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1 **Title :** Gender influences physical activity changes during adolescence: the HELENA study

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30

31

ABSTRACT

32

33 *Background*

34 We compared differences in physical activity (PA) between pre/mid-pubertal and
35 post-pubertal participants according to gender.

36 *Methods*

37 The study included a total of 1842 healthy participants aged 12.5–17.4 years, who
38 participated in the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study.
39 Participants wore a uniaxial accelerometer (ActiGraph[®] GT1M, Pensacola, FL, USA) attached
40 to their lower back for seven consecutive days to measure PA. Pubertal status was assessed
41 by physical examination and the population was classified as pre/mid-pubertal (Tanner
42 stages 1–3) or post-pubertal (Tanner stages 4–5). PA was compared between these groups
43 according to gender during the whole week, on school-free days and on school days, before
44 and after school, and during lessons and recesses.

45 *Results*

46 When comparing the pre/mid-pubertal group with the post-pubertal group, girls'
47 total PA did not differ between groups. However, a slight difference was observed in boys,
48 among whom PA on school-free days showed a difference of 17.6% between the pre/mid-
49 pubertal group and the post-pubertal group (679 kcounts vs 564 kcounts, respectively; $P =$
50 0.0007) and 20% (162 kcount vs 135 kcounts; $P = 0.006$) for school recess. There was no
51 difference among girls.

52 *Conclusions*

53 A reduced level of PA in the post-pubertal groups was only observed in boys during
54 non-organized times such as on school-free days and during school recesses, with a
55 moderate impact on total PA.

56

57 *Keywords:* Physical activity, Adolescence, Pubertal status, Europe, Sedentary behavior

58

59 **1. Introduction**

60 Physical activity (PA) is as an important determinant of health and has been shown to
61 have beneficial effects on body composition, metabolic markers, physical fitness and mental
62 health [1, 2]. Moreover, decreasing PA during adolescence increases the risk of obesity in
63 later years [3]. Despite these observations, population-level PA is usually below public health
64 recommendations during adolescence [4]. A decrease in PA is generally observed during the
65 transition from childhood to adolescence [5], and has been acknowledged as a causal factor
66 behind the current obesity epidemic [6].

67 The main factors known to influence PA in adolescents are: (i) individual intrinsic
68 motivation [2, 7]; (ii) family factors such as socioeconomic level or parental encouragement
69 [8, 9]; and (iii) general factors such as an urban environment (access to green public parks,
70 traffic density), natural conditions (seasons, temperature) and societal environments such as
71 daily school schedule [10-12]. However, the causes of a decline in PA during the transition to
72 adolescence [7, 12], which then tracks from adolescence to adulthood [13], are not well
73 understood [8]. The analysis of PA changes during the daily cycle and differences between
74 girls and boys could advance our understanding of the PA decline during the transition to
75 adolescence.

76 The study aim was to compare differences in PA between pre/mid-pubertal and post-
77 pubertal participants according to gender during the daily cycle of school days and school-
78 free days.

79

80

81

82 **2. Subjects and methods**

83 *2.1. Study design and ethical approvals*

84 Data were collected from the Healthy Lifestyle in Europe by Nutrition in Adolescence
85 (HELENA study; www.helenastudy.com) conducted in European adolescents. The aim of the
86 HELENA study was to obtain a broad range of standardized, reliable, and comparable
87 nutrition- and health-related data from a random sample of European adolescents aged
88 12.5–17.5 years. A detailed description of the HELENA study methodology and sampling has
89 been published elsewhere [13, 14]. In total, 3528 participants (1844 girls and 1684 boys)
90 meeting the inclusion criteria completed all examinations. The analyses in the present study
91 are based on 1842 healthy participants aged 12.5–17.4 years from seven European cities :
92 Lille (France), Spain Zaragoza (Spain), Dortmund (Germany), Pécs (Hungary), Ghent
93 (Belgium), Roma (Italy) and Athens (Greece). Data were excluded because of missing
94 accelerometer data ($n = 709$), missing school schedules ($n = 1504$) and missing Tanner
95 staging information ($n = 401$).

96 The study objectives and methodology were explained carefully to each participant
97 and their both parents. Written informed consent was obtained from all participants. The
98 local ethics committee for each country approved the HELENA study, and all procedures
99 were performed in accordance with the ethical standards of the 1975 Helsinki Declaration
100 (as revised in 2008) and the European Good Clinical Practice Guidelines [15].

101

102 *2.2. Participant characteristics and physical examinations*

103 Weight was measured in light clothes, without shoes, to the nearest 0.1 kg using an
104 electronic scale (SECA 871; SECA, Hamburg, Germany). Height was measured without shoes

105 to the nearest 0.1 cm using a telescopic height-measuring instrument (SECA 225; SECA).
106 Body mass index (BMI) was calculated using the standard formula (kg/m^2). Nutritional status
107 was defined using the sex specific cutoff points established by the World Obesity Federation
108 (formerly the International Obesity Task Force) [16].

109 Pubertal status was assessed according to Tanner stage, the standard reference
110 method, during a physical examination by a well-trained physician [17]. Signs of puberty
111 were scored according to pubic hair status using the standard pictures of pubic hair
112 development from the Tanner scale. The degree of pubertal development was also assessed
113 according to the size of the testes, scrotum and penis in boys, and according to breast
114 development in girls using the standard pictures of Tanner and five categories for both
115 genders. Following Crowley *et al.* [18], adolescents' pubertal status was classified into two
116 groups : pre/mid-pubertal (Tanner stages 1–3) and post-pubertal (Tanner stages 4–5). We
117 used this classification because pubertal status correlates with changes in adolescent
118 hormone levels. Previous studies observed changes in adolescent personalities using
119 pubertal status as a marker of the transition and concluded that age was not a good marker
120 [19]. In this context, pubertal status is the most appropriate marker to assess adolescent
121 behavioral changes that may influence PA levels.

122

123

124 2.3. Physical activity *assessment*

125 The GT1M Monitor (ActiGraph©, Pensacola, FL, USA) was used to assess PA in free-
126 living conditions. The process for the use of this device, data collection and data cleaning has
127 been described previously [20]. Briefly, a fieldworker researcher at each centre completed
128 workshop training in how to instruct participants in using the device. The adolescents were

129 instructed to wear the accelerometer on their lower back on elastic belt and adjustable
130 buckle during seven consecutive days during their normal daily routine. They were also
131 instructed to remove the accelerometer during swimming, showering, bathing and at night.

132 Data were collected at 15 sec an epoch intervals. After downloading of data, PA levels
133 were converted and expressed as an average PA in mean counts per minute. Data from
134 06.00 to 23.00 were analyzed. Strings of 20 consecutive minutes recording zero counts were
135 classified as non-wear and excluded from the analysis [21]. Participants who did not record
136 at least 3 days with a minimum of 8 h of wearing time per day were excluded from the
137 analyses.

138 PA was expressed as a cumulative amounts counts or the group mean (i.e., boys and
139 girls) kcounts over the one-week wearing period. Next, different periods of time schedule
140 (i.e., school free days, before school, after school, etc) were compared. Moderate vigorous
141 physical activity (MVPA) was defined as minutes when PA was >2000 counts/min [22] .

142

143 *2.4. Adolescent schedule rhythms*

144 A researcher from each center was instructed to complete a weekly schedule
145 questionnaire to separate school days from school-free days, and to split the school days
146 into different periods, including : (i) school days and school-free days; (ii) hours before and
147 after school; (iii) hours of teaching/lessons; and (iv) before school recesses and lunch breaks.
148 According to each participant's rhythm, the school schedule was separated into three
149 periods : before and after school, during lessons, and during recesses. A detailed time
150 schedule for each participating school class was previously described by Vanhelst *et al* [23].

151

152 *2.5. Sedentary behavior*

153 Sedentary behavior was assessed using a structured questionnaire with items about
154 the amount of time habitually spent in front of the television (TV), computer (PC), or playing
155 video games (VG) during school days and on school-free days. This included questions such
156 as: “On weekdays, how many hours do you usually spend watching television?”, “On
157 weekdays, how many hours do you usually spend on the computer?”, and “On weekdays,
158 how many hours do you usually spend playing video games?” The answers were classified
159 into two categories: $<2 \text{ h/day}^{-1}$ and $\geq 2 \text{ h/day}^{-1}$. The 10-min questionnaire was administered
160 in the classroom, under the supervision of an HELENA fieldworker, during the morning
161 before the PA assessment. This measure has been shown to have a reliable intraclass
162 correlation (0.82; 95% CI 0.75–0.87) and criterion validity (0.3) ([24]

163

164 2.6. *Potential confounders*

165 Based on previous studies, we considered the following potential confounders study.

- 166 • City.
- 167 • BMI converted to z-scores [25].
- 168 • Parental educational level (PEL) (father and mother separately) collected with a
169 specific questionnaire adapted from the International Standard Classification of
170 Education (ISCED) ([http://www.uis.unesco.org/Library/Documents/isced97-
171 en.pdf](http://www.uis.unesco.org/Library/Documents/isced97-en.pdf)) and scored as described previously [26].
- 172 • Smoking status, defined as the regular consumption of at least one cigarette per
173 day in the past month [27].

174

175 2.7. *Statistics*

176 Data are presented as percentages for qualitative variables, and as the mean \pm
177 standard deviation for quantitative variables. The normality of distribution was checked
178 graphically and by using the Shapiro–Wilk test. To assess any potential bias linked to missing
179 or incomplete data on PA or Tanner staging, the main characteristics of included and
180 excluded participants were compared using Student’s *t*-test for quantitative variables, a Chi-
181 squared test for categorical variables and the Cochran–Armitage trend test for ordered
182 categorical variables. To evaluate the magnitude of differences between included and
183 excluded participants, we calculated the absolute standardized differences: a standardized
184 difference $>20\%$ denotes meaningful imbalance. All comparisons on the influence of
185 pubertal status on PA change were conducted separately for boys and girls separately. We
186 first compared the main participants’ characteristics and recorded PA time between the two
187 pubertal status categories; Student’s *t*-test was used for quantitative variables, the chi-
188 squared test for categorical variables and the Cochran–Armitage trend test for ordered
189 categorical variables.

190 Next, we investigated the associations between pubertal status and PA (total counts)
191 and during different periods (school-free days, school days, before and after school, during
192 lessons and during recesses) after adjustment on prespecified confounding factors (namely
193 the Z-score for BMI, PEL, smoking status and study center). We used linear mixed models
194 including the city as random effects and other variables as fixed effects; adjusted means of
195 physical activity (\pm standard error of the mean, SEM) were calculated using the least-squares
196 mean approach. Heterogeneities in associations of pubertal status with PA measures across
197 gender were tested using formal interaction tests.

198 All statistical tests were performed with a two-tailed α level of 0.05 except for
199 heterogeneity in which an α level of 0.10 was chosen. Data were analyzed using SAS
200 software version 9.4 (SAS Institute Inc., Cary, NC, USA).

201

202 **3. Results**

203 *3.1. Study population*

204 Table 1 shows a comparison of the main characteristics of included participants (i.e.,
205 with PA and Tanner staging data available) vs those excluded from statistical analyses.
206 Except for age and the paternal educational level, we found no meaningful difference
207 between the included and excluded participants. Table 2 shows the included participants'
208 main characteristics and their accelerometer wearing time according to pubertal status for
209 boys and girls separately. Boys and girls at post-pubertal stages were older, heavier, taller,
210 and more often smokers compared with those at pre/mid-pubertal stages, and spent more
211 time at school for lessons. The BMI z-scores did not differ between groups or genders.

212

213 *3.2. Total physical activity data*

214 After adjustment for the study city, BMI z-score, PEL, and smoking status, there was
215 no significant difference in total PA during the whole one-week study between the pre/mid-
216 pubertal and post-pubertal boys or girls (Figure 1). However, post-pubertal boys
217 accumulated fewer kcounts compared with their pre/mid pubertal peers (143 kcounts; $P =$
218 0.07). Based on time schedule during school days, post-puberty was associated with a
219 significant difference (17.6%) in total PA during school-free days only for boys (adjusted
220 mean total counts: 679 kcounts in pre/mid-puberty vs 564 kcounts in post-puberty; $P =$

221 0.0007; Figure 1). Similarly, post-puberty was associated with a difference of 20% in total PA
222 during recesses for boys (adjusted mean total counts: 162 kcounts in pre/mid-puberty vs 135
223 kcounts in post-puberty; $P = 0.006$). A significant difference was observed in sedentary
224 behavior. The percentage of boys who played VG ≥ 2 h/day was 33% higher in the
225 postpubertal group than in the prepubertal group ($P = 0.02$) during school-free days,
226 whereas there was no difference for TV and PC.

227 There was no difference between prepubertal vs postpubertal girls for PA in whole
228 week, school free days and any period of school day.

229

230 *3.3. Moderate to vigorous physical activity data*

231

232 The difference of MVPA duration between prepubertal vs postpubertal boys was
233 14.6% (61.0 min vs 52.1 min, respectively; $P = 0.005$) for school-free days and 14.9% (7.4 min
234 vs 6.3 min, respectively; $P = 0.038$) for school recesses in boys. There was no difference
235 between prepubertal vs postpubertal group girls for MVPA in whole week, school free days
236 and any period of school day.

237

238 **4. Discussion**

239 To our knowledge, this study is the first to investigate the impact of gender on PA
240 during the transition to adolescence using a detailed weekly schedule and pubertal status
241 (maturational status) as a marker of adolescent phase. The use of pubertal status
242 (maturational status) instead of adolescence (chronological age) is a better approximation of
243 the changes observed during adolescence. Most previous studies on the impact of this

244 transitional period on PA have used age rather than pubertal status, and questionnaires
245 instead of accelerometry for assessing PA, and did not take the time schedule during school
246 days into consideration [8].

247 The PA level observed in the HELENA study was higher in boys than in girls, as has
248 been previously observed in developing countries [4, 8, 28, 29]. PA difference between
249 prepubertal vs postpubertal during whole week did not reach significance, probably due to
250 the high variability in PA patterns observed. While there was no significant difference of PA
251 between prepubertal vs postpubertal during the whole week, the difference was significant
252 during school-free days and recesses in boys. This result is consistent with the difference in
253 PA observed in boys during non-organized times shown by Dale *et al.* [30]. A longitudinal by
254 Sallis JF *et al.*, reported an annual decline in PA of 2.7% for boys and 7.4% for girls throughout
255 adolescence [31]. However, these studies did not analyze PA during school days and school-
256 free days separately. Corder *et al.* showed changes in PA based on gender, age, and school-
257 free days/school days [32]. The absence of PA differences between pubertal stages in girls
258 was probably due to the lack of sedentary pursuits in girls suggested by Matthews *et al.* [29]

259 Concerning MVPA, between the pubertal stages studied, boys showed a significant
260 difference during school free-days and recesses. MVPA duration between prepubertal vs
261 postpubertal boys was -17.6% for school free days and -20% for recess.

262 Girls showed a trend of + 14.9 % between prepubertal vs postpubertal girls (29.6 min
263 vs 34.0 min, respectively; $P = 0.09$) for MVPA during school free days. This suggest that there
264 are changes in PA patterns among girls during puberty. These changes of PA patterns were
265 not statistically different probably due to the high variability in PA patterns observed.

266 This study showed a difference in PA between prepubertal vs postpubertal group, but
267 only in boys during non-organized times such as recesses and school-free days. This

268 difference in PA was not reversed during school periods, as was shown by Dale *et al* [30].
269 This is probably because PA during school days is more organized. In this context, PA during
270 school days is less likely to change. Thus, this study confirms the crucial role of recesses for
271 PA during school periods, as they provide good opportunities for PA promotion in all
272 adolescents [33].

273 Some limitations of this study should be acknowledged. The main limitation was the
274 cross-sectional design of the study which prevented us from describing within-individual PA
275 change patterns. Another limitation was the difference in participants' ages and paternal
276 education levels between those adolescents who were included vs those excluded. The
277 study strengths include the large sample sizes in seven European cities, the use of
278 standardized procedures, inclusion of several confounding factors within the analyses,
279 objective assessment of PA with prolonged wearing time, and the inclusion of school day
280 schedule analysis.

281 Understanding the decline in PA during the transition to adolescence is useful for
282 planning PA interventions. This study shown difference in PA between prepubertal vs
283 postpubertal boys, especially less PA in postpubertal boys during non-organized time. This
284 suggests that prepubertal boys become less active when they become postpubertal,
285 especially during school-free days. The finding highlights the importance of emphasizing
286 sports programs and hobbies that include PA for this population.

287

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292

293

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298

299

300 **Conflict of interest**

301 Frederic Gottrand has received consulting fees from Numico Clinical Nutrition, lecture fees
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305

306

307 **Author Contributions**

308 The authors' contributions are as follows: L. A. M. coordinated the HELENA project at the
309 international level; L. A. M., K. W., S. D., and F. G. were involved in the design of the HELENA
310 project and locally coordinated the HELENA project; L. B. and J. V. organized the fieldwork
311 and collected the data locally; L. B. was responsible for regulatory issues; E. D. carried out
312 the statistical analysis; L. B. drafted the article. J. H. M. was involved in the interpretation of
313 data and revising article by providing significant advice and consultation. All authors read
314 and approved the final manuscript.

315

316

317 **5. References**

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426 **FIGURE LEGENDS**

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428 **Figure 1. Total physical activity (*kcounts*) differences according to pubertal status**
429 **stratified by gender.**

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431 **Het: Heterogeneity.**

432 ^a calculated from linear mixed model adjusted for city, Z-score BMI, parental educational
433 level and smoking.

434 ^b calculated using pre/mid-puberty as reference group.

435

436 **Figure 2. Moderate and vigorous PA (*min/day*) differences according to pubertal status**
437 **stratified by gender**

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439 ^a calculated from linear mixed model adjusted for city, Z-score BMI, parental educational
440 level and smoking.

441 ^b calculated using pre/mid-puberty as reference group.

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Table 1. Main characteristics of included and non-included adolescents

	Included N=1842	Not included N=1814	P-value	Absolute standardized difference (%)
Gender (%boys)	49.7	45.5	0.012	8.5
Age (yr)	14.6 ± 1.2	14.9 ± 1.3	<0.0001	21.3
Height (cm)	165.7 ± 9.2	165.9 ± 9.1	0.47	2.5
Body weight (kg)	58.4 ± 12.3	59.9 ± 13.1	0.0003	12.3
Z-score BMI	0.3 ± 0.9	0.4 ± 0.9	0.86	8.8
Nutritional status (%UW/%NW/%OW/%O) ^a	6.7/71.6/16.5/5.2	5.4/69.9/18.7/6.0	0.017	8.4
Father education level (%I/%II/%III) ^b	33.4/28.9/37.7	42.9/26.5/30.6	<0.0001	20.2
Mother education level (%I/%II/%III) ^b	32.4/31.5/36.1	37.8/31.2/31.0	0.0003	12.7
Smoker (%)	15.5	20.1	0.0005	12.0

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

472 BMI: body mass index

473 ^b PEL (Parental Education Level) : lower education (I); higher secondary education (II); higher education or
474 university degree (III).

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Table 2. Characteristics of the subjects and accelerometer wearing time duration according to pubertal status stratified by gender

	Girls			Boys		
	Pre/mid puberty N=224	Post-puberty N=702	P-value	Pre/mid puberty N=301	Post puberty N=615	P-value
Characteristics						
Age (yr)	13.8 ± 0.93	14.8 ± 1.1	<0.0001	13.8 ± 0.9	15.1 ± 1.1	<0.0001
Height (cm)	159.6 ± 7.1	162.6 ± 6.8	<0.0001	162.4 ± 8.9	173.1 ± 7.6	<0.0001
Body weight (kg)	51.1 ± 10.6	57.0 ± 9.4	<0.0001	54.5 ± 14.4	64.5 ± 12.1	<0.0001
Z-score BMI	0.1 ± 1.0	0.4 ± 0.8	<0.0001	0.3 ± 1.1	0.4 ± 0.9	0.08
Nutritional status (%UW/%NW/%OW/%O) ^a	12.0/73.2/10.3/4.5	5.7/72.9/18.0/3.4	0.009	10.0/65.4/14.6/10.0	4.2/72.5/18.1/5.2	0.94
Father education level (%I/%II/%III) ^b	26.5/29.9/43.6	36.9/28.7/34.4	0.003	35.0/27.8/37.2	31.2/29.2/39.6	0.31
Mother education level (%I/%II/%III) ^b	23.9/35.3/40.8	36.8/29.0/34.2	0.003	33.8/29.5/36.7	29.9/33.8/36.2	0.56
Smoker (%)	5.8	20.3	<0.0001	7.5	17.4	<0.0001
Accelerometer wearing time (min/day)						
Whole week	1019.0 ± 0.1	1018.9 ± 1.0	0.26	1019.0 ± 0.3	1019.0 ± 0.5	0.96
School day	1019.0 ± 0.1	1018.9 ± 1.2	0.27	1019.0 ± 0.4	1019.0 ± 0.8	0.97
Before and after school	649.1 ± 79.7	611.6 ± 78.1	<0.0001	646.0 ± 68.1	622.2 ± 77.8	<0.0001
Lessons	305.5 ± 59.5	342.2 ± 58.5	<0.0001	307.2 ± 51.4	333.6 ± 58.5	<0.0001
Recess	65.4 ± 27.5	65.9 ± 30.8	0.83	66.0 ± 26.7	64.0 ± 30.0	0.31
Free-day	1019 ± 0.0	1019 ± 0.1	0.32	1019.0 ± 0.1	1019.0 ± 0.3	0.58

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

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

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Figure 1.

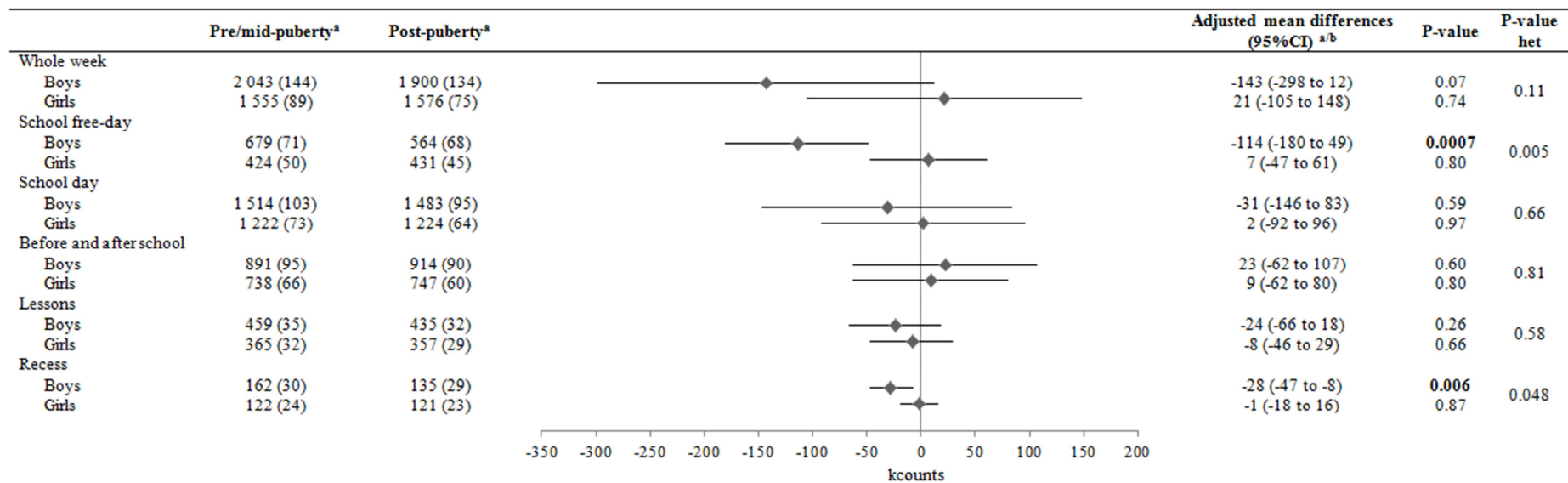


Figure 2.

