Correlates of ideal cardiovascular health in European adolescents: The HELENA study

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Abbreviations: AHA, American Heart Association; ANOVA, analysis of variance; ANCOVA, analysis of covariance, BMI, body mass index; iCVH, ideal cardiovascular health; FAS, family affluence scale; IPAQ, international physical activity questionnaire, HELENA study, Healthy Lifestyle in Europe by Nutrition in Adolescence study.

ABSTRACT

Background and Aims

The ideal cardiovascular health (iCVH) construct consists of 4 health behaviors (smoking status, body mass index, physical activity and diet) and 3 health factors (total cholesterol, blood pressure and fasting glucose). A greater number of iCVH components in adolescence is related to better cardiovascular health, but little is known about the correlates of iCVH in adolescents. Thus, the aim of the study was to examine correlates of iCVH in European adolescents.

Methods and Results

The study comprised 637 European adolescents with complete iCVH data. Participants were part of the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study, a cross-sectional, multicenter study conducted in 9 different European countries. Correlates investigated were sex and age, family affluence scale, maternal education, geographic location, sleep time, television viewing, duration of pregnancy, birth weight and breastfeeding. Younger adolescents, those whose mothers had medium/high education or those who watched television less than 2 h per day had a greater number of iCVH components compared to those who were older, had a mother with low education or watched television 2 h or more daily ($P \leq 0.01$).

Conclusion

Since in our study older adolescents had worse iCVH than younger adolescents, early promotion of cardiovascular health may be important. Future studies may also investigate the usefulness of limiting television viewing to promote iCVH. Finally, since adolescents of mothers with low education had poorer iCVH, it may be of special interest to tailor public health promotion to adolescents from families with low socioeconomic status.

Key words: cardiovascular health, epidemiology, prevention, public health, risk factor, television, socioeconomic status.

INTRODUCTION

Cardiovascular disease is a major cause of mortality and morbidity worldwide (1, 2). In 2010, the American Heart Association (AHA) launched a new construct to monitor cardiovascular health named ideal cardiovascular health (iCVH). It combines 4 health behaviors (smoking status, body mass index (BMI), physical activity and diet) and 3 traditional cardiovascular risk factors (cholesterol, blood pressure and glucose). Cut-offs to define ideal status of these behaviors and risk factors have been published both for children and adults (1). To date, a number of studies have reported that a greater number of iCVH components at ideal level in adulthood is associated with better health outcomes (3, 4). For instance, in a recent meta-analysis, adults with the greatest number of iCVH components had considerably lower risk of all-cause and cardiovascular mortality, as well as cardiovascular disease and stroke than adults with the least number of iCVH components (3).

The importance of obtaining iCVH early in life has been stressed (4, 5), and previous studies have reported that a higher iCVH already in adolescence is related to better current and later cardiovascular health (6-10). In this regard, longitudinal studies have reported that higher iCVH in adolescence is associated with a more favorable cardiac structure and function (9), as well as a substantially lower risk of hypertension and metabolic syndrome in adulthood (8). Despite the importance of iCVH already in youth, few studies have examined iCVH in contemporary adolescents. We have previously reported that the prevalence of iCVH, especially the behavioral components, were low in European adolescents from 9 different countries (11). These results are in agreement with previous reports of iCVH in US adolescents (12), and in urban Chinese children and adolescents in whom adverse trends in the prevalence of iCVH have been observed (13). Although previous studies have indicated that sex, age, socioeconomic status, sleep, television viewing and early life factors (i.e.

97 duration of pregnancy, birth weight and breastfeeding) may be related to cardiovascular risk
98 factors (10, 14-20), there is limited data regarding whether these variables are associated with
99 iCVH in youth. This is of importance, since a greater understanding of which factors are
100 associated with iCVH may be useful in order to identify groups of children and adolescents at
101 special risk, as well as to tailor interventions to promote iCVH. Hence, the aim of the present
102 study was to examine the correlates of iCVH in European adolescents. To address this aim
103 we utilized data from the Healthy Lifestyle in Europe by Nutrition in Adolescence
104 (HELENA) study, which has detailed data of iCVH and several of its potential correlates.

METHODS

Study design and participants

Data in the HELENA cross-sectional study were collected between 2006 and 2007. Ten cities from 9 different European countries (Dortmund in Germany, Ghent in Belgium, Lille in France, Pécs in Hungary, Stockholm in Sweden, Vienna in Austria, Athens and Heraklion in Greece, Rome in Italy and Zaragoza in Spain) participated in the HELENA study (21-23). In total, 3528 boys and girls aged between 12.5 and 17.5 years were included. A detailed description of sampling procedures and methods in the HELENA study are found elsewhere (21-23). Blood samples were taken in a randomly selected sub-group of the sample (n=1089). In this study, 637 participants (288 boys and 349 girls) with complete data for all 7 iCVH behaviors and factors (7) were included. There were no statistically significant differences in key variables such as age, BMI, sex-distribution and maternal education (all $P>0.05$) between the 637 participants included in this study and the remaining HELENA study sample. In an explorative analysis, we also examined if adherence to the Mediterranean diet and the diet quality index differed between adolescents from Central-Northern and Southern Europe. These dietary indices was calculated as previously described (24). All adolescents and their parents/guardians provided their informed written consent and the local Human Research Review Committees for each of the involved centers approved the study (25).

Ideal Cardiovascular Health

We classified the components of iCVH as ideal or non-ideal according to the cut-offs for adolescents provided by the AHA (1) as described in detail previously (26). *Smoking:* Adolescents reported their smoking status, and ideal smoking status was classified as never having smoked a cigarette. *BMI:* The weight and height of the participants were measured using standardized procedures and BMI was then calculated as weight (in kg) divided by

height (in m) squared. Subsequently, BMI was classified into categories according to the cut-offs by Cole *et al.* (27), and the ideal status was defined as not being overweight or obese. *Physical activity:* Participants reported their physical activity using the International Physical Activity Questionnaire (IPAQ) (28), and ≥60 minutes of moderate-to-vigorous intensity physical activity every day was considered as ideal. *Diet:* Two non-consecutive 24 h dietary recalls were conducted for each participant (29, 30) and diet was assessed using 5 dietary indicators (fruits and vegetables, fish, fiber rich grains, sodium and soft drinks). Ideal diet was defined as having ideal intakes for ≥ 4 of these dietary indicators. *Total cholesterol:* Ideal status for cholesterol was <4.4 mmol/L (<170 mg/dL). *Fasting glucose:* Ideal status for fasting serum glucose was <5.6 mmol/L (<100 mg/dL). *Blood pressure*: Blood pressure was assessed twice during resting conditions and the lowest values were used in the analyses. Ideal blood pressure was classified as a systolic and diastolic blood pressure <90th percentile utilizing age-specific centiles from the HELENA study.

Indices of the Ideal Cardiovascular Health

We calculated an iCVH score using the number of iCVH components at an ideal level (1 point for each) which could vary between 0 and 7. Moreover, a specific iCVH behavior score and an iCVH factor score were also calculated using the number of ideal health behaviors (0-4) and health factors (0-3) respectively. In accordance with previous studies (9, 10, 31), we used these variables as continuous variables

Correlates of Ideal Cardiovascular Health

Based on previous literature of cardiovascular risk factors (10, 14-20), we hypothesized that the following correlates are potentially associated to iCVH: sex and age of the adolescents,

Family Affluence Scale (FAS), maternal education, geographic location, sleep time, television viewing, duration of pregnancy, birth weight and breastfeeding.

Information regarding socioeconomic status was obtained through maternal education which was self-reported by the mother (32). Maternal education was categorized as low (lower education and lower secondary education) and medium/high (higher secondary education or higher education/university degree). We also assessed additional information of socioeconomic status using the FAS questionnaire, completed by the adolescents, which investigated family availability of bedrooms, cars, personal computers and internet (33). Subsequently, FAS was categorized as low, medium and high as previously described (33). Geographic location was categorized as Central-Northern Europe (Dortmund, Ghent, Lille, Pécs, Stockholm and Vienna) and Southern Europe (Athens, Heraklion, Rome and Zaragoza) (17). Habitual sleeping time and television viewing were assessed by a self-reported questionnaire (34) and categorized into <8 h/day and ≥8 h/day and <2 h/day and ≥2 h/day, respectively. Parents reported duration of pregnancy (categories: <37, 37-42, and >42 weeks), their child's birth weight (classified into categories: <2.5, 2.5-3.9, and ≥4 kg) and breastfeeding (classified into categories: never, <3, and ≥3 months), and they were instructed to recall as much information as possible regarding these variables from health booklets of their children (35).

Statistical analysis

Data are presented as means and standard deviations (SD), if not stated otherwise. There were no significant interactions (P>0.05) between sex and any of the potential correlates in the ANCOVA analyses, which indicates that the pattern of the associations is similar in boys and girls and thus the results are presented for the whole sample. Differences in mean iCVH score were compared between the different potential correlates. Independent t-tests and one-way

179 analysis of variance (ANOVA) with Bonferroni post hoc were used to test unadjusted
180 differences between groups (presented as supplementary material). Adjusted results were
181 obtained using analysis of covariance (ANCOVA) with Bonferroni post hoc. In these
182 analyses, iCVH score was the dependent variable, and each determinant was entered as a
183 fixed factor, whereas age and sex were included as covariates (when age and sex were not the
184 fixed factor). All statistical tests were two-sided and $P<0.05$ was considered statistically
185 significant. Analyses were conducted using SPSS Statistics 22 (IBM, Armonk, NY, USA).

RESULTS

Descriptive data of the adolescents in the study is presented in **Table 1**. The adolescents' average age was 14.7 ± 1.2 years and their average iCVH score was 4.53 ± 1.14. There were no differences between the groups for younger (< 15 years) and older (≥ 15 years) adolescents regarding sex-distribution, maternal education and the prevalence of ideal BMI (i.e. not overweight/obese). Adolescents from Southern Europe had identical prevalence of ideal diet as adolescents from Central-Northern Europe (1.9 % vs. 1.9 %, $P > 0.99$). However, participants from Southern Europe had a diet with a greater diet quality index (59.7 vs. 49.5, $P<0.0001$) and higher adherence to the Mediterranean diet (4.57 vs. 4.02, $P<0.0001$) than participants from Central-Northern Europe.

Figure 1 presents adjusted associations of potential correlates with iCVH score. Complete data regarding unadjusted and adjusted associations are found in **Table S1.** In adjusted analyses, younger participants had higher iCVH than older participants (mean ± standard error (SE); 4.69 ± 0.06 vs. 4.29 ± 0.07, $P<0.001$). Adolescents of mothers with medium/high education had higher iCVH than adolescents of mothers with low education (4.63 ± 0.05 vs. 4.28 ± 0.08, $P<0.001$). In addition, adolescents who viewed television less than 2 h per day had higher iCVH than adolescents who viewed it 2 h or more per day (4.62 ± 0.06 vs. 4.38 ± 0.07, $P=0.010$).

Figure 2 shows the association between the potential correlates with the iCVH behavior score (Figure 2A) and the iCVH factor score (Figure 2B). In adjusted analyses, younger participants had a higher score for iCVH behaviors ($P<0.001$) compared to older participants. Furthermore, adolescents of mothers with a medium/high education had a greater score for the iCVH behavior score ($P=0.026$) and for the iCVH factor score ($P=0.001$) than

adolescents of mothers with low education. Participants from Central-Northern Europe had better health behaviors (P=0.031), yet worse health factors (P=0.007) than participants from Southern Europe. Finally, adolescents who viewed television less than 2 h per day had better health behaviors (P=0.018) compared to those who watched television 2 h or more of per day. **Table S2** shows the complete data regarding unadjusted and adjusted associations for iCVH behavior and factor scores.

DISCUSSION

This study investigates potential correlates of iCVH of contemporary European adolescents from the HELENA study. The main findings were that age, maternal educational attainment and television viewing were associated with iCVH. In this regard, adolescents who were younger, had a mother with medium/high education or watched television less than 2 h per day had higher iCVH than those who were older, had a mother with low education or watched television 2 h or more per day.

We observed that the number of iCVH components were similar between sexes, which concurs with previous studies in Finnish adolescents (8, 10). However, this finding is in contrast with Dong *et al.* who reported that Chinese girls had greater odds of having an iCVH score of ≥ 6 (13) compared to boys. The observed differences between the studies may be due to the fact that the involved countries had different socioeconomic status (high vs. low/middle). However, differences could also be due to the methods used (e.g. differential misreporting) or the statistical analysis, i.e. using the average iCVH score in this study and the Finnish studies (8, 10) versus iCVH score of ≥ 6 in the study of Chinese children (13). In the present study, older adolescents were found to have worse iCVH, in particular health behaviors. These observations can be reconciled with data from Chinese youth in which adolescents (12-18 years) had worse iCVH, particularly the iCVH behavior score, than younger children (6-11 years). Likewise, Pahkala *et al.* (10) showed that the number of ideal iCVH components in Finish adolescents decreased with increasing age. The difference observed in this study between younger and older adolescents in regards to iCVH behaviors may be due to several reasons. Firstly, parental control decreases with age which may enable poorer choices in terms of smoking and diet. Secondly, physical activity decreases throughout

childhood and adolescence (36) which may be due to less spontaneous physical activity (i.e. playing) and more demanding school requirements (36).

We observed a relatively strong association of maternal education with adolescent's cardiovascular health as indicated by the greater number of iCVH components, both health behaviors and factors, in adolescents whose mothers had medium/high educational attainment. These results are, to our knowledge, the first of such data in European youth, and are partially in agreement with Dong *et al.* (13) who observed a statistically significant association of maternal educational attainment with iCVH behaviors, but not with the total iCVH score or iCVH factors in Chinese youth. Our results can also be reconciled with Laitinen *et al.* (15) who reported that a favorable socioeconomic environment, as indicated by higher parental education and occupation, in Finnish, Australian and U.S. youth were associated with a greater iCVH in adulthood. Thus, our findings indicate that the influence of a favorable socioeconomic environment, as measured by maternal education, in youth on later iCVH might be detectable already in adolescence. Previous studies have suggested that a higher socioeconomic status is associated with a lower BMI (37) as well as with healthier diet, physical activity and smoking behaviors (38), which in turn may influence cardiovascular health. Furthermore, our results agree with studies in adults that have reported a negative association between social risk and iCVH (39), as well as a positive association between socioeconomic status and iCVH (40). To the best of our knowledge, no previous studies have examined associations of television viewing with iCVH in adolescents. Thus, a novel finding of our study was that adolescents who watched < 2 h of television, as compared to ≥ 2 h per day, had greater iCVH. This observation supports the finding from a previous study in an adult population (41). Also, a previous meta-analysis reported that higher television viewing was associated with higher risk of cardiovascular disease and all-cause

mortality (14). Television viewing has been suggested to be a particularly detrimental sedentary behavior type (42), and has been associated with increased cardiometabolic risk in youth (43). Furthermore, television viewing may also be related to worse dietary behaviors such as greater intakes of sugar sweetened beverages in children and adolescents (44). Nevertheless, future studies, preferably randomized controlled trials, are needed to determine the effect and causality of limiting television to increase cardiovascular health. Finally, participants from Central-Northern and Southern Europe had similar iCVH scores, although adolescents from Central-Northern Europe had a better iCVH behavior score, but a worse iCVH factor score as compared to their peers from Southern Europe. Differences between the Central-Northern and Southern Europe have been previously observed, with the former being more active (45), fitter and having lower levels of adiposity (17) than their counterparts from the southern part of Europe. Hence, it is somewhat unexpected that adolescents from Southern Europe had a greater iCVH factor score, despite a lower iCVH behavior score, than adolescents from Central-Northern Europe. A possible reason could be that although the prevalence of an ideal diet in the studied adolescents was in general extremely low (1.7 %), participants from Southern Europe had a much healthier diet as indicated by adherence to the Mediterranean diet (and diet quality index). This may be a relevant finding considering the suggested cardioprotective properties of the Mediterranean diet (46). However, further studies are needed to confirm and explain potential differences in iCVH factors between adolescents from Southern and Central-Northern Europe.

An important strength of this study is the relatively large sample of adolescents from nine European countries with complete iCVH data. Furthermore, we were able to investigate several relevant correlates of iCVH (10, 14-20). A limitation of this study is its cross-sectional design, which limits conclusions about the causality of the observed associations.

Moreover, in this report we used self-reported data of health behaviors, socioeconomic status and early life factors (i.e. birth weight, breastfeeding and pregnancy duration) which is a limitation of this study. Nevertheless, all methods were extensively pilot-tested before the initiation of the study (28, 29, 47, 48). Furthermore, the physical activity questionnaire (i.e. IPAQ) (28), the screen time and sedentary behavior questionnaire (48) as well as the dietary recall method (29) were all validated within the HELENA study.

This study provides novel data regarding correlates of iCVH in a diverse European adolescent sample. We identified age, maternal education and television viewing as correlates of iCVH. The higher iCVH associated with being younger (+ 0.40 in average iCVH score), having a mother with medium/high education (+ 0.35) or watching less than 2 h of television per day (+ 0.24) may be important from a public health perspective, since a 1 point increase in iCVH score is strongly associated with better cardiovascular outcomes in adulthood (8). Thus, our identified correlates of iCVH may be useful when tailoring public health interventions to improve the cardiovascular health of the adolescent population.
Future work could identify and confirm correlates of iCVH in childhood and identify the mechanisms by which correlates such as maternal education and television viewing may influence iCVH. Furthermore, considering the importance of iCVH at an early age (4, 5), forthcoming studies could focus on early promotion of cardiovascular health. In this context, it is of interest to note that the so-called STRIP Study found that repeated dietary and antismoking counseling throughout childhood and adolescence resulted in higher adolescent iCVH as compared to the control group (10). Nevertheless, future intervention studies are needed to examine the effect of the promotion iCVH in childhood. Such studies should target the iCVH behavior components (i.e. non-smoking as well as healthy BMI, physical activity

and diet), but may also aim to limit television viewing and/or specially target children of families with low socioeconomic status.

Acknowledgements

We thank the adolescents who participated in the study and their parents and teachers for their collaboration. We also acknowledge the members involved in fieldwork for their efforts. HELENA study group members are attached as supplementary material.

Funding

The HELENA project was supported by the European Community Sixth RTD Framework Programme (contract FOOD-CT-2005-007034). The data for this study was gathered under the aegis of the HELENA project, and further analysis was additionally supported by the Spanish Ministry of Economy and Competitiveness (grants RYC-2010-05957 and RYC-2011-09011), the Spanish Ministry of Health: Maternal, Child Health and Development Network (grant RD16/0022), the Fondo Europeo de Desarrollo Regional (MICINN-FEDER) and by the University of Granada, Plan Propio de Investigación 2016, Excellence actions: Units of Excellence; Unit of Excellence on Exercise and Health (UCEES). Pontus Henriksson was supported by a grant from Henning and Johan Throne-Holst Foundation. Hanna Henriksson was supported by grants from the Swedish Society of Medicine and the County Council of Östergötland, Sweden. The funders of the HELENA project had no role in study design, data collection, analysis, or interpretation, writing of the report, or in the decision to submit the paper for publication. The content of this paper reflects the authors' views alone, and the European Community is not liable for any use that may be made of the information contained herein.

Conflict of interest

The authors report no relationships that could be construed as a conflict of interest.

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FIGURE LEGENDS

Figure 1. Associations of potential correlates with ideal cardiovascular health (iCVH) score in European adolescents. Results were obtained using analysis of covariance (ANCOVA) with Bonferroni post hoc and were adjusted for age and sex (when age and sex were not the potential correlates in the model). Data are presented as estimated marginal means and standard error bars. *P* refers to the difference between two groups or the overall *P* value (three groups).

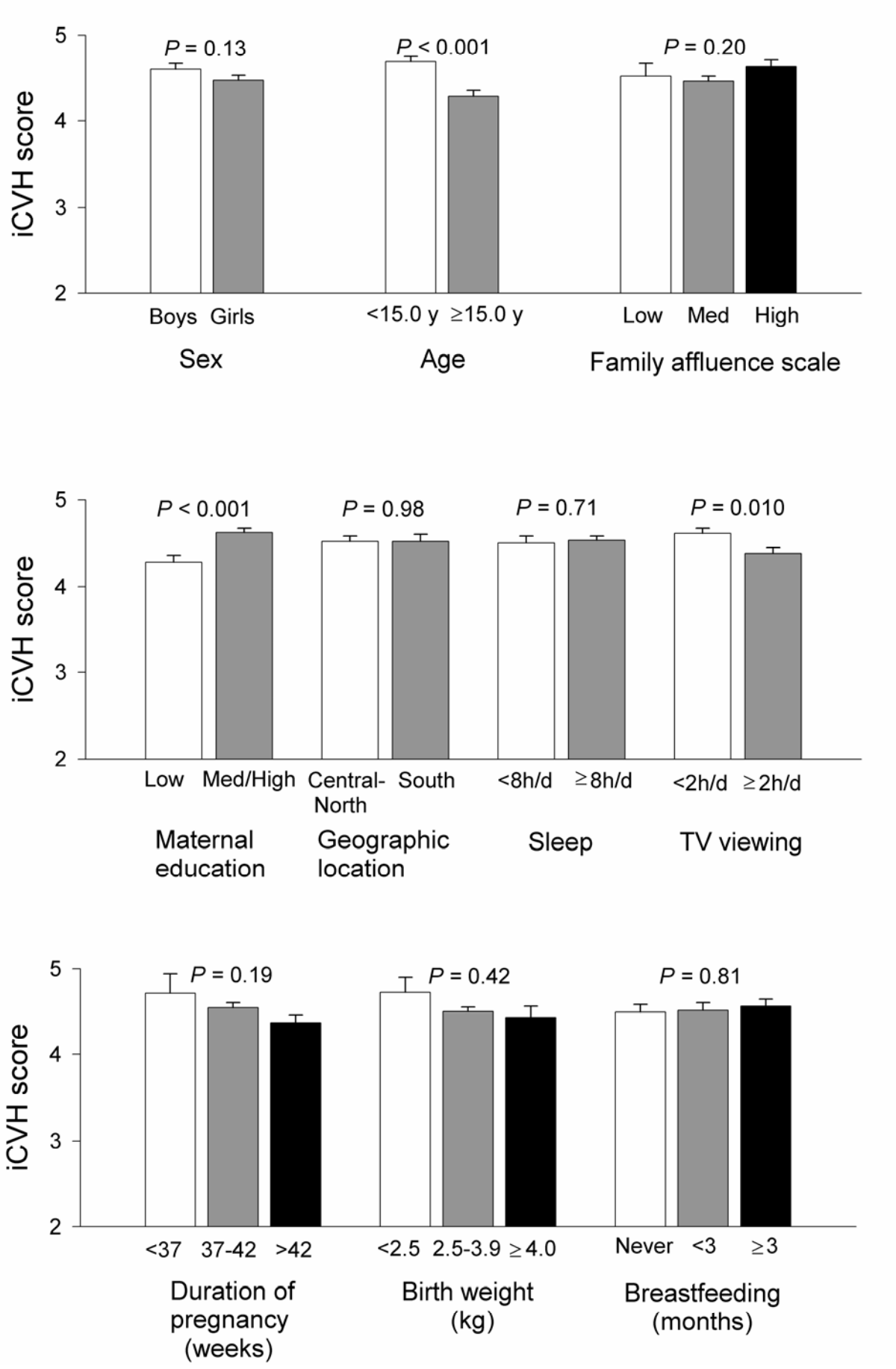
Figure 2A. Associations of potential correlates with ideal cardiovascular health (iCVH) behaviour score in European adolescents. Results were obtained using analysis of covariance (ANCOVA) with Bonferroni post hoc and were adjusted for age and sex (when age and sex were not the potential correlates in the model). Data are presented as estimated marginal means and standard error bars. *P* refers to the difference between two groups or the overall *P* value (three groups).

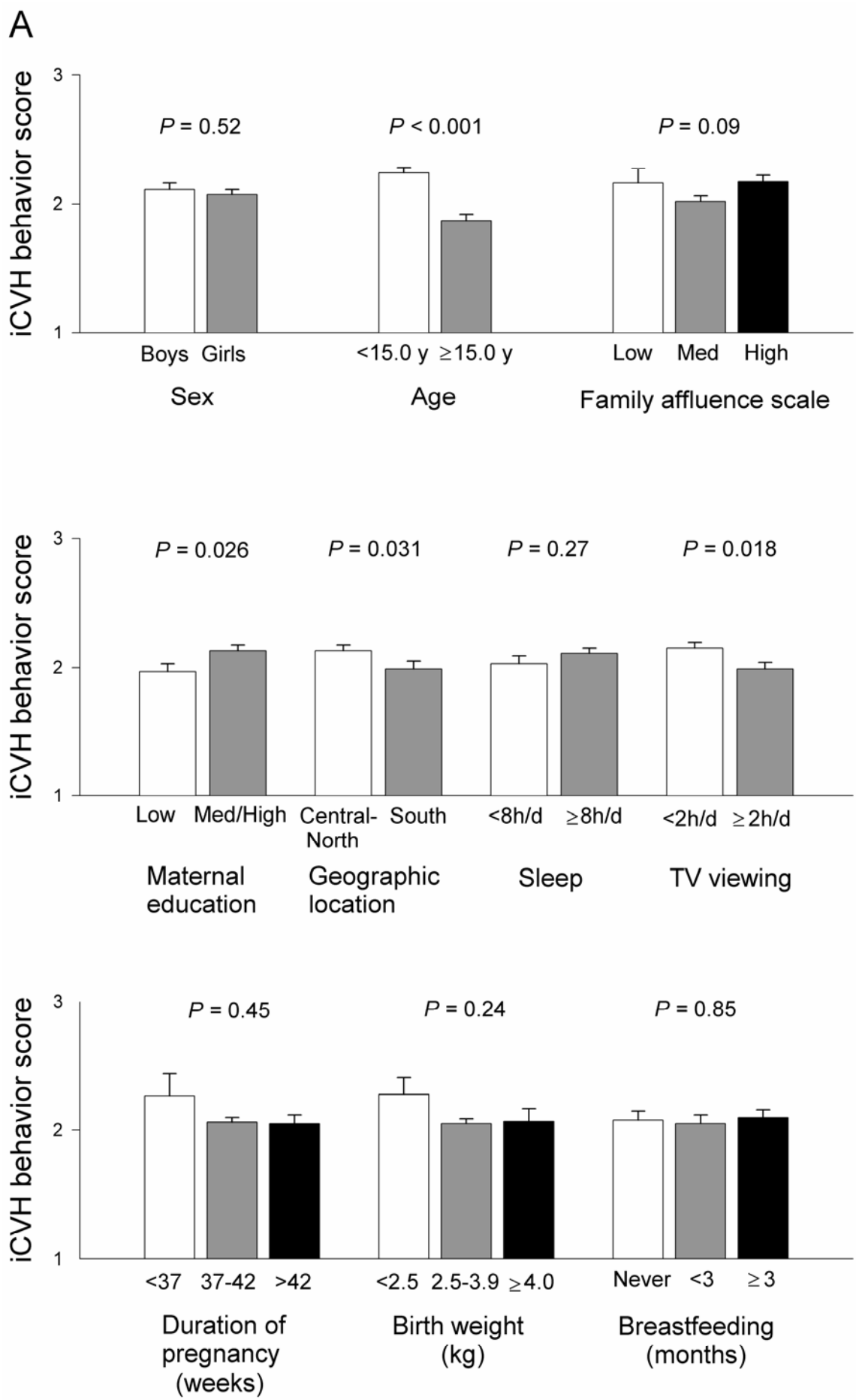
Figure 2B. Associations of potential correlates with ideal cardiovascular health (iCVH) factor score in European adolescents. Results were obtained using analysis of covariance (ANCOVA) with Bonferroni post hoc and were adjusted for age and sex (when age and sex were not the potential correlates in the model). Data are presented as estimated marginal means and standard error bars. *P* refers to the difference between two groups or the overall *P* value (three groups).

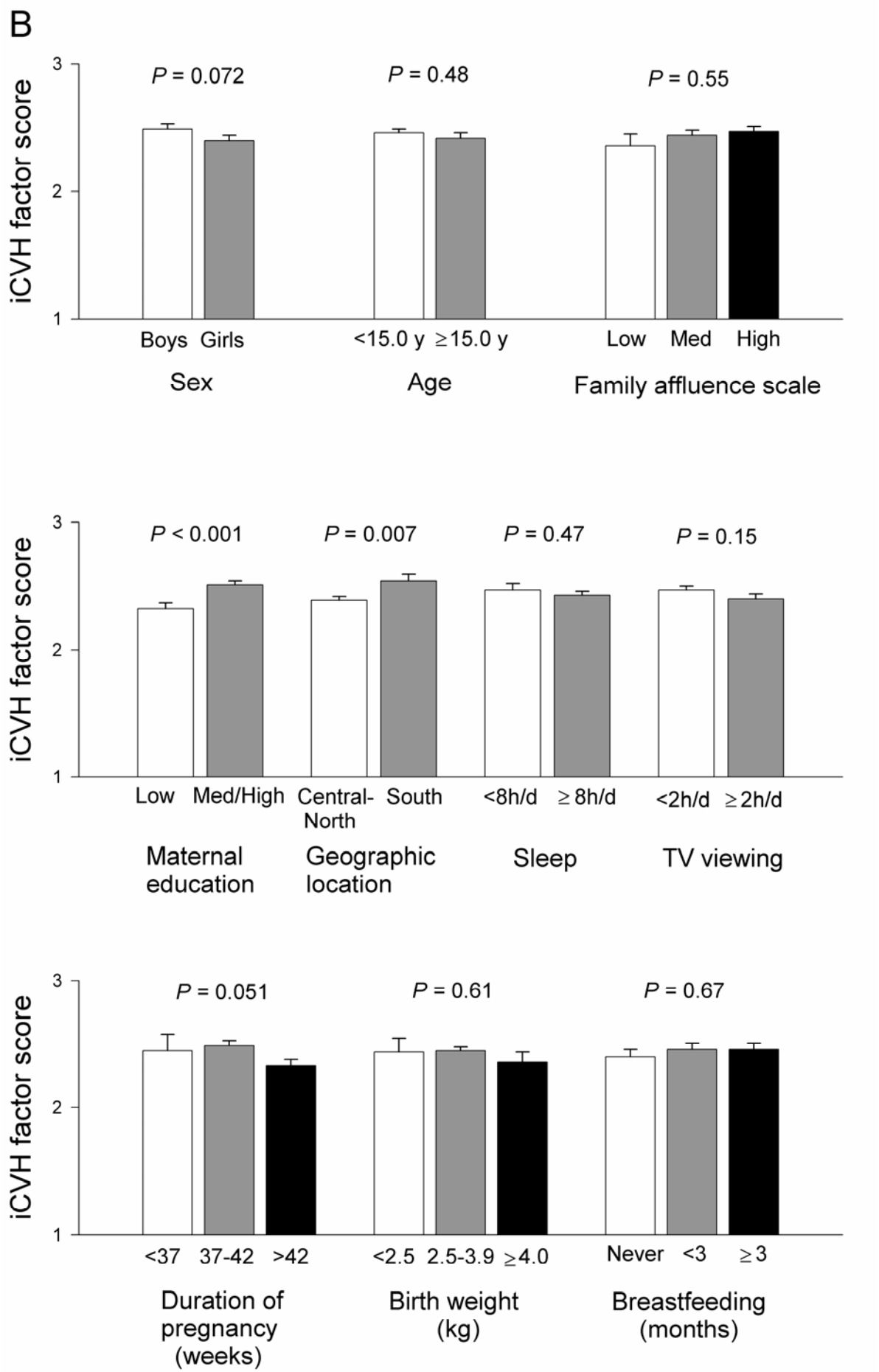
Table 1. Descriptive data of the European adolescents in the study.

	n	Mean ± SD or % (n)
Age (years)	637	14.7 ± 1.2
BMI (kg/m^2)	637	21.2 ± 3.8
iCVH score (0-7)	637	4.53 ± 1.14
iCVH behavior score (0-4)	637	2.08 ± 0.83
iCVH factor score (0-3)	637	2.44 ± 0.66
Sex	637	
Boys		45.2 % (288)
Girls		54.8 % (349)
Age group	637	
< 15 years		58.7 % (374)
≥ 15 years		41.2 % (263)
Family Affluence Scale (FAS)	637	
Low		9.1 % (58)
Medium		55.9 % (356)
High		35.0 % (223)
Maternal education attainment	609	
Low		31.7 % (193)
Medium/High		68.3 % (416)
Geographical location	637	
Central-North		66.6 % (424)
South		33.4 % (213)
Sleep	624	
< 8 h per day		30.8 % (192)
≥ 8 h per day		69.2 % (432)
Television viewing	620	
< 2 h per day		60.8 % (377)
≥ 2 h per day		39.2 % (243)
Pregnancy duration	531	
< 37 gestational weeks		4.7 % (25)
37-42 gestational weeks		66.3 % (352)
> 42 gestational weeks		29.0 % (154)
Birth weight	549	
< 2.5 kg		7.3 % (40)
2.5-3.9 kg		79.8 % (438)
≥ 4.0 kg		12.9 % (71)
Breastfeeding	526	
Never		27.9 % (147)
< 3 months		31.0 % (163)
≥ 3 months		41.1 % (216)

iCVH, ideal cardiovascular health; iCVH score, ideal cardiovascular health score calculated as number of iCVH components (0-7); iCVH behavior score, ideal cardiovascular health behavior score calculated as number of iCVH behavior (0-4); iCVH factor score, ideal cardiovascular health factor score calculated as number of iCVH factors (0-3).


iCVH score
5
4
3
2
P = 0.13
P < 0.001
P = 0.20
Boys Girls
Sex
<15.0 y ≥15.0 y
Age
Low Med High
Family affluence scale
P < 0.001
P = 0.98
P = 0.71
P = 0.010
Low Med/High
Maternal education
Central-North South
Geographic location
<8h/d ≥8h/d
Sleep
<2h/d ≥2h/d
TV viewing
P = 0.19
P = 0.42
P = 0.81
<37 37-42 >42
Duration of pregnancy (weeks)
<2.5 2.5-3.9 ≥4.0
Birth weight (kg)
Never <3 ≥3
Breastfeeding (months)


A
iCVH behavior score
3
2
1
P = 0.52
P < 0.001
P = 0.09
Boys Girls
<15.0 y ≥15.0 y
Low Med High
Sex
Age
Family affluence scale
iCVH behavior score
3
2
1
P = 0.026
P = 0.031
P = 0.27
P = 0.018
Low Med/High
Central-North South
<8h/d ≥8h/d
<2h/d ≥2h/d
Maternal education
Geographic location
Sleep
TV viewing
iCVH behavior score
3
2
1
P = 0.45
P = 0.24
P = 0.85
<37 37-42 >42
<2.5 2.5-3.9 ≥4.0
Never <3 ≥3
Duration of pregnancy (weeks)
Birth weight (kg)
Breastfeeding (months)


B
iCVH factor score
3
2
1
P = 0.072
P = 0.48
P = 0.55
Boys
Girls
<15.0 y
≥15.0 y
Low
Med
High
Sex
Age
Family affluence scale
P < 0.001
P = 0.007
P = 0.47
P = 0.15
Low
Med/High
Central-North
South
<8h/d
≥ 8h/d
<2h/d
≥2h/d
Maternal education
Geographic location
Sleep
TV viewing
P = 0.051
P = 0.61
P = 0.67
<37
37-42
>42
<2.5
2.5-3.9
≥4.0
Never
<3
≥3
Duration of pregnancy (weeks)
Birth weight (kg)
Breastfeeding (months)

Highlights

- Little is known about the correlates of adolescent iCVH (ideal cardiovascular health)
- This study included 637 European adolescents from the multi-center HELENA study
- Younger age (<15 y) and less TV viewing (< 2h/day) was related to greater iCVH
- Adolescents of mothers with medium/high education, compared to low, had higher iCVH
- These correlates may be useful for promoting cardiovascular health in adolescence