0.05-2.5 g in
180 dynamic range in the vertical axis. Adolescents who did not record at least 3 days
181 (including at least one weekend day) of recording with a minimum of 10 h of activity
182 per day were excluded from the analyses (Mâsse et al., 2005; Ward, Evenson,
183 Vaughn, Rodgers, & Troiano, 2005). We excluded from the analysis bouts of 20
184 continuous minutes of activity with intensity counts of 0, considering these periods
185 to be nonwearing time. The times engaged in sedentary, light, moderate, vigorous,
186 and moderate to vigorous PA (MVPA) throughout the day were calculated using
187 previously validated thresholds (Vanhelst et al., 2011).

188

189 *Statistical analysis*

190 The data are presented as percentage for qualitative variables and mean \pm standard
191 deviation (SD) for quantitative variables. Normality of distribution was checked
192 graphically and by using the Shapiro–Wilk test. To assess the potential bias related to
193 missing or incomplete data on the school schedules, the main characteristics of
194 included and excluded adolescents were compared using Student's *t* test for
195 quantitative variables, the chi-squared test for categorical variables, and the

196 Cochran–Armitage trend test for ordered categorical variables. To evaluate the
197 magnitude of differences between the included and not included participants, we
198 calculated the absolute standardized differences; a standardized difference >20%
199 denotes a meaningful imbalance. To assess the potential bias related to missing or
200 incomplete data for physical fitness, the main adolescent characteristics were
201 compared between adolescents with and without physical fitness data using Student’s
202 *t* test for quantitative variables, the chi-squared test for categorical variables, and the
203 Mantel–Haenszel trend test for ordered categorical variables.

204 Associations between physical fitness with school time were identified using
205 analysis of covariance models adjusted for prespecified confounding factors,
206 including age, sex, BMI, pubertal status, total time in MVPA during the week, and
207 PEL. To avoid case deletion in the analyses, missing data were imputed by multiple
208 imputations using the regression-switching approach (chained equations with $m =$
209 10) (Buren & Groothuis-Oudshoorn, 2011). The imputation procedure was
210 performed under the missing-at-random assumption using all adolescents’
211 characteristics, school rhythm and physical fitness using the predictive mean-
212 matching method for quantitative variables, logistic regression model for binary
213 variables, and ordinal logistic regression for ordered categorical variables. Rubin’s
214 rules were used to combine the estimates derived from multiple imputed data sets
215 (Rubin, 1990). All statistical tests were performed at the two-tailed α level of 0.05.
216 Data were analyzed using SAS software (version 9.4; SAS Institute Inc., Cary, NC,
217 USA).

218

219 **Results**

220 The physical characteristics of the adolescents are presented in Table 2. We found
221 some differences between the included and not included adolescents but no
222 meaningful differences regarding the absolute standardized differences expected for
223 age and pubertal status (see supplemental table).

224 Table 3 shows the physical fitness levels according to school time group before
225 and after adjustment for the prespecified confounding factors. Cardiorespiratory
226 fitness was higher in the long school time group than in the short school time group
227 in both model 1 and 2. The other components of physical fitness, including
228 flexibility, upper and lower muscular strength, and speed/agility, did not differ
229 between groups (Table 3).

230

231 **Discussion**

232 To our knowledge, this study is the first to assess whether school time is
233 associated with physical fitness in European countries. The main finding from our
234 study is that a long school time was associated with better cardiorespiratory fitness.

235 Our main finding showing that school time is associated with cardiorespiratory
236 fitness independently of the time spent in MVPA suggests that other factors, such as
237 sedentary behavior or sleep parameters, might explain the low physical fitness level
238 in adolescents with a short school time (Baiden, Tadeo, & Peters, 2019; Chang &
239 Chen, 2015; Santos et al., 2014). Since we did not assessed these parameters in the
240 present study, we cannot speculate more about their roles in explaining a better
241 cardiorespiratory fitness in the adolescents spending less time at school and should
242 deserve further studies.

243 Our results suggest that the development of prevention strategies for improving
244 cardiorespiratory fitness should consider the school environment. A meta-analysis

245 has shown that interventional after-school programs have a positive impact on
246 various health outcomes, such as reduced sedentary behaviors and BMI, and
247 increased MVPA and physical fitness (Beets, Beighle, Erwin, & Huberty, 2009). In
248 the shorter school rhythm, in which adolescents finish earlier, after-school programs
249 should be devoted to promoting healthy habits, including decreasing sedentary
250 behaviors. The results from our study suggest that a longer school time and its
251 environment can provide a good opportunity for reducing the time spent in sedentary
252 activities, which may help to lower fat mass and improve fitness and cardiovascular
253 health. In addition, considering MVPA as a potential factor of cardiorespiratory
254 fitness (Armstrong, Tomkinson, & Ekelund, 2011) and since that we previously
255 shown that time spent in MVPA increased in long school time (Vanhelst et al.,
256 2017), long school hours and their environment could be also an opportunity to
257 increase MVPA. We suggest that European countries with school policies with short
258 school time and recesses, and less time in teaching per day should focus their
259 policies on reducing sedentary behaviors during school free time and promoting PA
260 and healthy habits.

261 When comparing the results of our present study showing an increase of 1.3
262 mL.kg.min⁻¹ of cardiorespiratory fitness to the modest of MVPA (3.5 min.day⁻¹) and
263 sedentary behaviors (12.4 min.day⁻¹) we found in our previous study (Vanhelst et al.,
264 2017), we are questioned on the type of PA the adolescents performed during school
265 time. Although our study was not designed to answer this question, it has been
266 shown that the type of PA impact differently cardiorespiratory fitness (Ratel et al.,
267 2004). Future interventional study should take this point into account and choose
268 specific PA which impact cardiorespiratory fitness.

269 The current study has both strengths and limitations. The strengths are the large
270 sample size of adolescents with sex-specific information from several European
271 cities, use of standardized procedures, inclusion of many confounding factors (PA
272 assessed objectively, sex, pubertal status, parental education level, and breastfeeding)
273 in the analyses, and the strong methodology for assessing physical fitness and
274 anthropometric data. The main limitation of the study is the lack of some detailed
275 information about school time. The number of physical education lessons in each
276 class was not available and could not be included in the statistical analysis, which
277 may have influenced our results. However, the accelerometry data obtained for 1
278 week would have included time spent in physical education classes. Using other VO₂
279 peak prediction equation rather than those of Léger et al. (1988) or VO₂ peak without
280 performing the allometric scale could have influence our results. Lastly, the
281 HELENA study was performed 14 years ago (2006-2007), we cannot be sure our
282 results represent the present situation. However, school **time** structures in
283 participating countries did not change from date where data was collected and the
284 date of the present analysis.

285

286 **Conclusion**

287 A long time spent at school is associated with higher cardiorespiratory fitness in
288 adolescents. This finding suggests that school time should be considered in future
289 interventions and health promotion strategies. As short time school is associated with
290 lower cardiorespiratory fitness, efforts should be focused on after-school programs
291 for promoting MVPA and reducing sedentary **behaviors**. Future research on
292 intervention programs on school free time for adolescent having a short school time
293 should be performed.

294 **Conflict of interest**

295 The authors do not have any competing interests.

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Table 1. Impact of school time on school rhythm

	Short time group (N school=60)	Long time group (N school=44)
Recess duration (<i>min/day</i>)	40 [15; 105]	90 [60; 150]*
Time spent at school per day (<i>h</i>)	5.50 [4.00; 7.10]	7.58 [6.55; 9.55]*
Time spent at school per week (<i>h</i>)	25.25 [20.00; 35.50]	34.00 [27.40; 49.35]*
Hours of teaching per day (<i>h</i>)	5.15 [3.00; 6.00]	6.25 [5.45; 8.15]*
Hours of teaching per week (<i>h</i>)	22.00 [15.00; 30.00]	26.30 [23.00; 41.15]*
Number of classes with < 5 days of school per week, n (%)	19 (31.7)	36 (81.8)*

402 Data are median [range] unless indicated.

403 "*" means p-value <0.0001.

404

Table 2. Characteristics of the study population of adolescents.

	Before imputation		After imputation
	Without missing data	With missing data	
N	1473	551	2024
Gender (%M)	49.5	50.8	49.5
Age (y)	14.6 ± 1.2	14.7 ± 1.1	14.6 ± 1.2
Height (cm)	165.7 ± 9.2	165.9 ± 9.1	165.7 ± 9.2
Body mass (kg)	58.2 ± 12.2	59.4 ± 13.0	58.4 ± 12.4
BMI (kg.m ⁻²)	21.1 ± 3.5	21.5 ± 3.8	21.2 ± 3.6
Nutritional status (%UW/%NW/%OW/%O) ^a	6.6/72.2/16.2/5.0	6.8/68.8/18.7/5.7	6.6/71.4/16.8/5.2
Pubertal status (%I/%II/%III/%IV) ^b	6.9/23.0/34.0/36.1	5.2/18.4/34.6/41.8 *	6.5/22.0/34.0/37.5
Father education level (%I/%II/%III) ^c	32.8/30.3/36.9	36.7/24.1/39.2	34.3/28.7/37.0
Mother education level (%I/%II/%III) ^c	33.1/31.4/35.5	32.5/30.3/37.3	33.2/30.9/35.9
MVPA (min.day ⁻¹)	52.9 ± 26.1	50.2 ± 25.6 *	52.2 ± 25.9

406 * P < 0.05 for comparison between the two samples, without and with missing data

407 ^a Nutritional status: underweight (UW), normal weight (NW), overweight (OW), obese (O)

408 ^b Pubertal status staging according to Tanner

409 ^c PEL: lower education (I); higher secondary education (II); higher education or university degree (III).

410

411

Table 3. Physical fitness levels according to school **time** group

	Short time group	Long time group	Model 1	Model 2
Cardiorespiratory Fitness ($mL.kg.min^{-1}$)	40.7 ± 7.2	42.0 ± 7.6	<0.001	0.04
Flexibility (<i>cm</i>)	22.8 ± 8.1	23.1 ± 7.9	0.47	0.52
Upper Muscular Strength (<i>kg</i>)	30.3 ± 8.8	30.6 ± 9.0	0.46	0.28
Lower Muscular Strength (<i>cm</i>)	164.1 ± 35.2	163.1 ± 35.0	0.56	0.34
Speed/Agility (<i>sec</i>)	12.2 ± 1.3	12.2 ± 1.3	0.65	0.64

412 Mean (± SEM) and P-value were calculated after multiple imputations (m=10) to handle missing data.

413 Model 1: unadjusted.

414 Model 2: adjusted for age, gender, pubertal status, BMI, MVPA during whole week, father education

415 level and mother education level