8

Daily variations in weather and the relationship with physical activity and sedentary time in European 10-12yr olds: The ENERGY-project

Mine Yıldırım, Anna Schoeni, Amika S Singh, Teatske M Altenburg,
Johannes Brug, Ilse De Bourdeaudhuij, Eva Kovacs, Bettina Bringolf-Isler,
Yannis Manios, Mai JM Chinapaw
Journal of Physical Activity and Health, in press

Abstract

Background: The aim of the study was to examine the association of daily variations in rainfall and temperature with sedentary time (ST) and physical activity (PA) in European children.

Methods: Children were included from five countries (Belgium, Greece, Hungary, the Netherlands, Switzerland) as part of the ENERGY- project. We used cross-sectional data from 722 children aged 10-12 years (47% boys). ST and PA were measured by accelerometers for six consecutive days, including weekend days. Weather data was collected from online national weather reports. Multilevel regression models were used for data analyses.

Results: Maximum temperature was positively associated with light PA (b=3.1 min/day; 95% CI=2.4; 3.8), moderate-to-vigorous PA (b=0.6 min/day; 95% CI=0.4; 0.8) and average PA (b=4.1 counts per minute (cpm); 95% CI=1.6; 6.5, quadratic relationship). Rainfall was inversely and quadratically associated with light PA (b=-1.3 min/day; 95% CI=-1.9; -0.6), moderate-to-vigorous PA (b=-0.6 min/day; 95% CI=-0.8; -0.3) and average PA (b=-1.6 cpm; 95% CI=-2.2; -0.9). Maximum temperature was not significantly associated with ST (b=-0.2 min/day; 95% CI=-1.0; 0.6), while rainfall was positively associated with ST (b=0.9 min/day; 95% CI=0.6, 1.3).

Conclusion: The present study shows that temperature and rainfall are significantly associated with PA and ST in 10-12 years European children.

Introduction

Being sufficiently physically active during childhood is important to prevent obesity, cardiovascular diseases and other chronic disorders throughout life (1). However, even if children meet the recommended daily physical activity (PA), there may still be an increased health risk due to prolonged time spent sedentary (2,3). Large proportions of children across different European countries do not meet PA recommendations and spend a lot of time sedentary. Recently, striking differences in physical activity and sedentary behaviors were found among schoolchildren across seven European countries (4).

Previous studies have identified demographic, socio-cultural, psychological and environmental factors associated with levels of physical activity and sedentary behavior in children (5,6). Physical environmental factors that may influence physical activity and sedentary time are, for example, access to facilities, neighbourhood safety and weather conditions. Recent research has focussed on environmental opportunities and safety issues (7,8) but to date, there is limited information about the role of weather conditions on children's physical activity and sedentary time.

Being outdoor is one of the main predictors of physical activity in children and it is likely that weather conditions will influence the likelihood of being outdoors (9,10). Some earlier studies have explored the influence of weather conditions on children's physical activity by looking at seasonal differences. Loucaides et al. (11) reported that Greek-Cypriot children aged 11-12 were more physically active during summer compared to winter. Kolle et al.(12) revealed that Norwegian children aged 9 were more active in spring than in winter. Fisher et al.(13) reported that physical activity in preschool children in Scotland was slightly higher in summer than in winter, and Riddoch et al.(14) including 11year old British children reported that physical activity assessed by accelerometer was highest in summer and lowest in winter. However, in these studies only seasonal differences were considered but not daily variations in temperature and rainfall. Moreover, to the best of our knowledge there is only one study that assessed the influence of meteorological factors on both objectively assessed sedentary time and physical activity of children (15). They found that physical activity increased with temperature and decreased with rainfall, whereas sedentary time increased with rainfall.

The purpose of the present study was to examine the association between daily variations in observed meteorological factors (i.e., rainfall and temperature) and objectively measured sedentary time and physical activity in 10-12 year old children across five European countries.

Methods

Design and participants

The children selected for the current study participated in the cross-sectional survey as part of the EuropeaN Energy balance Research to prevent excessive weight Gain among Youth (ENERGY)-project (16). The ENERGY-project is a European Commission-funded project aiming at the development of a school-based intervention programme to prevent overweight in children. As part of the main survey, accelerometer data were collected in subsamples in five countries (Belgium, Greece, Hungary, the Netherlands and Switzerland) between March and September 2010. Data collection periods in each country varied as follows; in Belgium between April-May, in Greece between March-May, in Hungary between April-July, in the Netherlands between April-July, in Switzerland between June-September. Ethical approval was obtained in every participating country and parents provided informed consent. Details of the cross- sectional survey are described elsewhere (17).

In short, 1082 children aged 10-12 years participated from 37 schools in Belgium (5 schools, 196 children), Greece (8 schools, 215 children), Hungary (8 schools, 194 children), the Netherlands (7 schools, 200 children) and Switzerland (9 schools, 277 children).

Physical activity and sedentary time

Physical activity and sedentary time data were collected using Actigraph accelerometers (Actitrainer (triaxial), GT3X and GT1M models) using a standardised protocol (18). The children wore the accelerometer for six consecutive days including weekend days. The accelerometer was located at the waist at the right side of the body and was only removed during night while sleeping or during water activities. Data cleaning was conducted with Meterplus, a Microsoft Windows-based program (19). Data was included in the study if there were valid records for at least 3 weekdays and 1 weekend day. Non-wearing of the device was considered if there were more than 20 minutes of consecutive zero counts (20,21). The average counts per 15 seconds provided information on the overall activity level and was converted to counts per minute. Minutes of sedentary time, light physical activity (light PA) and moderate-to-vigorous physical activity (MVPA) were estimated using cut- points from Treuth et al. (22), which were identified as good classification accuracy for children aged 10-12 years (23). Cut- points used were: sedentary time ≤ 100cpm, light PA 101-2999cpm, MVPA ≥ 3000cpm. The details of data processing have been previously described (18).

Meteorological data collection

Data on daily minimal and maximal temperatures (in degree Celsius) and total rainfall (in millimetres per day) was obtained from official national weather online services (www.sfmeteo.ch, www.meteobelgique.be, www.knmi.nl) and a publicly accessible weather report web site (www.weatheronline.co.uk). The weather data ascribed to the location of every school was collected from the nearest weather station. All schools were located within 65 km of the nearest weather station. For one school in Switzerland (100 km) and one in Greece (110 km), rainfall data had to be obtained from a more distant weather station.

Socio-demographic characteristics

Self-reported age, gender, and ethnicity were administered. Ethnicity was categorised as "native" if the spoken language at home was the country's primary language and as "non-native" if otherwise.

Statistical analysis

Descriptive statistics were used to calculate mean, standard deviation, interquartile range (IQR), median and percentage using SPSS (version 15.0 for Windows). Median and interquartile range were presented for all PA and sedentary time measures due to non-normal distribution of MVPA and average PA. The residuals from linear regression analysis were checked for normality by plotting standardized residuals against standardized predicted values. The residuals were normally distributed. Weather condition was merged with data on sedentary time and physical activity on that particular day using the corresponding dates of data collection (day, month, year). Multilevel regression analysis (MLwin version 2.23 for Windows) was used to examine the association between sedentary time and physical activity and daily weather condition (temperature and rainfall). In a subsequent model, adjustments for country, gender, age and ethnicity were made. Three levels were defined: 1) observations (days), 2) individual and, 3) weather station. Potential effect modification by gender was assessed by including an interaction term between gender and temperature or gender and rainfall respectively into the regression models. In case of significant effect modification the analysis was stratified by gender. Non-linearity of the association was checked by adding quadratic terms, i.e., a squared term of the independent variable, to the regression models and evaluating the value of its regression coefficient. If the regression coefficient of the quadratic term is significant, there is a quadratic relationship between the independent and dependent variables (24,25). Significance levels for all analysis were set at $p<0.05$. Since the minimum temperature mostly occurs during the night while activity data collection took place during the day only, we did not examine the association between minimum temperature and PA and sedentary time, respectively.

Results

Descriptive Statistics

Table 1 shows the characteristics of the participants and meteorological factors per country. From 1082 children that wore an accelerometer, 722 children provided valid data. The average age was 11.6 (SD=0.9) years and 47% were boys. Native language was spoken at home by 86% of the children.

On average, children were sedentary for 489 (SD=103) minutes per day, performed light physical activity for 276 (SD=73) minutes and MVPA for 38 (SD=27) minutes per day. Average physical activity was 141 (SD=68) counts per minute.

The average maximum temperature in the different countries varied from 15.5°C in Belgium to 22.0°C in Hungary. The IQR values in table 1 show that there was a large variation in maximum temperature values within each country. The average minimum temperature varied from 6.0°C in Belgium to 12.7°C in Switzerland. Rainfall varied from 0.2 mm per day in Hungary to 8.7 mm per day in Switzerland.

Table 1. Characteristics of participants and meteorological factors (mean and SD (unless otherwise is stated)) for the different countries and the total study population.

	Belgium N=107	Greece N=160	Hungary N=147	Netherlands N=102	Switzerland N=206	Total N=722
Demographics						
Age (years)	11.4 (0.7)	11.3 (0.6)	12.2 (0.6)	11.8 (0.6)	11.3 (1.2)	11.6 (0.9)
Ethnicity (native %)	97.2	89.5	99.3	87.5	66.1	85.8
Gender (boys %)	43.9	46.8	48.5	56.6	41.3	46.6
Activity levels (min/day) [a]						
Sedentary	498.9 (423.4-576.1)	530.1 (454.3-605.9)	507.9 (439.2-581.5)	479.3 (411.9-553.6)	479.1 (412.0-548.3)	497.8 (427.8-574.0)
Light PA	277.1 (223.7-338.1)	283.5 (235.0-339.7)	268.5 (215.6-336.8)	290.0 (237.8-359.6)	283.3 (234.5-330.6)	280.8 (229.8-338.4)
MVPA	28.8 (15.7-50.0)	29.5 (16.5-45.5)	32.0 (18.5-49.8)	26.0 (15.0-44.4)	39.5 (23.8-59.7)	32.3 (18.3-51.3)
Average PA (cpm)	131.1 (90.9-183.3)	119.9 (91.3-151.1)	124.9 (94.8-164.4)	129.7 (94.5-173.2)	142.2 (106.5-189.4)	129.6 (96.1-172.8)
Meteorological factors [b]						
Max Temp (degree celsius)	15.5 (13.0-18.0)	20.1 (17.5-22.5)	22.0 (19.0-25.0)	20.4 (14.5-26.5)	20.2 (16.0-21.8)	19.8 (16.0-24.0)
Min Temp (degree celsius)	6.0 (3.5-9.0)	10.5 (8.0-12.0)	12.0 (10.5-13.5)	7.7 (4.0-10.5)	12.7 (10.0-15.5)	10.4 (7.5-13.5)
Rainfall (mm/day)	0.8 (0.0-1.0)	0.2 (0.0-0.0)	3.4 (0.0-2.0)	1.8 (0.0-0.0)	8.7 (0.0-7.0)	3.7 (0.0-0.1)

cpm = counts per minute, mm = millimeter, PA= physical activity, MVPA=moderate-to-vigorous physical activity

a Median (Interquartile range) was reported

b Mean (Interquartile range) was reported

Temperature and sedentary time and physical activity

Table 2 shows the associations between daily maximum temperature and sedentary time and PA. We found no association between temperature and sedentary time. Temperature and light PA were significantly positively associated. Due to a significant interaction between temperature and gender (β=-1.49, SE=0.50), we stratified the analysis by gender (model 1). The association between maximum temperature and light PA was stronger in girls than in boys and these associations remained significant after adjusting for country, age and ethnicity (model 2). A 10°C higher maximum temperature was associated with 15.4 minutes/day more light PA in boys and 29.3 minutes/day in girls.

Temperature was significantly positively associated with MVPA and average physical activity (model 1). The association between temperature and average PA was not linear, therefore a quadratic term was added. The regression coefficient of the quadratic term was negative (b=-0.07 (95%CI:-0.01, -0.13)) indicating a decrease in average PA above a certain temperature (30 degree Celsius). After adjusting for country, gender, age and ethnicity the significance and direction of the association remained similar (both for MVPA and average PA) (model 2). A 10°C higher temperature was associated with 6 minutes/day more MVPA.

Table 2. Associations (unstandardized regression coefficient, i.e., β and 95% confidence intervals (CI)) between daily temperature and sedentary time and physical activity in children.

	Maximum temperature **Model 1** **β (95% CI)**	**Model 2** **β (95% CI)**
Sedentary (min/d)	-0.6 (-1.3; 0.1)	-0.2 (-1,0; 0,6)
Light PA (min/d)	2.5 (2.0; 3.0)*	3.1 (2.4; 3.8)*
	B 1.5 (0.7; 2.3)*#	B 1.5 (0.7; 2.4)*#
	G 3.0 (2.3; 3.7)*#	G 2.9 (2.2; 3.6)*#
MVPA (min/d)	0.6 (0.4; 0.8)*	0.6 (0.4; 0.8)*
Average PA (cpm)	1.4 (0.9; 1.9)*	4.1 (1.6; 6.5)* [a]

Model 1: crude model
Model 2: adjusted model (country, gender, age, ethnicity and [a]quadratic term)
= modification by gender, G = girls, B = boys, PA= physical activity, MVPA=moderate-to-vigorous physical activity
* = significant association
Cpm= counts per minute

Rainfall and sedentary time and physical activity

Table 3 displays the associations between daily rainfall and sedentary time and PA. Since the association between rainfall and light PA, MVPA and average PA was not linear, quadratic terms were added. Rainfall and sedentary time were significantly positively associated, and rainfall and PA were inversely associated (Model 1) and remained significant after adjusting for country, gender, age and ethnicity (model 2). The positive regression coefficients for the quadratic terms indicate that light PA, MVPA and average PA did not further decrease after a certain amount of rain (i.e., 20 mm/d).

Table 3. Associations (unstandardized regression coefficient, i.e., β and 95% confidence intervals (CI)) between rainfall and sedentary time and physical activity in children.

	Rainfall Model 1 β (95% CI)	Model 2 β (95% CI)
Sedentary (min/d)	1.0 (0.6; 1.3)*	0.9 (0.6; 1.3)*
Light PA (min/d)	-0.1 (-0.3; 0.1)*	-1.3 (-1.9; -0.6)* [a]
MVPA (min/d)	-0.2 (-0.2; -0.1)*	-0.6 (-0.8; -0.3)* [a]
Average PA (cpm)	-0.5 (-0.3; -0.3)*	-1.6 (-2.2; -0.9)* [a]

Model 1: crude model
Model 2: adjusted model (country, gender, age, ethnicity, [a] quadratic term)
* = significant association, PA= physical activity, MVPA=moderate-to-vigorous physical activity

Discussion

To the best of our knowledge, this is the first study examining daily variations in daily meteorological factors and objectively assessed PA and sedentary time by accelerometers among European school-aged children.

In the present study, we found a significant association between meteorological factors and sedentary time and physical activity in children. Our results suggest that a lower maximum daily temperature or a higher amount of total rainfall per day have a negative impact on children's light PA, MVPA and average PA, and rainfall may lead to more sedentary time. Gender moderated the association between maximum temperature and light PA indicating that girls' light PA may be more dependent on maximum daily temperature than boys' light PA. For average PA and maximum temperature we found a non-linear relationship indicating that above a certain temperature average PA did not further increase, but started to decline. This result shows that not only extreme low but also so high temperatures influence children's activity level unfavorably. Non-linear relationships between rainfall and light PA, MVPA and average PA also indicated that after a certain amount of rain, PA levels did not further decrease.

Similar results were found in a study by Bringolf-Isler et al.(15) examining the effects of meteorological factors on physical activity and sedentary time of children measured by accelerometry. They found that temperature was positively and rainfall was negatively associated with physical activity while rainfall was positively associated with sedentary time (15). Duncan et al. (26) investigated the influence of weather on children's PA measured by pedometers. They also found that a decrease in mean ambient temperature and an increase in total rainfall were significantly negatively associated with PA. Another study found a significant relationship between wind speed and children's active transport to/from school (27). This study used observation techniques to count the number of individuals walking to school, exercising on oval tracks and walking/jogging/biking on sidewalks/streets.

A major strength of our study includes the fact that the association between sedentary time and PA and daily - and not seasonal–differences in meteorological factors was examined. Second, our study included a large sample of children across five European countries. Furthermore, PA and sedentary time were objectively assessed using accelerometry. Accelerometers provide accurate and objective data and are one of the

most promising tools for PA measurement among free-living children and adolescents. However, accelerometers are not able to accurately measure upper body movement (e.g., carrying or lifting weights with arms), cycling, water based activities and/or distinguish between different types of sedentary behavior (18,28). A limitation of the study was that data were collected between March and September, implicating that the results of this study may not be generalisable to the fall and winter seasons with in general more rainfall and lower temperatures. Second, we had no information on the duration of rainfall, wind speed and humidity that may be additional weather factors of relevance. Finally, we had no detailed information on time spent indoor and outdoor, which is important since being physically active indoor may be less influenced by weather conditions. Previous research showed that rainfall increased indoor sedentary time and light physical activity but not moderate-vigorous activity (15).
For future weight gain prevention intervention studies it may be important to take weather conditions into account, and include strategies that are less dependent on favourable weather. For example, activities might be planned for all types of weather condition to overcome negative effects of extreme low and high temperatures and rainfall on children's PA and sedentary time. Furthermore, the influence of weather condition should be taken into account when comparing activity levels of children from different geographical regions that have dissimilar climate conditions as well as at comparison of pre and post intervention period.

Conclusion

To the best of our knowledge this is the first study examining the association between daily meteorological factors and sedentary time and physical activity in European children. Our findings suggest that there is a significant association between temperature and PA, and between rainfall and both PA and sedentary time in 10-12 years old children across Europe.

References

1. Boreham C, Riddoch C. The physical activity, fitness and health of children. J Sports Sci. 2001; 19: 915-929.
2. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. Exerc Sport Sci Rev. 2010; 38: 105-113.
3. Chinapaw MJM, Proper KI, Brug J, Van Mechelen W, Singh AS. Relationship between young peoples' sedentary behavior and biomedical health indicators: a systematic review of prospective studies. Obes Rev. 2011; 12(7): e621-632.
4. Brug J, van Stralen MM, te Velde SJ, et al. Differences in weight status and energy-balance related behaviors among schoolchildren across Europe: the ENERGY-Project. PLoS ONE. 2012; 7(4): e34742.
5. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000; 32: 963-975.
6. Van Der Horst K, Chinapaw MJM, Twisk JWR, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. Med Sci Sports Exerc. 2007; 39: 1241-1250.
7. De Vet E, De Ridder DT, De Wit JB. Environmental correlates of physical activity and dietary behaviors among young people: a systematic review of reviews. Obes Rev. 2011; 12(5): 130-142.
8. Carver A, Timperio A, Crawford D. Playing it safe: the influence of neighbourhood safety on children's physical activity. A review. Health Place 2008; 14(2): 217-227.
9. Baranowski T, Thompson WO, DuRant RH, Baranowski J, Puhl J. Observations on physical activity in physical locations: age, gender, ethnicity, and month effects. Res Q Exerc Sport. 1993; 64: 127-133.
10. Burdette HL, Whitaker RC, Daniels SR. Parental report of outdoor playtime as a measure of physical activity in preschool-aged children. Arch Pediatr Adolesc Med. 2004; 158: 353-357.
11. Loucaides CA, Chedzoy SM, Bennett N. Differences in physical activity levels between urban and rural school children in Cyprus. Health Educ Res. 2004; 19: 138-147.
12. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Seasonal variation in objectively assessed physical activity among children and adolescents in Norway: a cross-sectional study. Int J Behav Nutr Phys Act. 2009; 6: 36.
13. Fisher A, Grant S, Jackson DM, et al. Seasonality in physical activity and sedentary behavior in young children. Pediatr Exerc Sci. 2005; 17: 31-40.
14. Riddoch CJ, Mattocks C, Deere K, et al. Objective measurement of levels and patterns of physical activity. Arch Dis Child. 2007; 92: 963-969.
15. Bringolf-Isler B, Grize L, Mader U, Ruch N, Sennhauser FH, Braun-Fahrlander C. Assessment of intensity, prevalence and duration of everyday activities in Swiss school children: a cross-sectional analysis of accelerometer and diary data. Int J Behav Nutr Phys Act. 2009; 6: 50.
16. Brug J, Te Velde SJ, Chinapaw MJM, et al. Evidence-based development of school-based and family-involved prevention of overweight across Europe: The ENERGY-project's design and conceptual framework. BMC Public Health. 2010; 10: 276.
17. Van Stralen MM, Te Velde SJ, Singh AS, et al. EuropeaN Energy balance Research to prevent excessive weight Gain among Youth (ENERGY) project: Design and methodology of the ENERGY cross-sectional survey. BMC Public Health. 2011; 11: 65.
18. Yıldırım M,Verloigne M, De Bourdeaudhuij I, et al. Study protocol of physical activity and sedentary behavior measurement among schoolchildren by accelerometry--cross-sectional survey as part of the ENERGY-project. BMC Public Health. 2011; 11: 182.
19. MeterPlus version 4.2 software from Santech, Inc. [Available from: http://www.meterplussoftware.com].
20. Stevens J,Murray DM, Baggett CD, et al. Objectively assessed associations between physical activity and body composition in middle-school girls: the Trial of Activity for Adolescent Girls. Am J Epid. 2007; 166: 1298-1305.
21. Treuth MS, Sherwood NE, Butte NF, et al. Validity and reliability of activity measures in African-American girls for GEMS. Med Sci Sports Exerc. 2003; 35: 532-539.
22. Treuth MS, Schmitz K, Catellier DZ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. Med Sci Sports Exerc. 2004; 36: 1259-1266.
23. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc. 2011; 43: 1360-1368.

24. Ambrosius WT. Topics in biostatistics. Humana Press, New Jersey; 2007.
25. Ganzach Y. Misleading interaction and curvilinear terms. Psych Meth. 1997; 2(3): 235-247.
26. Duncan JS, HopkinsWG, Schofield G, Duncan EK. Effects of weather on pedometer-determined physical activity in children. Med Sci Sports Exerc. 2008; 40 (8): 1432-1438.
27. Suminski RR, Poston WC, Market P, Hyder M, Sara PA. Meteorological conditions are associated with physical activities performed in open-air settings. Int J Biometeorol. 2008; 52: 189-197.
28. Trost S. State of the art reviews: measurement of physical activity in children and adolescents. Am J Lifestyle Med. 2007; 1(4): 299-314.