Excessive sedentary time and low cardiorespiratory fitness in European adolescents: the HELENA study

David Martinez-Gomez,[1,2] Francisco B Ortega,[1,3] Jonatan R Ruiz,[1] Germán Vicente-Rodriguez,[4] Oscar L Veiga,[5] Kurt Widhalm,[6] Yannis Manios,[7] Laurent Béghin,[8] Jara Valtueña,[9] Anthony Kafatos,[10] Denes Molnar,[11] Luis A Moreno,[4] Ascension Marcos,[2] Manuel J Castillo,[3] Michael Sjöström[1] ; on behalf of the HELENA study group

For numbered affiliations see end of article

Correspondence to Michael Sjöström, Unit for Preventive Nutrition, Department of Biosciences and Nutrition at NOVUM, Karolinska Institutet, 14157 Huddinge, Sweden; michael.sjostrom@prevnut.ki.se

Accepted 2 November 2010
Published Online First 10 January 2011

ABSTRACT

Background The aims of this study were to examine what amount of sedentary time is associated with low cardiorespiratory fitness (CRF) in adolescents and whether this association is independent of physical activity.

Methods The study comprised 1808 adolescents aged 12.5–17.5 years from 10 European cities. Sedentary time and moderate-to-vigorous physical activity (MVPA) were measured by accelerometer. CRF was assessed by the 20 m shuttle-run test. Adolescents were divided into two groups (high/low) according to FITNESSGRAM guidelines. Receiver-operating characteristic (ROC) analysis was used to determine thresholds that best discriminate between high and low CRF in adolescents.

Results Adolescent girls had more sedentary time than boys ($p<0.001$). ROC analysis showed that girls spending ≥69% of waking time in sedentary activities had low CRF, but no significant threshold discriminated between high and low CRF in boys. Adolescent girls who exceeded this threshold had lower levels of CRF ($p \le 0.001$) and were more likely to have a low CRF (OR 1.68, 95% CI 1.22 to 2.31) independent of centre, age and body mass index. The negative influence of excessive sedentary time on CRF remained significant ($p=0.045$) in adolescent girls who did not meet the physical activity guidelines (<60 min/day in MVPA) but was abolished ($p>0.05$) in those who met the recommendation (≥60 min/day in MVPA).

Conclusion Excessive sedentary time is associated with low CRF in adolescent girls but not in boys. However, this adverse effect might be attenuated if adolescent girls meet the current physical activity guidelines.

What is already known on this topic

- Sedentary activities are associated with increased risk of all-cause and cardiovascular disease mortality.
- Cardiorespiratory fitness (CRF) is a powerful health marker across the lifespan which declines during adolescence, specially in girls.

What this study adds

- Excessive sedentary time (~2/3 of awake hours) is associated with low CRF in adolescent girls but not in boys.
- The adverse influence of sedentariness might be attenuated if adolescent girls meet the current physical activity guidelines (60 min per day in moderate-to-vigorous physical activity).

INTRODUCTION

Cardiorespiratory fitness (CRF) is a health marker across the lifespan.[1–4] Thus, higher levels of CRF have been related to a healthier cardiovascular disease (CVD) risk factors profile in youth.[5] Moreover, there is strong evidence indicating that higher levels of CRF in childhood and adolescence are associated with a healthier cardiovascular profile later in life.[6] Indeed, CRF attenuates the detrimental effect of body fat.[4]

CRF is influenced by genetic and biological determinants.[7] Several studies suggested that the genetic heritability of CRF is approximately 50%.[7] Biological factors such as sex, age, pubertal status and growth, are also important predictors of CRF.[7 8] Since CRF tends to track moderately from childhood to adulthood,[9 10] it has been suggested that adolescence is a specific period in life when CRF levels decrease.[11] Lifestyle factors also play an important role in explaining the remaining variance in CRF.[7] For example, several studies show that regular physical activity might explain around 10% of CRF variance.[2 12] However, little is known regarding the impact of sedentary time on CRF during adolescence.

The harmful health consequences of a sedentary lifestyle are the focus of recent research.[13–16] Sedentary activities have been defined as "activities that do not increase energy expenditure substantially above the resting level", that is, activities that involve energy expenditure of <1.5 metabolic equivalents,[17] such as lying down, sitting and watching television. Overall, previous studies defined sedentary behaviours as time in screen time (television+computer) to examine the associations between sedentariness and CRF.[18 19] Nevertheless, these sedentary behaviours are far from capturing the total amount of everyday sedentary time in both adults and young people.[20 21] Therefore, it has been suggested that activity monitors would more accurately assess sedentariness in humans.[17] For preventive purposes, it would be of interest to know how much sedentary time measured by accelerometry is associated with unhealthy CRF in adolescents. Minimising the decline in CRF during adolescence may have a positive impact on adulthood health.[9] It is not known if engagement in physical activity counteracts the effect of sedentary time on CRF during adolescence.[22 23]

The aim of this study was to examine how much sedentary time is associated with an unhealthy CRF according to FITNESSGRAM sex- and age-referenced standards in European adolescents. We also examined whether engagement in physical activity attenuates the effect of excessive sedentariness on CRF in this population.

METHODS

Participants

Adolescents were participants in the Healthy Lifestyle in Europe by Nutrition in Adolescence-Cross-Sectional Study (HELENA-CSS). The HELENA-CSS is a multicentre study conducted in 10 European cities from nine countries: Athens (Greece), Dortmund (Germany), Ghent (Belgium), Heraklion (Greece), Lille (France), Pécs (Hungary), Rome (Italy), Stockholm (Sweden), Vienna (Austria) and Zaragoza (Spain). The main aim of the HELENA-CSS was to obtain reliable and comparable data on nutrition and health-related parameters such as physical activity and fitness, obesity, food choices and preferences, CVD risk factors, vitamin and mineral status, immunological biomarkers and genetic markers in a representative 12.5–17.5-year-old sample of European adolescents.[24] Data collection for the HELENA-CSS took place between 2006 and 2007.

A total of 3865 adolescents were recruited at high schools and met the inclusion criteria established in the HELENA study.[24] Of these, 1808 adolescents (964 girls) had valid data on weight, height, accelerometry and CRF. Ethic committees from each country approved the HELENA-CSS protocols.[25] Adolescents and theirs parents/guardians were informed about the HELENA-CSS and all provided written informed consent.

Anthropometry

Body weight was measured to the nearest 0.1 kg with an electronic scale (seca 861; seca, Hamburg, Germany). Body height was measured barefoot with a telescopic stadiometer (seca 225) to the nearest 0.1 cm.[26] Adolescents were barefoot and in light clothing during anthropometric measurements. Body mass index (BMI) was calculated as body weight divided by the square of height (kg/m^2).

Assessments of sedentary time and physical activity

Habitual sedentary time and physical activity were objectively monitored using the ActiGraph GT1M activity monitor (ActiGraph, Pensacola, Florida, USA). This accelerometer is a robust, small (3.8×3.7×1.8 cm), lightweight (27 g) and uniaxial monitor designed to detect vertical accelerations. The ActiGraph has been widely validated in youth.[27] Adolescents were instructed to wear the accelerometer against the lower back for 7 consecutive days using an elastic waistband. The accelerometer was worn during awake time and removed during water-based activities. The interval of time (epoch) was set at 15 s in accordance with consensus recommendations for children and adolescents.[28] Bouts of 20 continuous minutes of zero counts were considered as non-wearing time periods and were removed from the analysis. To be included in the analysis participants had to wear the accelerometer for a minimum of 8 h per day for at least 3 days a week.

The amount of time (min/day) spent in sedentary time was calculated by using the standardised cut-off point of <100 counts per minute.[29] This cut-off has been widely used in previous studies to capture low energy expenditure activities (eg, watching TV, playing video games, painting). Percentage of time spent daily in sedentary time was calculated as the proportion of time spent in sedentary activities over the wear time (called 'adjusted sedentary time') and was considered the main variable for all analyses. The time spent (min/day) in moderate-to-vigorous physical activity (MVPA) was calculated using the standardised cut-off point of ≥2000 counts per minute.[22] Adolescents were dichotomised into those who met (≥60 min/day in MVPA) or did not meet (<60 min/day in MVPA) the current physical activity recommendations for youth.

Assessment of CRF

CRF was assessed using the 20 m shuttle-run test.[30] The methods used and reliability of this test have been reported in detail elsewhere.[31 32] Briefly, participants were required to run between two lines 20 m apart while keeping pace with audio signals emitted from a pre-recorded CD. The initial speed was 8.5 km/h, which increased by 0.5 km/h each minute or stage. The test was terminated when the participant failed to reach the end lines concurrently with the audio signals on two consecutive occasions or stopped due to fatigue. The maximal oxygen consumption (VO_{2max}) in ml/kg/min was estimated by the Leger equation.[30] Following this, the sample was divided into levels (high/low) of VO_{2max} according to age- and sex-referenced standards (http://www.fitnessgram.net). In particular, high CRF corresponds to 42 ml/kg/min for boys, 38 ml/kg/min for girls 13 years of age and 35 ml/kg/min for girls 14 years of age or older.

Statistical analyses

Sex differences in descriptive statistics were examined by analysis of variance for continuous variables and the χ^2 test for nominal variables. Because sedentary time was strongly and positively associated with the wear time ($r=0.81$, $p<0.001$), analysis of covariance (ANCOVA) controlled for wear time was performed to examine sex differences in objectively measured sedentariness.

Receiver-operating characteristic (ROC) curves[33] were used to calculate the optimal sedentary time cut-off points that best discriminate between adolescents with high and low CRF. The area under the ROC curve (AUC) represents the ability of the test to correctly classify adolescents with high or low CRF. Values of AUC range from 0.5 (non-informative test) to 1.0 (ideal test). Sensitivity was considered as the probability to correctly identify an adolescent with low CRF (true-positive rate). Specificity was considered as the probability to correctly identify an adolescent with a high CRF. The ROC curve provides the whole spectrum of specificity/sensitivity values for all possible cut-off points. The optimal combination of true-positive rate and false-positive rate is the point closest to the perfect test (upper left corner of the graph). ROC analyses were performed separately by sex. Differences in CRF between adolescents who met or did not meet the cut-offs obtained in the ROC curves were analysed by ANCOVA controlling for centre, age and BMI.

To examine whether the association between sedentary time and CRF is independent of the time spent in MVPA, we analysed differences in CRF levels across sedentary time (excessive and not excessive according to the cut-offs obtained in the ROC curve) and physical activity (<60 min/day and ≥60 min/day in MVPA) groups by ANCOVA controlling for centre, age and BMI. Binary logistic regression was also performed to examine the relationship between excessive sedentary time and high CRF. ROC curve statistics were calculated with MedCalc statistical software v 10.4.5 (MedCalc Software, Mariakerke, Belgium). The other analyses were conducted using SPSS v 15.0 for Windows (SPSS, Chicago, Illinois, USA). The level of significance was set at <0.05 for all analyses.

RESULTS

The descriptive characteristics of the adolescent European sample stratified by low/high levels of CRF for the whole sample and by gender are shown in table 1. Adolescent girls had lower levels of CRF than boys, whereas adolescent boys had higher levels of MVPA than girls. Also, a higher percentage of adolescent boys than girls met the current physical activity recommendations for youth. In contrast, adolescent girls spent more time in sedentary activities than boys.

ROC analysis showed that a cut-off of ≥69% in sedentary time significantly discriminates (AUC 0.542; 95% CI 0.505 to 0.579; sensitivity 74.8% and specificity 33.0%) between adolescent girls with low and high CRF, whereas in boys, a cut-off of ≥75% revealed no significant differences (AUC 0.513; 95% CI 0.470 to 0556; sensitivity 24.7% and specificity 81.6%) between CRF status groups (figure 1). Overall, 73.2% of adolescent girls spent more than 69% of their waking time in sedentary activities.

ANCOVA controlling for centre, age, sex and BMI showed that the adolescent girls who exceeded this threshold had significantly lower levels of VO_{2max} ($p<0.001$) and 20 m shuttle-run test stages ($p=0.001$) than less sedentary adolescent girls (figure 2). The odds ratio for exceeding this threshold in sedentary time and having a low CRF status in girls was 1.68 (95% CI 1.22 to 2.31) after adjustments for the same potential confounders.

To further explore whether the association between this sedentary time threshold and CRF in adolescent girls is independent of physical activity, we performed the same analysis by stratifying the adolescent sample into four groups according to sedentary time (<69% and ≥69% in sedentary time)

Table 1 Descriptive characteristics of the European adolescent sample

	All (n=1808)		Adolescent boys (n=844)		Adolescent girls (n=964)			
	Low CRF (n=676)	High CRF (n=1132)	Low CRF (n=267)	High CRF (n=577)	Low CRF (n=409)	High CRF (n=555)	p Value by sex	p Value by CRF group
Prevalence (%)	37.4	62.6	31.6	68.4	42.4	57.6	<0.001	<0.001
Age (years)	14.7±1.2	14.6±1.2	14.8±1.3	14.6±1.2	14.6±1.2	14.6±1.1	0.100	0.072
Height (cm)	164.5±9.3	166.2±9.2	169.4±9.9	169.7±9.6	161.3±7.2	162.4±7.1	<0.001	0.087
Weight (kg)	61.2±14.1	56.0±10.3	66.0±15.8	58.4±11.2	58.0±11.9	53.5±8.6	<0.001	<0.001
Body mass index (kg/m^2)	22.5±4.3	20.2±2.6	22.9±4.6	20.1±2.7	22.2±4.0	20.2±2.6	0.102	<0.001
20 m shuttle-run test (stage)	2.8±1.3	6.7±2.3	3.8±1.4	8.2±1.8	2.2±0.7	5.2±1.6	<0.001	<0.001
VO_{2max} (ml/kg/min)	34.9±3.7	45.7±6.2	37.4±3.4	49.7±4.7	33.2±2.8	41.6±4.5	<0.001	<0.001
Sedentary time (min/day*)	539±82	547±81	531±92	540±88	544±74	553±72	<0.001	0.054
Accelerometer wearing time (min/day)	760±90	780±90	769±96	785±94	754±85	774±85	0.005	<0.001
Adjusted sedentary time (%)	71±6	70±6	69±7	69±7	72±5	71±5	<0.001	0.070
Moderate-to-vigorous PA (min/day)	54±23	62±24	63±26	70±25	48±20	54±19	<0.001	<0.001
Meeting PA guidelines (%)	31.8	47.7	46.8	63.4	22.0	31.4	<0.001	<0.001

Values are mean±SD.
*Controlled for wearing time.
CRF, cardiorespiratory fitness; PA, physical activity.

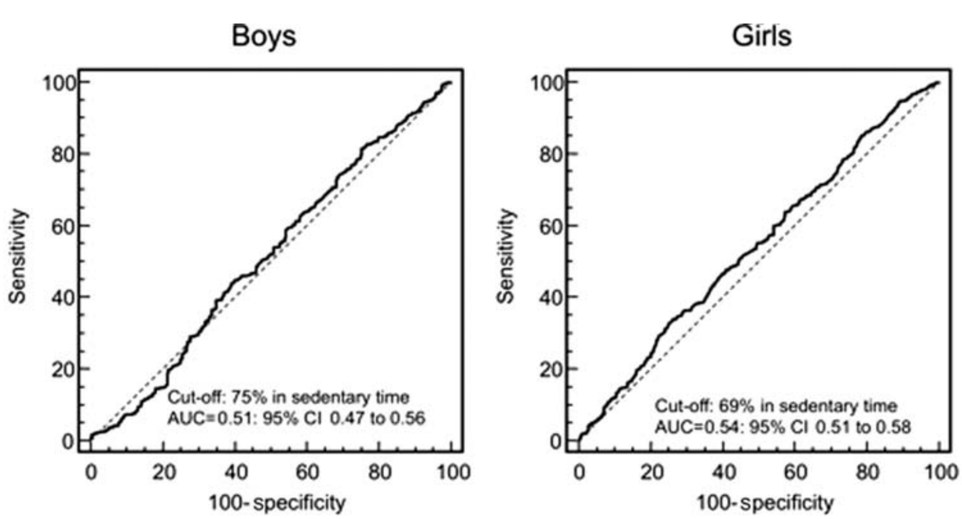

Figure 1 Sedentary time cut-off points to discriminate between unfit and fit adolescents by receiver-operating characteristics (ROC) analysis. AUC, area under the ROC curve.

 Arch Dis Child 2011;**96**:240–246. doi:10.1136/adc.2010.187161

and physical activity (<60 min/day and ≥60 min/day). The ANCOVA showed that adolescent girls who did not meet the current physical activity recommendations and exceeded the 69% in sedentary time threshold had significantly lower levels of VO_{2max} ($p=0.045$) and 20 m shuttle-run test stages ($p=0.049$) than those girls with lower levels of sedentary time within the same physical activity group after adjustments for centre, age, sex and BMI (figure 3). The odds ratio for exceeding this threshold in sedentary time and having a low CRF status in girls who did not meet the physical activity recommendation was 1.70 (95% CI 1.07 to 2.71) after adjustments for the same potential confounders. Overall, 85% of adolescent girls did not meet the physical activity recommendations and spent ≥69% of their waking time in sedentary activities. Interestingly, there were no significant differences in VO_{2max} or 20 m shuttle-run variables between sedentary time levels in those adolescent girls who met the current physical activity recommendations (figure 3). These analyses were repeated in boys, but there were no significant differences in CRF across physical activity and sedentary time groups (all $p>0.05$).

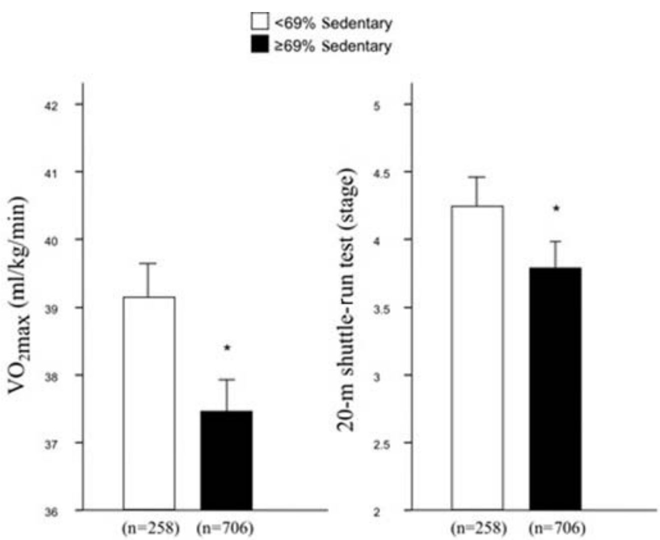

Figure 2 Differences in cardiorespiratory fitness sedentary time groups among European adolescent girls (n=964). Bars represent mean±SEM. Data were adjusted for centre, age and body mass index. *Significantly different from the <69% sedentary time group ($p\leq0.001$).

DISCUSSION

The main findings in our study indicated that adolescent girls who spent ≥69% of their waking hours in sedentary time had lower levels of CRF and were more likely to have a low CRF status, independently of potential confounders and BMI. However, physical activity may attenuate the harmful effect of sedentary time on CRF in adolescent girls if they meet the current physical activity guidelines. This study also showed that an excess of sedentary activities was not significantly associated with a low CRF in adolescent boys.

Several previous studies have also examined the associations between sedentariness and CRF.[18 19 34–36] However, most of them have used subjective measures of sedentariness such as television viewing, computer use or screen time (television+computer). For example, Pate *et al*[18] found an inverse association between television viewing and CRF in a representative US youth sample aged 12–19 years, participants in the National Health and Nutrition Examination Survey 1999–2002. Earlier cross-sectional studies only found low correlations between television and CRF in young people.[34–36] Recently, Lobelo *et al*[19] showed that adolescent girls who exceeded the current recommendations for screen time (>2 h/day) also had lower levels of CRF in both cross-sectional and longitudinal analyses.

One study in younger children used accelerometer-measured sedentary time and parent-reported screen time variables.[37] In this study, children spent approximately 5 h/day in sedentary

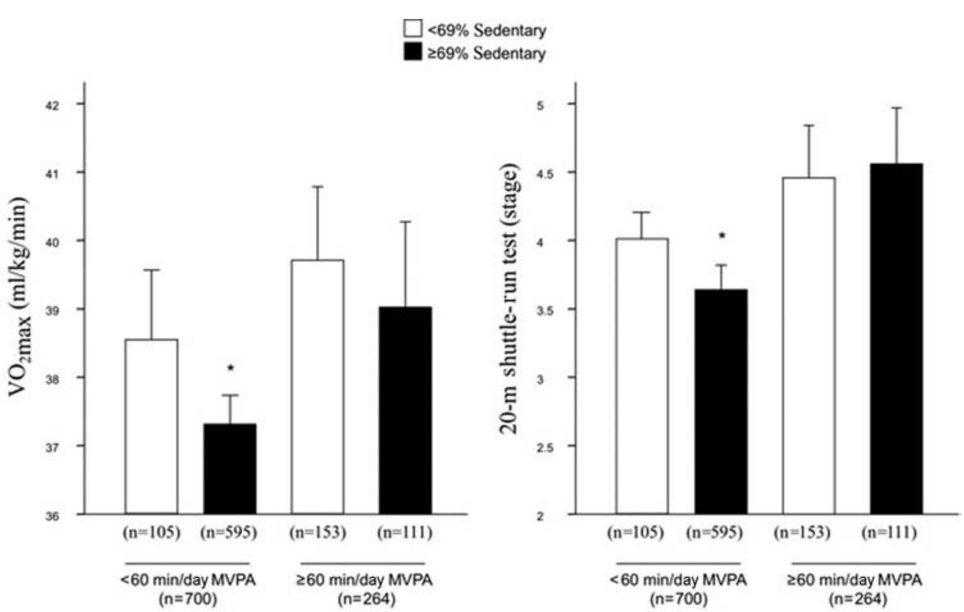

Figure 3 Differences in cardiorespiratory fitness across sedentary time and moderate-to-vigorous physical activity (MVPA) groups in European adolescent girls (n=964). Bars represent mean±SEM. MVPA, moderate-to-vigorous physical activity. Data were adjusted for centre, age and body mass index. *Significantly different from the <69% sedentary time group within the <60 min per day group in MVPA status and the ≥60 min per day groups ($p<0.05$).

time and 1.5 h/day in screen time activities (approximately 70 min/day viewing television and 20 min/day using a computer). These data suggest that self-reported behaviours such as time watching television are not a broad marker of sedentary time.[20 21] Only two studies have analysed the relationships between objectively measured sedentary time and CRF in youth. Ekelund *et al*[22] showed an inverse correlation (partial r=−0.11) in 1709 European children and adolescents aged 9 and 15 years old from the European Youth Heart Study. In a Swiss sample, accelerometer-measured sedentary activity was not related to CRF.[23] It must be noted that the main purposes of these two studies were not to examine the associations between sedentary time and CRF and, in addition, associations were not controlled for body fat and physical activity measures.

Our results suggest a sex effect of excessive sedentary time on CRF. Thus, in the current study, objectively measured sedentary time was only significantly associated with a low CRF in adolescent girls but not in boys. Specifically, ROC analysis showed that spending ≥69% of waking time in sedentary activity was associated with a low CRF in girls. Although the association found was weak (AUC 0.54), adolescent girls who exceeded this threshold had lower levels of CRF and were more likely to be classified as having an unhealthy CRF status.

A second important aim of our study was to examine whether the inverse association between sedentary time and CRF in adolescents girls was independent of physical activity levels since several studies have shown that sedentary time might have a negative role on CVD development independently of physical activity.[13–15] To avoid possible multicollinearity by including sedentary time and physical activity variables in the same model, we divided the sample into two groups according to the current physical activity recommendations for adolescents. This analysis showed that among girls who did not meet current physical activity requirements, sedentary girls (≥69%) had lower levels of CRF than less sedentary adolescent girls (<69%). Additionally, there were no differences in CRF levels between sedentary groups who met the physical activity recommendations. Taken together, these results suggest that physical activity might attenuate the damaging effect of sedentary time on CRF in adolescent girls.

Sex differences in CRF levels have been attributed to differences in muscle mass.[38] In girls with insufficient MVPA (ie, <60 min/day), light physical activity might play a key role in CRF levels, as shown in a previous work from the HELENA study.[39] Thus, light physical activity may stimulate muscle mass to build CRF in adolescent girls. On the other hand, muscle mass might be adequately stimulated by physical activity in adolescent girls who meet the physical activity recommendation (ie, ≥60 min/day in MVPA), and therefore the influence of sedentary time or light physical activity could be attenuated among these girls.

These findings may have important public health and clinical implications. In fact, longitudinal studies have shown that CRF decreases during transition from childhood to adulthood, although this decrease is more evident in girls.[11] Moreover, adolescent girls spent more time in sedentary activities and less time engaged in physical activity than boys in our study, similarly to other studies with objective measurements.[29 40] For these reasons, adolescent girls who spend too much time in sedentary activities and do not achieve the recommended levels of physical activity may be considered a target group for intervention strategies to improve CRF. Further efforts, therefore, should be made to decrease sedentary time in girls in addition to increasing physical activity.

On average, over 73% of adolescents in our study exceeded the recommended sedentary time. This figure may be alarming, but previous studies have found that over 50% of adolescents already exceed the screen time recommendations of <2 h/day in television and computer activities.[41] To offer a concise and public health message may be difficult due to the complex nature of this particular lifestyle factor. However, the cut-off of 69% found in the present study may be rounded down to provide a concise and easy message (eg, adolescent girls should not spend more than 2/3 of their waking hours in sedentary activities).

To the best of our knowledge, this is the first study to suggest the amount of daily sedentary time that is associated with an unhealthier outcome. Nowadays, sedentary behaviour recommendations for youth are exclusively limited to screen time.[42] In contrast, Hamilton *et al*[13] have proposed an overall recommendation to "limit sitting times". Likewise, Corbin and Pangrazi[43] recommended limiting extended periods of >2 h/day on sedentary activities in children. The recommendation proposed in our study is based on the amount of daily sedentary time, and may be considered a first attempt for preventive purposes. Further studies are necessary to support our findings and formulate a useful public health recommendation related to excessive sedentary time.

Several limitations must be taken into consideration. For example, the cross-sectional design precludes firm conclusions about the causality of our findings. Moreover, there is no definitive consensus regarding the best cut-off point to assess sedentary activities using the ActiGraph accelerometer. In the current study, we have used the cut-off point of <100 counts per minute, which was validated for adolescents,[44] whereas others have used higher thresholds to assess these types of activities in children and adolescents.[22 45]

In conclusion, adolescent girls who spent ≥69% or over 2/3 of their waking hours in sedentary activities had lower levels of CRF and were more likely to have a low CRF status, independently of potential confounders including BMI. However, this adverse effect might be lessened if these girls meet the physical activity guidelines. Major efforts are necessary to reduce sedentary time in girls, in addition to increasing physical activity.

HELENA Study Group

Co-ordinator Luis A Moreno

Core Group members Luis A Moreno, Fréderic Gottrand, Stefaan De Henauw, Marcela González-Gross, Chantal Gilbert

Steering Committee Anthony Kafatos (President), Luis A Moreno, Christian Libersa, Stefaan De Henauw, Jackie Sánchez, Fréderic Gottrand, Mathilde Kersting, Michael Sjöstrom, Dénes Molnár, Marcela González-Gross, Jean Dallongeville, Chantal Gilbert, Gunnar Hall, Lea Maes, Luca Scalfi

Project Manager Pilar Meléndez

1. Universidad de Zaragoza (Spain)Luis A Moreno, Jesús Fleta, José A Casajús, Gerardo Rodríguez, Concepción Tomás, María I Mesana, Germán Vicente-Rodríguez, Adoración Villarroya, Carlos M Gil, Ignacio Ara, Juan Revenga, Carmen Lachen, Juan Fernández Alvira, Gloria Bueno, Aurora Lázaro, Olga Bueno, Juan F León, Jesús Mª Garagorri, Manuel Bueno, Juan Pablo Rey López, Iris Iglesia, Paula Velasco, Silvia Bel
2. Consejo Superior de Investigaciones Científicas (Spain)Ascensión Marcos, Julia Wärnberg, Esther Nova, Sonia Gómez, Esperanza Ligia Díaz, Javier Romeo, Ana Veses, Mari Angeles Puertollano, Belén Zapatera, Tamara Pozo, David Martinez-Gomez
3. Université de Lille 2 (France)Laurent Beghin, Christian Libersa, Frédéric Gottrand, Catalina Iliescu, Juliana Von Berlepsch
4. Research Institute of Child Nutrition Dortmund, Rheinische Friedrich-Wilhelms-Universität Bonn (Germany)Mathilde Kersting, Wolfgang Sichert-Hellert, Ellen Koeppen

5. Pécsi Tudományegyetem (University of Pécs) (Hungary)Dénes Molnar, Eva Erhardt, Katalin Csernus, Katalin Török, Szilvia Bokor, Mrs Angster, Enikö Nagy, Orsolya Kovács, Judit Répasi
6. University of Crete School of Medicine (Greece)Anthony Kafatos, Caroline Codrington, María Plada, Angeliki Papadaki, Katerina Sarri, Anna Viskadourou, Christos Hatzis, Michael Kiriakakis, George Tsibinos, Constantine Vardavas, Manolis Sbokos, Eva Protoyeraki, Maria Fasoulaki
7. Institut für Ernährungs- und Lebensmittelwissenschaften-Ernährungphysiologie, Rheinische Friedrich Wilhelms Universität (Germany)Peter Stehle, Klaus Pietrzik, Marcela González-Gross, Christina Breidenassel, Andre Spinneker, Jasmin Al-Tahan, Miriam Segoviano, Anke Berchtold, Christine Bierschbach, Erika Blatzheim, Adelheid Schuch, Petra Pickert
8. University of Granada (Spain)Manuel J Castillo Garzón, Ángel Gutiérrez Sáinz, Francisco B Ortega Porcel, Jonatan Ruiz Ruiz, Enrique García Artero, Vanesa España Romero, David Jiménez Pavón, Cristóbal Sánchez Muñoz, Victor Soto, Palma Chillón, Jose M Heredia, Virginia Aparicio, Pedro Baena, Claudia M Cardia, Ana Carbonell
9. Istituto Nazionalen di Ricerca per gli Alimenti e la Nutrizione (Italy)Davide Arcella, Giovina Catasta, Laura Censi, Donatella Ciarapica, Marika Ferrari, Cinzia Le Donne, Catherine Leclerq, Luciana Magrì, Giuseppe Maiani, Rafaela Piccinelli, Angela Polito, Raffaela Spada, Elisabetta Toti
10. University of Napoli 'Federico II' Department of Food Science (Italy)Luca Scalfi, Paola Vitaglione, Concetta Montagnese
11. Ghent University (Belgium)Ilse De Bourdeaudhuij, Stefaan De Henauw, Tineke De Vriendt, Lea Maes, Christophe Matthys, Carine Vereecken, Mieke de Maeyer, Charlene Ottevaere, Inge Huybrechts
12. Medical University of Vienna (Austria)Kurt Widhalm, Sabine Dietrich
13. Harokopio University (Greece)Yannis Manios, Eva Grammatikaki, Zoi Bouloubasi, Tina Louisa Cook, Sofia Eleutheriou, Orsalia Consta, George Moschonis, Ioanna Katsaroli, George Kraniou, Stalo Papoutsou, Despoina Keke, Ioanna Petraki, Elena Bellou, Sofia Tanagra, Kostalenia Kallianoti, Dionysia Argyropoulou, Katerina Kondaki, Stamatoula Tsikrika, Christos Karaiskos
14. Institut Pasteur de Lille (France)Jean Dallongeville, Aline Meirhaeghe
15. Karolinska Institutet (Sweden)Michael Sjöstrom, Patrick Bergman, María Hagströmer, Lena Hallström, Mårten Hallberg, Eric Poortvliet, Julia Wärnberg, Nico Rizzo, Linda Beckman, Anita Hurtig Wennlöf, Emma Patterson, Lydia Kwak, Lars Cernerud, Per Tillgren, Stefaan Sörensen
16. Asociación de Investigación de la Industria Agroalimentaria (Spain)Jackie Sánchez-Molero, Elena Picó, Maite Navarro, Blanca Viadel, José Enrique Carreres, Gema Merino, Rosa Sanjuán, María Lorente, María José Sánchez, Sara Castelló
17. Campden BRI (United Kingdom)Chantal Gilbert, Sarah Thomas, Elaine Allchurch, Peter Burguess
18. SIK - Institutet foer Livsmedel och Bioteknik (Sweden)Gunnar Hall, Annika Astrom, Anna Sverkén, Agneta Broberg
19. Meurice Recherche & Development asbl (Belgium)Annick Masson, Claire Lehoux, Pascal Brabant, Philippe Pate, Laurence Fontaine
20. Campden & Chorleywood Food Industry Development Institute (Hungary) Andras Sebok, Tunde Kuti, Adrienn Hegyi
21. Productos Aditivos SA (Spain)Cristina Maldonado, Ana Llorente
22. Cárnicas Serrano SL (Spain)Emilio García
23. Cederroth International AB (Sweden)Holger von Fircks, Marianne Lilja Hallberg, Maria Messerer
24. Lantmännen Food R&D (Sweden)Mats Larsson, Helena Fredriksson, Viola Adamsson, Ingmar Börjesson
25. European Food Information Council (Belgium)Laura Fernández, Laura Smillie, Josephine Wills
26. Universidad Politécnica de Madrid (Spain)Marcela González-Gross, Agustín Meléndez, Pedro J Benito, Javier Calderón, David Jiménez-Pavón, Jara Valtueña, Paloma Navarro, Alejandro Urzanqui, Ulrike Albers, Raquel Pedrero, Juan José Gómez Lorente

Acknowledgements The content of this article reflects only the authors' views, and the European Community is not liable for any use that may be made of the information contained therein.The authors gratefully acknowledge the help of all the adolescents who took part in the HELENA study.

Funding The HELENA study was supported by the European Community 6th RTD Framework Programme (Contract FOOD-CT-2005-007034). This study is also being supported by grants from the Spanish Ministry of Education (EX-2007-1124, EX-2008-0641, AP2006-02464) and the Spanish Ministry of Health (Maternal, Child Health and Development Network, RD08/0072).

Competing interests None.

Patient consent Obtained.

Contributors Statistical analysis: DMG; drafting the manuscript: DMG, JRR, FBO; funding and overall concept and design: AM, MJC, LAM, MS, YM, KW, DM, AK; interpretation and acquisition of data: DMG, JRR, FBO, AM, MJC, LAM, MS, YM, KW, DM, AK, GVR, OLV, LB, JV. All authors approved the final version of this manuscript.

Ethics approval Ethic committees from each country approved the HELENA-CSS protocols.

Provenance and peer review Not commissioned; externally peer reviewed.

Author Affiliations [1]Department of Biosciences and Nutrition at NOVUM, Unit for Preventive Nutrition, Karolinska Institutet, Huddinge, Sweden
[2]Department of Metabolism and Nutrition, Immunonutrition Research Group, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council, Madrid, Spain
[3]Departments of Metabolism and Nutrition and Medical Physiology, University of Granada, Granada, Spain
[4]GENUD (Growth, Exercise, Nutrition and Development Research Group), University School of Health Sciences, University of Zaragoza, Zaragoza, Spain
[5]Department of Physical Education, Sport and Human Movement, Universidad Autonoma de Madrid, Madrid, Spain
[6]Department of Pediatrics, Division of Nutrition and Metabolism, Medical University of Vienna, Vienna, Austria
[7]Department of Nutrition and Dietetics, Harokopio University, Athens, Greece
[8]CIC-9301 (Inserm CHRU de Lille), IMPRT, University Lille 2, Lille, France
[9]Department of Health and Human Performance, Universidad Politécnica de Madrid, Madrid, Spain
[10]Department of Social Medicine, School of Medicine, Preventive Medicine and Nutrition Clinic, Heraklion, Crete, Greece
[11]Department of Pediatrics, University of Pecs, Pécs-József, Hungary

REFERENCES

1. **Kodama S,** Saito K, Tanaka S, *et al.* Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA* 2009;**301**:2024–35.
2. **Ortega FB,** Ruiz JR, Castillo MJ, *et al.* Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)* 2008;**32**:1–11.
3. **Blair SN,** Kohl HW 3rd, Paffenbarger RS Jr, *et al.* Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* 1989;**262**:2395–401.
4. **Blair SN,** Kampert JB, Kohl HW 3rd, *et al.* Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA* 1996;**276**:205–10.
5. **Steele RM,** Brage S, Corder K, *et al.* Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. *J Appl Physiol* 2008;**105**:342–51.
6. **Ruiz JR,** Castro-Piñero J, Artero EG, *et al.* Predictive validity of health-related fitness in youth: a systematic review. *Br J Sports Med* 2009;**43**:909–23.
7. **Teran-Garcia M,** Rankinen T, Bouchard C. Genes, exercise, growth, and the sedentary, obese child. *J Appl Physiol* 2008;**105**:988–1001.
8. **Malina RM,** Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity*. Champaign, IL, USA: Human Kinetics 2004.
9. **Malina RM.** Physical activity and fitness: pathways from childhood to adulthood. *Am J Hum Biol* 2001;**13**:162–72.
10. **Malina RM.** Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport* 1996;**67**:S48–57.
11. **Pfeiffer KA,** Dowda M, Dishman RK, *et al.* Physical fitness and performance. Cardiorespiratory fitness in girls-change from middle to high school. *Med Sci Sports Exerc* 2007;**39**:2234–41.
12. **Baquet G,** van Praagh E, Berthoin S. Endurance training and aerobic fitness in young people. *Sports Med* 2003;**33**:1127–43.
13. **Hamilton MT,** Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 2007;**56**:2655–67.
14. **Katzmarzyk PT,** Church TS, Craig CL, *et al.* Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc* 2009;**41**:998–1005.
15. **Warren TY,** Barry V, Hooker SP, *et al.* Sedentary behaviors increase risk of cardiovascular disease mortality in men. *Med Sci Sports Exerc* 2010;**42**:879–85.
16. **Dunstan DW,** Barr EL, Healy GN, *et al.* Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Circulation* 2010;**121**:384–91.
17. **Pate RR,** O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev* 2008;**36**:173–8.
18. **Pate RR,** Wang CY, Dowda M, *et al.* Cardiorespiratory fitness levels among US youth 12 to 19 years of age: findings from the 1999–2002 National Health and Nutrition Examination Survey. *Arch Pediatr Adolesc Med* 2006;**160**:1005–12.
19. **Lobelo F,** Dowda M, Pfeiffer KA, *et al.* Electronic media exposure and its association with activity-related outcomes in female adolescents: cross-sectional and longitudinal analyses. *J Phys Act Health* 2009;**6**:137–43.
20. **Sugiyama T,** Healy GN, Dunstan DW, *et al.* Is television viewing time a marker of a broader pattern of sedentary behavior? *Ann Behav Med* 2008;**35**:245–50.

21. **Biddle SJ,** Gorely T, Marshall SJ, *et al.* Physical activity and sedentary behaviours in youth: issues and controversies. *J R Soc Promot Health* 2004;**124**:29–33.
22. **Ekelund U,** Anderssen SA, Froberg K, *et al.* Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. *Diabetologia* 2007;**50**:1832–40.
23. **Kriemler S,** Manser-Wenger S, Zahner L, *et al.* Reduced cardiorespiratory fitness, low physical activity and an urban environment are independently associated with increased cardiovascular risk in children. *Diabetologia* 2008;**51**:1408–15.
24. **Moreno LA,** De Henauw S, González-Gross M, *et al.* Design and implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. *Int J Obes (Lond)* 2008;**32**(Suppl 5):S4–11.
25. **Béghin L,** Castera M, Manios Y, *et al.* Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA Cross-Sectional Study. *Int J Obes (Lond)* 2008;**32**(Suppl 5):S12–18.
26. **Nagy E,** Vicente-Rodriguez G, Manios Y, *et al.* Harmonization process and reliability assessment of anthropometric measurements in a multicenter study in adolescents. *Int J Obes (Lond)* 2008;**32**(Suppl 5):S58–65.
27. **Freedson P,** Pober D, Janz KF. Calibration of accelerometer output for children. *Med Sci Sports Exerc* 2005;**37**:S523–30.
28. **Ward DS,** Evenson KR, Vaughn A, *et al.* Accelerometer use in physical activity: best practices and research recommendations. *Med Sci Sports Exerc* 2005;**37**:S582–8.
29. **Matthews CE,** Chen KY, Freedson PS, *et al.* Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol* 2008;**167**:875–81.
30. **Léger LA,** Mercier D, Gadoury C, *et al.* The multistage 20 metre shuttle-run test for aerobic fitness. *J Sports Sci* 1988;**6**:93–101.
31. **Ruiz JR,** Ortega FB, Gutierrez A, *et al.* Health-related fitness assessment in childhood and adolescence: a European approach based on the AVENA, EYHS and HELENA studies. *J Public Health* 2006;**14**:269–77.
32. **Ortega FB,** Artero EG, Ruiz JR, *et al.* Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. *Int J Obes (Lond)* 2008;**32**(Suppl 5):S49–57.
33. **Zweig MH,** Campbell G. Receiver-operating characteristic (ROC) plots: a fundamental evaluation tool in clinical medicine. *Clin Chem* 1993;**39**:561–77.
34. **Katzmarzyk PT,** Malina RM, Song TM, *et al.* Television viewing, physical activity, and health-related fitness of youth in the Québec Family Study. *J Adolesc Health* 1998;**23**:318–25.
35. **Armstrong CA,** Sallis JF, Alcaraz JE, *et al.* Children's television viewing, body fat, and physical fitness. *Am J Health Promot* 1998;**12**:363–8.
36. **Tucker LA.** The relationship of television viewing to physical fitness and obesity. *Adolescence* 1986;**21**:797–806.
37. **Martinez-Gomez D,** Tucker J, Heelan KA, *et al.* Associations between sedentary behavior and blood pressure in young children. *Arch Pediatr Adolesc Med* 2009;**163**:724–30.
38. **Armstrong N,** Welsman JR. Assessment and interpretation of aerobic fitness in children and adolescents. *Exerc Sport Sci Rev* 1994;**22**:435–76.
39. **Martinez-Gomez D,** Ruiz JR, Ortega FB, *et al.* Recommended levels and intensities of physical activity to avoid low cardiorespiratory fitness in European adolescents. The HELENA Study. *Am J Human Biol* 2010;**22**:750–6.
40. **Troiano RP,** Berrigan D, Dodd KW, *et al.* Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008;**40**:181–8.
41. **Sisson SB,** Church TS, Martin CK, *et al.* Profiles of sedentary behavior in children and adolescents: the US National Health and Nutrition Examination Survey, 2001–2006. *Int J Pediatr Obes* 2009;**4**:353–9.
42. American Academy of Pediatrics. Committee on Public Education. American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics* 2001;**107**:423–6.
43. **Corbin CB,** Pangrazi RP. *Physical Activity for Children: A Statement of Guidelines for Children Ages 5–12*. Reston, VA, USA: National Association for Sport and Physical Education 2004.
44. **Treuth MS,** Schmitz K, Catellier DJ, *et al.* Defining accelerometer thresholds for activity intensities in adolescent girls. *Med Sci Sports Exerc* 2004;**36**:1259–66.
45. **Reilly JJ,** Coyle J, Kelly L, *et al.* An objective method for measurement of sedentary behavior in 3- to 4-year olds. *Obes Res* 2003;**11**:1155–8.

Excessive sedentary time and low cardiorespiratory fitness in European adolescents: the HELENA study

David Martinez-Gomez, Francisco B Ortega, Jonatan R Ruiz, et al.

Arch Dis Child 2011 96: 240-246 originally published online January 10, 2011
doi: 10.1136/adc.2010.187161