Relationships between outdoor time, physical activity, sedentary time and body mass index in children: a 12-country study

Running head: Outdoor time and children's physical activity

ABSTRACT

Purpose: This study investigated the relationship between outdoor time and physical activity (PA), sedentary time (SED), and BMI Z-scores among children from 12 lower-middle-income, upper-middle-income, and high-income countries.

Methods: 6,478 children (54.4% girls) aged 9-11 years participated. Outdoor time was self-reported, PA and SED were assessed with ActiGraph GT3X+ accelerometers, and height and weight were measured. Data on parental education, neighbourhood collective efficacy, and accessibility to neighborhood recreation facilities were collected from parent questionnaires. Country latitude and climate statistics were collected through national weather data sources. Gender-stratified multilevel models with parental education, climate, and neighborhood variables as covariates were used to examine the relationship between outdoor time, accelerometry measures, and BMI Z-scores.

Results: Each additional hour/day spent outdoors was associated with higher moderate- to vigorous-intensity PA (boys: +2.8 min/day; girls: +1.4 min/day), higher light-intensity PA (boys: +2.0 min/day; girls: +2.3 min/day) and lower SED (boys: -6.3 min/day; girls: -5.1 min/day). Effect sizes were generally weaker in lower-middle-income countries. Outdoor time was not associated with BMI Z-scores.

Conclusions: Outdoor time was associated with higher PA and lower SED independent of climate, parental education and neighborhood variables, but effect sizes were small. However, more research is needed in low- and middle-income countries.

Consistent evidence indicates that the vast majority of children and youth worldwide are insufficiently active (18, 39). This situation is concerning because, even in children, insufficient physical activity (PA) is associated with a clustering of cardiovascular disease risk factors (12), higher risk of obesity (22), and poorer mental health outcomes (5). While secular trends in children's PA are difficult to establish because of inconsistent survey methodologies and lack of data on overall PA (13), researchers have suggested that PA within specific domains has decreased over time (3, 11). For example, data from the United States show that while participation in organized sports has increased over time, engagement in active transportation and outdoor play has markedly decreased over the last four decades (3).

Mounting evidence suggests that children who spend more time outdoors are more physically active overall (17, 25, 26, 35, 38) and spend less time sedentary (26, 35, 38). Outdoor play is instrumental in developing children's resilience, self-regulation and coping skills (40), and spending more time outdoors is associated with reduced odds of peer relationship problems (26). Furthermore, exposure to natural environments could augment the benefits of PA for mental health (36). However, previous studies examining the relationship between outdoor time and adiposity have obtained conflicting findings (1, 9, 26, 35, 38). To our knowledge, all previous studies investigating the relationship between outdoor time and PA were conducted in high-income countries; thus, it is unclear if similar relationships exist in low- and middle-income countries.

In addition to outdoor time, previous research suggests that children's PA is associated with variables such as gender (18, 37), parental education (37), access to PA facilities in the neighborhood (32), weather and season (28, 41), and daylight hours (16). Furthermore, a recent study reported that children spent more time outdoors if their mother had a positive perception of her neighborhood's collective efficacy (24), which refers to "*social cohesion among neighbors* *combined with their willingness to intervene on behalf of the common good*" (34). It is unclear if previously reported associations between outdoor time and PA are independent of such variables and if they vary by gender. Moreover, previous studies conducted in a single country or region may provide less variability in environmental conditions.

Therefore, this study aimed to investigate whether outdoor time is associated with PA levels, sedentary time (SED), and BMI Z-scores in a large sample of 9- to 11-year-old children from 12 countries located in all inhabited continents. We hypothesized that, in both boys and girls, outdoor time would be positively associated with PA, and negatively associated with SED and BMI z-scores across lower-middle-income, upper-middle-income, and high-income countries.

Methods

The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) was designed to investigate the influence of behavioural settings and the physical, social, and policy environments on the observed relationship between lifestyle and weight status among school-aged children from study sites located in 12 countries (21). ISCOLE countries represent five major geographic regions including Africa (Kenya, South Africa), the Americas (Brazil, Colombia, Canada, United States), Europe (Finland, Portugal, United Kingdom), South Asia (India), and the Western Pacific (China, Australia). These include lower-middle-income (Kenya and India), upper-middle-income (Brazil, China, Columbia and South Africa), and high-income countries (Australia, Canada, Finland, Portugal, United Kingdom and United States) based on the World Bank classification (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups). The study design also incorporated comprehensive and robust indicators of lifestyle behaviours (e.g. PA, food consumption, SED, and sleep) and anthropometry. A detailed account of the ISCOLE study protocol has been published elsewhere (21). Data collection was conducted in accordance with the Declaration of Helsinki, following ethical approval from relevant research ethics boards in each country and after obtaining parental consent and child assent.

ISCOLE study design. Recruitment in each country targeted a gender-balanced sample of at least 500 children 9–11 years of age. The primary sampling frame in all sites was schools in urban and suburban areas, stratified by indicators of socio-economic status to maximize variability within sites. Classrooms were then selected to include children with minimum variability around age 10 years. Data collection was conducted during a full school year, which varied across countries. In all sites, data were collected between September 2011 and December 2013. Any variations in recruitment strategies employed in the different countries are reported elsewhere (21). Overall, 739 schools were approached and 256 registered in ISCOLE (34.6% participation rate), as described by Katzmarzyk et al. (23). Of the 13,015 students invited to participate, 7,372 did so (56.6% participation rate). The analytical sample for this study comprised 6,478 children (54.4% girls) with measured BMI, valid accelerometry data and child questionnaire data for outdoor time and gender.

Questionnaires. Children completed a Diet and Lifestyle Questionnaire (21) adapted from the United States Youth Risk Behavior Surveillance System (http://www.cdc.gov/HealthyYouth/yrbs/index.htm) and the Health Behaviour in School-aged Children Survey (http://www.hbsc.org/). Outdoor time was assessed via the three following items developed specifically for this study: "*On a school day how much time did you spend outside before school*?"; "*On a school day how much time did you spend outside after school before bedtime*?"; "*On a weekend day, how much time did you spend outside*?". For all items, response options were: 1) < 1 hour; 2) 1 hour; 3) 2 hours; 4) 3 hours; 5) 4 hours; and 6) 5 or more hours. Together, the three outdoor time items had good internal consistency (Cronbach $\alpha = 0.83$).

Parents completed a Demographic and Family History Questionnaire to provide information on demographics, family health, and socioeconomic factors (21). A collective efficacy index was computed as the sum of two 5-item subscales. Specifically, social cohesion and informal social control items were collected pertaining to the participants' neighbors and/or neighborhoods (34), with higher scores indicating greater perceived collective efficacy. In the ISCOLE sample, both subscales had a Cronbach α value of 0.75 (27). We also calculated an index of accessibility to neighborhood recreation facilities (e.g., parks, trails, beaches and indoor recreation facilities) based on 9 items adapted from the Neighborhood Environment Walkability Scale for Youth (32). Parents reported how long it would take them to walk to each destination. Response options were: 1) 1-5 min; 2) 6-10 min; 3) 11-20 min; 4) 21-30 min; 5) ≥ 31 min; and 6) don't know. "Don't know" responses were recoded as ≥ 31 min because if respondents do not know whether the facility is within walking distance, it is likely more than a 30 minute walk away (James F. Sallis, personal communication). Smaller scores on this index indicate shorter travel time to destinations. This index had good internal consistency ($\alpha = 0.85$) in the ISCOLE sample (27). Mothers' and fathers' education was assessed on a 6-point scale ranging from less than high school to professional/graduate degree. Then, the highest level of either parents' education was used as a measure of socioeconomic status.

Anthropometry. Participants' standing height was measured by trained research staff using a Seca 213 portable stadiometer (Hamburg, Germany), with the participants standing as erect as possible and head positioned in the Frankfort horizontal plane. Participants' weight was measured using a portable Tanita Body Composition Analyser (Arlington Heights, Illinois, United

States), after all outer clothing, heavy pocket items, shoes, and socks were removed. Body mass index (BMI) was derived from weight and height (kg/m^2), and BMI z-scores calculated based on growth reference algorithms developed by the World Health Organization (10).

Accelerometry. PA and SED were objectively measured with ActiGraph GT3X+ accelerometers (Pensacola, Florida, United States). Accelerometers were attached firmly to belts, and worn on the right side of the waist. Children were instructed to wear the devices 24 h/day for 7 consecutive days (at all times except when bathing or swimming), in addition to an initial familiarization day (42). This protocol maximized the number of children providing ≥ 4 days (including one weekend day) with ≥10 waking hours per day of monitored wear time. Non-wear time within a day was classified as 20 or more consecutive minutes of '0' counts after extracting sleep time (2, 21). Sleep time was defined as the time between sleep onset and the end of sleep, including all sleep epochs and wakefulness after onset (42), using an algorithm developed specifically for a 24 h/day waist-worn accelerometry protocol (2). Moderate- to vigorous-intensity physical activity (MVPA) was defined as all activity ≥ 574 counts per 15 s, light-intensity physical activity (LPA) was defined as all activity between 26 and 573 counts per 15 s, and SED was defined as all movement 25 or less counts per 15 s (14).

Weather. Geographical and climate data for each city were extracted from the respective country's national geographical or climate organization's website for the month of data collection. For instances where the geographical or climate data were not available from the city's national online resources, global geographical and climate web resources (i.e., http://www.weather-and-climate.com) were used to access the information. Historical mean monthly temperature and mean monthly precipitation for each city were obtained from the National Oceanic and Atmospheric Administration – National Climatic Data Center; the weather station closest to each city was utilized as the data source. For mean monthly daylight hours, each city's data were obtained from an independent climate website (available at http://www.climatemps.com/).

Data treatment. The following steps were used to compute an outdoor time index in hours/day. First, the response options "< 1 hour" and "5 hours or more" were converted to 0.5 hours and 5 hours respectively. Second, outdoor time before and after school were summed to obtain the time spent outdoors on weekdays. Third, outdoor time in hours per day was calculated as: (5 * outdoor time on weekdays) + (2 * outdoor time on weekend days) / 7. The highest level of parental education was collapsed into a 3-level variable and dummy-coded for analyses: 1) Did not complete high school; 2) Completed high school/some college; and 3) Bachelor's degree or postgraduate degree. Scores for the indices of collective efficacy and accessibility to neighborhood recreation facilities were calculated as the mean of the relevant items.

Statistical analysis. First, chi-squared and t-tests were used to examine differences between participants included in the analytical sample and those excluded. To examine variation in outdoor time by country-site, gender-stratified generalized linear mixed models including school as a random effect were used. Then, to assess differences between genders in outdoor time, MVPA, LPA, SED, and the likelihood of achieving an average of at least 60 minutes of MVPA per day, generalized linear mixed models including school and country-sites as random effects were used.

To test our main hypothesis that greater time spent outdoors is associated with higher MVPA and LPA and lower SED and BMI Z-scores, we performed a series of generalized linear mixed models. For each outcome, we built three gender-stratified models in a hierarchical fashion: 1) without covariates; 2) with climate variables and parent education; 3) with climate, parental education, and neighborhood variables. School and country-site were treated as random effects and their corresponding intra-class correlation coefficients were calculated. The Satterthwaite method was used to calculate degrees of freedom. Given the inclusion of 4 outcome variables, a *p*-value of <0.0125 was used for statistical significance based on Bonferroni adjustment. All predictors were grand-mean centered prior to analyses. Model fit was assessed using the deviance statistic which is expected to decline significantly if a model fits the data better than the previous one. When models are nested, differences in deviances follow a chi-square distribution whose degrees of freedom correspond to the number of predictors added to each model (31).

We conducted sensitivity analyses to examine our main hypothesis while stratifying by country income status. We also conducted additional analyses examining the relationship between outdoor time in different time periods (i.e., before school, after school, and on weekend days) and our outcome measures. All analyses were computed with IBM SPSS version 21 (IBM Corporation, Armonk, NY), except the analysis of differences between included and excluded participants which was performed with SAS version 9.3 (SAS Institute, Cary, North Carolina, USA).

Results

Descriptive characteristics of the sample are shown in Table 1. ISCOLE sites provided wide variability in terms of latitude, temperature, precipitation, and parental education. On average, children reported spending 2.5 ± 1.5 h/day outdoors with substantial variation between country-sites ($F = 23.25$; $p<0.01$), from 1.8 h/day in Portugal to 3.7 in South Africa. Participants with missing data on parental education, collective efficacy and accessibility to neighborhood recreation facilities scores reported spending more time outdoors and accumulated more minutes of MVPA ($p<0.05$), though differences were generally small (data not shown).

Using the United States as the reference group, boys and girls in Canada, China, Colombia, and Portugal had significantly lower outdoor time scores (all $p \leq 0.01$; data not shown).

Conversely, boys and girls in Brazil and South Africa had significantly higher scores (all $p \leq 0.01$). Compared to boys, girls spent 16.5 fewer minutes/day outdoors (95% CI = 12.6; 20.3; $p<0.01$), accumulated 17.3 less minutes of MVPA/day (95% CI = -18.3; -16.3; $p<0.01$), 7.8 fewer minutes of LPA/day (95% CI = -10.2; -5.3; $p<0.01$), and 16.3 more minutes of SED (95% CI = 13.2; 19.4; $p<0.01$). Girls were over four times less likely to accumulate at least 60 minutes of MVPA/day than boys (OR = 0.23; 95% CI = 0.20; 0.25; $p<0.01$).

Relationships between the outdoor time score and accelerometry measures are presented in Tables 2 to 4. After adjusting for covariates, each additional hour/day spent outdoors was consistently associated with higher MVPA (boys: +2.8 min/day; girls: +1.4 min/day), higher LPA (boys: +2.0 min/day; girls: +2.3 min/day) and lower SED (boys: -6.3 min/day; girls: -5.1 min/day). Inclusion of parental education, climate and neighborhood variables generally had minimal effects on these associations. Similar relationships were observed for outdoor time before school, after school, and on weekend days (Appendix 1). When stratifying by country income status, the effect sizes were generally weaker in lower-income countries (Appendix 2).

Lower parental education was consistently associated with more time spent in MVPA and LPA, and less SED in a graded manner (Tables 2 to 4). Each additional minute of daylight was associated with 0.02 minutes of additional MVPA (representing a 1.2 min/day increase for each hour of daylight), but this difference was only significant for girls. Similarly, each unit increase in collective efficacy scores was associated with 1.1 more minutes of MVPA/day in girls only. Each degree increase in mean daily temperature was associated with more LPA in boys (+0.9 min/day) and girls (+1.2 min/day) and with less SED in girls (-1.3 min/day). Finally, each unit increase in the index of accessibility to neighborhood recreation facilities (reflecting that facilities are further away) was associated with 3.5 less min/day of SED in girls only. In the models stratified by country income status, the climate, parental education, and neighborhood variables that were significantly associated with our outcomes of interest varied across country income groups and gender.

As shown in Table 5, neither the outdoor time score nor any of the included covariates were associated with BMI z-scores. In lower-middle-income countries, higher parental education was associated with higher BMI z-scores. The opposite was observed in high-income countries and parental education was not associated with BMI Z-scores in upper-middle-income countries.

Discussion

We examined the relationship between outdoor time and objective measures of PA, SED, and BMI in a large sample of children from study sites within 12 different countries representing all inhabited continents and providing wide variability in environmental conditions. In support of our hypotheses, greater time spent outdoors was associated with significantly higher MVPA, LPA, and lower SED, although the effect sizes were small. Our results were similar in boys and girls and observed differences persisted after adjusting for socioeconomic status, neighborhood environment and climate variables. However, effect sizes were weaker in lower-middle-income countries compared to high- and upper-middle-income countries. We found no relationship between outdoor time and BMI z-scores.

In line with previous research, we observed that children who spend more time outdoors were more active overall (9, 17, 25, 26, 35, 38) and accumulated less SED (26, 35, 38). The magnitude of the observed associations (about 2 additional min/day of MVPA and LPA, and 6 fewer min/day of SED for each additional hour spent outdoors) was smaller than in most previous studies conducted in high-income countries. Except for one study using global positioning systems (25), all previous studies discussed above have used self- or proxy-reports of outdoor time. However, it is worth noting that the differences that we observed were similar for boys and girls and remained virtually unchanged when controlling for parental education, climate and neighborhood variables. Our models examining outdoor time before school, after school, and on weekends also suggest that relationships between outdoor time, PA, and SED are similar regardless of when outdoor time occurs.

Increasing opportunities for children to spend more time outdoors is likely to be a scalable public health intervention that could simultaneously increase PA and reduce SED, among other positive outcomes (40). For instance, a recent study suggests that pediatrician prescriptions to spend time outdoors may be feasible, well-accepted by parents, and show some promise in increasing PA (44). In a brief 4-week program wherein parents merely received suggestions to increase family outdoor time and information about suitable locations to be active, family outdoor time increased by 100-135 minutes per week (15). Moreover, spending less time indoors may have additional benefits that were not examined in the present analyses (e.g., better mental health and air quality and lower exposure to unhealthy snacks and cyber-predators) (40).

Our study extends previous research by including countries at different stages of development. We observed that associations between outdoor time and indicators of MVPA, LPA and SED were weaker in lower-middle-income countries than in richer countries. Conceptually, the relationship between outdoor time and accelerometry measures depends on what children are actually doing while outdoors and this may vary between countries due to factors such as culture, social norms and the broader PA transition. Interestingly, the two lower-middle-income countries included, Kenya and India, are experiencing a rapid PA transition wherein physically demanding occupations and active transportation are replaced by sedentary occupations and motorized transportation (7, 29, 30). There may be limited opportunities for outdoor PA in the cities of Bangalore and Nairobi where data collection occurred. For instance, of all the ISCOLE sites, Bangalore had the lowest prevalence of active transportation (27).

Greater parental education was associated with lower BMI Z-scores in high-income countries, but higher BMI Z-scores in lower-middle-income countries. Broyles and colleagues previously reported a similar association between household income and anthropometric indicators (7). These findings are consistent with the epidemiological transition model, which suggests that lifestyle changes associated with economic growth and urbanization in developing countries initially affect families who are relatively well-off (29).

Despite the significant relationships with more PA and less SED, outdoor time was not associated with BMI z-scores. Other cross-sectional analyses have shown inconsistent relationships between outdoor time and body composition indicators with some showing no associations (9, 26, 35) and some showing beneficial effect of outdoor time (24, 38). In contrast, results from a longitudinal study indicated that Australian 10- to 12-year-olds who spent more time outdoors were less likely to be overweight after three years of follow-up (9). Similarly, a study of preschoolers in the United States found that, over one year, outdoor play was associated with more favourable changes in BMI and a reduced risk of obesity (1). While the effect of spending more time outdoors on energy expenditure may be small, it could add up over time in the absence of compensatory changes in PA or diet. In ISCOLE, diet was measured with a food frequency questionnaire which does not allow us to quantify energy intake precisely. Nevertheless, Chaput and colleagues (8) reported that children who spend more time outdoors had higher scores for the consumption of “healthy foods” (e.g., vegetables, fruit, whole grains, low-fat milk, etc.), but consumption of “unhealthy foods” (fast food, hamburgers, soft drinks, sweets, fried food, etc.) did not vary according to outdoor time. In a sensitivity analysis, we included these two diet scores in the models examining the effect of outdoor time on BMI, but our results were unchanged (data not shown). Given the inconclusive evidence, future studies should clarify the relationship between outdoor time and weight status.

We observed that girls spent significantly less time outdoors and were less active and more sedentary than boys. These findings are consistent with previous studies of outdoor time (9, 25) and with population-based studies of PA and SED (18). Gender studies suggest that parents may perceive girls to be more vulnerable than boys (19, 43), and as a result, they may impose more restrictions on girls' independent mobility which may partly explain why girls spend less time outdoors. Yet, previous research suggests that girls can achieve similar levels of independence as boys by traveling outdoors in groups (6). A neighborhood's collective efficacy and additional daylight could be other enablers of girls' PA as suggested by our observation that these variables were positively associated with MVPA in girls, but not in boys. Kimbro and colleagues (24) also observed that collective efficacy was associated with more outdoor time and less TV time among children in the United States. Neighborhoods with greater collective efficacy could help alleviate parental safety concerns, potentially encouraging more outdoor time and PA. When stratifying by country income status, we found that collective efficacy was associated with higher MVPA only in high-income countries. Previous research in developing countries suggest that individuals may be active in unfavorable environments by necessity rather than by choice, and our findings may reflect that (33).

We observed that, independent of temperature, additional daylight was associated with higher MVPA in girls. This association was only significant in high-income countries, which generally experience greater seasonal variations in daylight. While the amount of daylight is not modifiable, previous research suggests that daylight saving time is associated with increased PA, particularly in the late afternoon and evening (16). Interestingly, mean daily temperature was not associated with MVPA. The relationship between temperature and MVPA may be curvilinear (i.e., in the form of an inverted U), as suggested in a previous analysis of Australian and Canadian data (28). Nevertheless, we did find that higher temperature was associated with slightly more LPA in both genders and with less SED in girls. When stratifying by country income, different climate variables were associated with LPA and SED. However, given the limited variability in climate variables when stratified by country income status, these findings should be interpreted cautiously.

Limitations and strengths. The main study limitation is the cross-sectional design which precludes causal inference. In addition, reports of outdoor time may be subject to social desirability and recall biases, and the test-retest reliability and validity of the questions used to assess outdoor time is unknown. Yet, inaccuracies in reports of outdoor time (i.e., random error) could attenuate the effect sizes for the relationship between outdoor time and accelerometry measures. Limited data pertaining to the psychometric properties of methods to assess outdoor time are available in the extant literature (4), underscoring a clear need for future research. In the ISCOLE Diet and Lifestyle Questionnaire (21), participants were asked to report their activities in the "last week", so they may have reported their outdoor time in the week before they wore the accelerometer, which would likely bias our results towards the null hypothesis. Our measure of outdoor time does not provide contextual information about the activities that children did while outdoors, which may include play, sport, transportation, and sedentary activities. Finally, as in previous studies examining the relationship between outdoor time and anthropometric variables (1, 9, 26, 35, 38), we did not have a measure of total energy intake.

In contrast, the large sample size and the objective measures of PA, SED and BMI Z-scores are major study strengths. Unlike previous multi-country studies on childhood obesity and PA, which focused on high-income countries, ISCOLE included 12 countries at different stages of development representing all geographical regions of the world (21). Furthermore, our analyses included many potential covariates that have seldom been considered in previous studies on this topic.

Conclusion

Our study extends previous research by showing consistent positive associations between outdoor time and objective measures of MVPA, LPA and negative associations with SED in a large sample of boys and girls. Furthermore, although effect sizes were small, these relationships were independent of parental education, climate and neighborhood variables. However, we noted that the effect sizes were weaker in lower-middle-income countries, suggesting that the relationship between outdoor time and accelerometry measures might be context-dependent. This underscores a need for future studies examining the relationship between outdoor time and measures of PA and SED in developing countries where less evidence is currently available.

Given the consistency of the epidemiological evidence that more time spent outdoors is associated with higher PA in high-income countries (9, 17, 25, 26, 35, 38), researchers, practitioners, and other stakeholders should promote increased opportunities for children to spend time outdoors, and examine whether this leads to an increase in PA. Future research should also investigate the correlates of outdoor time to inform interventions, especially in low- and middle-income countries where such research is lacking. Finally, there remains a need for validating existing measures of outdoor time (4).

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Table 1: Descriptive statistics for child, household, neighborhood and country characteristics from the 12-country International Study of Childhood Obesity, Lifestyle and the Environment, 2011-2013.

Geographic Region	Africa		Americas				Europe			South East Asia	Western Pacific	
Country (site)	**Kenya (Nairobi)**	**South Africa (Cape Town)**	**Brazil (Sao Paulo)**	**Colombia (Bogota)**	**Canada (Ottawa)**	**US (Baton Rouge)**	**Finland (Helsinki)**	**Portugal (Porto)**	**UK (Bath)**	**India (Bangalore)**	**China (Tianjin)**	**Australia (Adelaide)**
World Bank Ranking (income)	**Lower-middle**	**Upper-Middle**	**Upper-Middle**	**Upper-Middle**	**High**	**High**	**High**	**High**	**High**	**Lower-Middle**	**Upper-Middle**	**High**
Child Level Characteristics	501	460	467	857	523	466	504	679	478	553	500	490
Age (years)	10.2	10.2	10.5	10.5	10.5	9.9	10.5	10.4	10.9	10.4	9.9	10.7
Sex - *n* (%)												
Boys	233 (47)	181 (39)	225(48)	422 (49)	217 (41)	191(41)	235 (47)	302 (44)	211 (44)	254 (46)	260 (52)	225 (46)
Girls	268 (53)	279 (61)	242 (52)	435 (51)	306 (59)	275(59)	269 (53)	377 (56)	267 (56)	299 (54)	240 (48)	265 (54)
BMI Categories - *n* (%)												
Underweight	19 (4)	11 (2)	10 (2)	13 (2)	2 (0)	2 (0)	8 (2)	2 (0)	4 (1)	26 (5)	13 (3)	4 (1)
Normal weight	383 (76)	323 (70)	249 (53)	646 (75)	360 (69)	284(61)	376 (75)	360 (53)	331 (69)	346 (63)	279 (56)	303 (62)
Overweight	66 (13)	74 (16)	107 (23)	149 (17)	98 (19)	98(21)	93 (18)	200 (29)	99 (21)	121 (22)	85 (17)	133 (27)
Obese	33 (7)	52 (11)	101 (22)	49 (6)	63 (12)	82(18)	27 (5)	117 (17)	44 (9)	60 (11)	123 (25)	50 (10)
Daily Minutes of - mean (SD)												
Sedentary time	495 (66)	487 (65)	500 (69)	500 (67)	511 (63)	520 (62)	530 (68)	552 (62)	497 (60)	516 (67)	565 (68)	477 (6)
LPA	330 (52)	325 (53)	337 (53)	333 (49)	305 (45)	314 (51)	293 (44)	302 (50)	285 (46)	340 (50)	293 (54)	311 (48)
MVPA	72 (31)	65 (25)	59 (26)	68 (25)	59 (19)	50 (19)	71 (26)	56(22)	63 (22)	49 (21)	45 (16)	65 (23)
Total reported outdoor time score	3.0 (1.6)	3.7(1.9)	3.4 (1.9)	2.2 (0.9)	2.0 (1.3)	2.7(1.5)	2.9 (1.5)	1.8 (0.9)	2.6 (1.2)	2.3 (1.1)	1.9 (1.1)	2.6 (1.3)
Screen time score	2.4 (1.7)	3.1 (2.1)	3.7 (2.3)	2.9 (1.5)	2.5 (1.9)	3.2 (2.3)	2.8 (1.7)	2.3 (1.5)	2.9 (1.7)	1.8 (1.3)	1.9 (1.7)	2.8 (1.8)
Accumulate ≥ 60 min/day of MVPA - *n* (%)	287 (57.3)	238 (51.7)	204 (43.7)	509 (59.4)	226 (43.2)	122 (26.2)	316 (62.7)	249 (36.7)	243 (50.8)	140 (25.3)	79 (15.8)	268 (54.7)
Household Characteristics												
Highest Parental Education – *n* (%)	500	396	433	856	517	459	470	615	430	546	497	478
Did not complete high school	72 (14)	187 (47)	103 (24)	263 (31)	10 (2)	25 (5)	13 (3)	280 (46)	13 (3)	28 (5)	166 (33)	54 (11)
Completed high school / Some college	229 (46)	154 (39)	233 (54)	439 (51)	136 (26)	188 (41)	259 (55)	208 (34)	217 (50)	119 (22)	223 (45)	224 (47)
Bachelor's degree or Post-graduate degree	199 (40)	55 (14)	97 (22)	154 (18)	371 (72)	246 (54)	198 (42)	127 (21)	200 (47)	399 (73)	108 (22)	200 (42)
Neighborhood Characteristics - *n*	496	396	429	857	517	452	466	614	430	545	500	479
Collective efficacy score	3.4 (0.8)	3.4 (0.8)	3.2 (0.6)	3.4 (0.8)	3.8 (0.7)	3.7 (0.8)	3.7 (0.7)	3.5 (0.7)	3.7 (0.7)	3.5 (0.7)	3.8 (0.6)	3.5 (0.7)
Accessibility to neighborhood recreation facilities score	4.2 (0.7)	4.0 (0.9)	3.7 (0.8)	3.3 (0.6)	2.5 (0.8)	3.8 (0.9)	2.5 (0.8)	3.9 (0.8)	3.1 (0.7)	3.8 (0.8)	3.6 (0.8)	3.1 (0.9)
Country Site Characteristics												
Latitude (degrees)	1˚ 25'S	33˚ 55'S	23˚ 31'S	4˚ 32'N	45˚ 24'N	30˚ 27'N	57˚ 9'N	41˚ 9'N	51˚26'N	12˚ 59'N	39˚ 8'N	34˚ 55'S
Mean daylight hours	12:06	12:08	12:07	12:06	12:10	12:07	12:21	12:09	12:13	12:06	12:08	12:08
Mean daily temperature	17.7°C	16.6°C	19.3°C	13.3°C	6.0°C	19.8°C	4.8°C	14.5°C	10°C	24.1°C	12°C	16.4°C
Yearly temperature variation	9°C - 30°C	4°C - 31°C	8°C - 32°C	2°C - 22°C	-24 - 31°C	-2°C - 35°C	-20°C - 27°C	2°C - 30°C	3°C - 20°C	16°C - 34°C	-4°C - 27°C	7°C - 29°C
Annual precipitation (mm)	925.0	475.0	1454.8	824.0	869.5	1546.7	688.0	1267.0	1128.0	905.0	600.0	447.5

Note: World Bank Ranking reflect the situation of each country at the time of data collection. BMI = Body Mass Index; LPA = Light-intensity physical activity; MVPA = Moderate-to-Vigorous Physical Activity; US = United States; UK = United Kingdom.

Table 2. Relationship between outdoor time and minutes of daily moderate to vigorous physical activity among participants in the 12-country International Study of Childhood Obesity, Lifestyle and the Environment, 2011-2013.

Variable	Model 1			Model 2			Model 3		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Boys									
Intercept	**69.68**	**2.43**	**<0.01**	**67.35**	**2.63**	**<0.01**	**67.09**	**2.61**	**<0.01**
Outdoor time (hours/day)	**2.87**	**0.32**	**<0.01**	**2.73**	**0.33**	**<0.01**	**2.76**	**0.33**	**<0.01**
Daylight (min/day)	-	-	-	0.02	0.01	0.03	0.02	0.01	0.03
Mean daily temperature (degrees)	-	-	-	-0.08	0.20	0.69	-0.08	0.20	0.70
Annual minimum temperature (degrees)	-	-	-	-0.18	0.31	0.58	-0.13	0.31	0.68
Annual maximum temperature (degrees)	-	-	-	-0.84	0.62	0.22	-0.80	0.62	0.24
Monthly precipitation (mm)	-	-	-	-0.01	0.01	0.46	-0.01	0.01	0.52
Latitude (degrees)	-	-	-	-0.08	0.11	0.46	-0.08	0.11	0.49
Parental education (< high school)	-	-	-	**8.03**	**1.48**	**<0.01**	**8.30**	**1.50**	**<0.01**
Parental education (high school/some college)	-	-	-	2.33	1.08	0.03	2.57	1.09	0.02
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	-1.18	0.56	0.04
Collective efficacy score	-	-	-	-	-	-	0.40	0.63	0.52
*Deviance statistic (model fit)**	26992.57	-	<0.01	25705.64	-	<0.01	25372.67	-	<0.01
Girls									
Intercept	**53.01**	**2.19**	**<0.01**	**51.24**	**2.07**	**<0.01**	**51.02**	**2.06**	**<0.01**
Outdoor time (hours/day)	**1.33**	**0.24**	**<0.01**	**1.35**	**0.24**	**<0.01**	**1.39**	**0.24**	**<0.01**
Daylight (min/day)	-	-	-	**0.02**	**0.01**	**<0.01**	**0.02**	**0.01**	**<0.01**
Mean daily temperature (degrees)	-	-	-	0.08	0.17	0.62	0.08	0.17	0.63
Annual minimum temperature (degrees)	-	-	-	-0.37	0.25	0.17	-0.37	0.25	0.17
Annual maximum temperature (degrees)	-	-	-	-0.99	0.50	0.08	-0.98	0.49	0.08
Monthly precipitation (mm)	-	-	-	0.00	0.01	0.83	0.00	0.01	0.78
Latitude (degrees)	-	-	-	-0.10	0.08	0.26	-0.11	0.08	0.25
Parental education (< high school)	-	-	-	**5.81**	**1.04**	**<0.01**	**6.43**	**1.05**	**<0.01**
Parental education (high school/some college)	-	-	-	1.17	0.75	0.12	1.46	0.76	0.05
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	-0.09	0.39	0.82
Collective efficacy score	-	-	-	-	-	-	**1.12**	**0.44**	**0.01**
*Deviance statistic (model fit)**	30270.50	-	<0.01	28976.04	-	<0.01	28445.59	-	<0.01

Note: regression coefficients represent the effect of each additional hour of outdoor time per day. Bold text indicates statistical significance. Model 1 is unadjusted. Model 2 is adjusted for climate variables and parental education. Model 3 is adjusted for climate variables, parental education, and the accessibility to neighborhood recreation facilities and collective efficacy scales. School-level intra-class correlation coefficient (ICC): boys = 0.123; girls = 0.161. Site-level ICC: boys = 0.185; girls = 0.291. *Improvement in fit for Model 1 was assessed by comparing its deviance to that of an “empty model” without fixed effects.

Table 3. Relationship between outdoor time and minutes of daily light physical activity among participants in the 12-country International Study of Childhood Obesity, Lifestyle and the Environment, 2011-2013.

Variable	Model 1			Model 2			Model 3		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Boys									
Intercept	**318.02**	**5.28**	**<0.01**	**313.86**	**4.41**	**<0.01**	**313.64**	**4.47**	**<0.01**
Outdoor time (hours/day)	**2.42**	**0.66**	**<0.01**	**1.96**	**0.68**	**<0.01**	**1.95**	**0.69**	**<0.01**
Daylight (min/day)	-	-	-	0.01	0.01	0.49	0.01	0.01	0.39
Mean daily temperature (degrees)	-	-	-	**0.91**	**0.33**	**<0.01**	**0.86**	**0.33**	**<0.01**
Annual minimum temperature (degrees)	-	-	-	-0.04	0.52	0.94	0.00	0.52	0.99
Annual maximum temperature (degrees)	-	-	-	1.29	1.03	0.25	1.30	1.04	0.25
Monthly precipitation (mm)	-	-	-	-0.02	0.02	0.38	-0.02	0.02	0.45
Latitude (degrees)	-	-	-	-0.13	0.18	0.47	-0.13	0.18	0.48
Parental education (< high school)	-	-	-	7.13	3.02	0.02	**7.88**	**3.08**	**0.01**
Parental education (high school/some college)	-	-	-	5.09	2.22	0.02	5.35	2.26	0.02
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	0.11	1.17	0.92
Collective efficacy score	-	-	-	-	-	-	1.32	1.33	0.32
*Deviance statistic (model fit)**	31278.20	-	<0.01	29836.87	-	<0.001	29458.08	-	<0.01
Girls									
Intercept	**311.21**	**5.82**	**<0.01**	**305.91**	**4.70**	**<0.01**			**<0.01**
Outdoor time (hours/day)	**2.45**	**0.66**	**<0.01**	**2.32**	**0.67**	**<0.01**	**2.29**	**0.68**	**<0.01**
Daylight (min/day)	-	-	-	0.01	0.01	0.26	0.01	0.01	0.24
Mean daily temperature (degrees)	-	-	-	**1.20**	**0.33**	**<0.01**	**1.21**	**0.33**	**<0.01**
Annual minimum temperature (degrees)	-	-	-	-0.15	0.55	0.80	-0.25	0.55	0.67
Annual maximum temperature (degrees)	-	-	-	1.08	1.11	0.36	0.94	1.12	0.43
Monthly precipitation (mm)	-	-	-	-0.04	0.02	0.07	-0.04	0.02	0.08
Latitude (degrees)	-	-	-	-0.18	0.19	0.37	-0.19	0.19	0.35
Parental education (< high school)	-	-	-	**8.06**	**2.86**	**<0.01**	**8.12**	**2.91**	**<0.01**
Parental education (high school/some college)	-	-	-	**6.30**	**2.10**	**<0.01**	**6.37**	**2.12**	**<0.01**
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	2.21	1.11	0.05
Collective efficacy score	-	-	-	-	-	-	0.58	1.25	0.64
*Deviance statistic (model fit)**	37489.01	-	<0.01	35919.48	-	<0.01	35297.31	-	<0.01

Note: regression coefficients represent the effect of each additional hour of outdoor time per day. Bold text indicates statistical significance. Model 1 is unadjusted. Model 2 is adjusted for climate variables and parental education. Model 3 is adjusted for climate variables, parental education, and the accessibility to neighborhood recreation facilities and collective efficacy scales. School-level intra-class correlation coefficient (ICC): boys = 0.130; girls = 0.151. Site-level ICC: boys = 0.083; girls = 0.104. *Improvement in fit for Model 1 was assessed by comparing its deviance to that of an “empty model” without fixed effects.

Table 4. Relationship between outdoor time and minutes of daily sedentary time among participants in the 12-country International Study of Childhood Obesity, Lifestyle and the Environment, 2011-2013.

Variable	Model 1			Model 3			Model 4		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Boys									
Intercept	**503.57**	**6.39**	**<0.01**	**508.62**	**6.29**	**<0.01**	**509.29**	**6.18**	**<0.01**
Outdoor time (hours/day)	**-6.40**	**0.90**	**<0.01**	**-6.27**	**0.92**	**<0.01**	**-6.26**	**0.93**	**<0.01**
Daylight (min/day)	-	-	-	0.00	0.02	0.88	0.00	0.02	0.82
Mean daily temperature (degrees)	-	-	-	-0.12	0.45	0.79	-0.09	0.45	0.84
Annual minimum temperature (degrees)	-	-	-	-0.08	0.73	0.92	-0.20	0.72	0.79
Annual maximum temperature (degrees)	-	-	-	0.89	1.47	0.56	0.76	1.44	0.61
Monthly precipitation (mm)	-	-	-	0.02	0.03	0.63	0.01	0.03	0.74
Latitude (degrees)	-	-	-	0.42	0.25	0.14	0.41	0.25	0.14
Parental education (< high school)	-	-	-	**-13.57**	**4.11**	**<0.01**	**-14.70**	**4.19**	**<0.01**
Parental education (high school/some college)	-	-	-	-5.50	3.03	0.07	-5.89	3.07	0.06
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	2.88	1.60	0.07
Collective efficacy score	-	-	-	-	-	-	-0.63	1.81	0.73
*Deviance statistic (model fit)**	33111.20	-	<0.01	31571.99	-	<0.01	31164.93	-	<0.01
Girls									
Intercept	**518.20**	**7.80**	**<0.01**	**522.13**	**8.00**	**<0.01**	**522.45**	**8.14**	**<0.01**
Outdoor time (hours/day)	**-4.99**	**0.81**	**<0.01**	**-4.85**	**0.83**	**<0.01**	**-5.10**	**0.84**	**<0.01**
Daylight (min/day)	-	-	-	-0.01	0.01	0.60	0.00	0.01	0.61
Mean daily temperature (degrees)	-	-	-	**-1.25**	**0.42**	**<0.01**	**-1.26**	**0.42**	**<0.01**
Annual minimum temperature (degrees)	-	-	-	1.07	0.93	0.28	1.23	0.94	0.23
Annual maximum temperature (degrees)	-	-	-	1.95	1.92	0.34	2.17	1.95	0.30
Monthly precipitation (mm)	-	-	-	0.04	0.03	0.16	0.04	0.03	0.16
Latitude (degrees)	-	-	-	0.56	0.33	0.13	0.58	0.33	0.12
Parental education (< high school)	-	-	-	**-10.17**	**3.53**	**<0.01**	**-10.39**	**3.58**	**<0.01**
Parental education (high school/some college)	-	-	-	-2.76	2.58	0.28	-3.15	2.60	0.23
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	**-3.54**	**1.36**	**<0.01**
Collective efficacy score	-	-	-	-	-	-	-2.01	1.53	0.19
*Deviance statistic (model fit)**	38917.98	-	<0.01	37289.58	-	<0.01	36630.93	-	<0.01

Note: regression coefficients represent the effect of each additional hour of outdoor time per day. Bold text indicates statistical significance. Model 1 is unadjusted. Model 2 is adjusted for climate variables and parental education. Model 3 is adjusted for climate variables, parental education, and the accessibility to neighborhood recreation facilities and collective efficacy scales. School-level intra-class correlation coefficient (ICC): boys = 0.115; girls = 0.188. Site-level ICC: boys = 0.077; girls = 0.120. *Improvement in fit for Model 1 was assessed by comparing its deviance to that of an "empty model" without fixed effects.

Table 5. Relationship between outdoor time and BMI Z-scores among participants in the 12-country International Study of Childhood Obesity, Lifestyle and the Environment, 2011-2013.

Variable	Model 1			Model 3			Model 4		
	Estimate	SE	p	Estimate	SE	p	Estimate	SE	p
Boys									
Intercept	**0.55**	**0.10**	**<0.01**	**0.51**	**0.12**	**<0.01**	**0.51**	**0.12**	**<0.01**
Outdoor time (hours/day)	0.02	0.02	0.31	0.02	0.02	0.32	0.01	0.02	0.50
Daylight (min/day)	-	-	-	0.00	0.00	0.62	0.00	0.00	0.58
Mean daily temperature (degrees)	-	-	-	0.00	0.01	0.58	0.00	0.01	0.57
Annual minimum temperature (degrees)	-	-	-	0.00	0.01	0.78	-0.01	0.01	0.70
Annual maximum temperature (degrees)	-	-	-	0.01	0.03	0.64	0.01	0.03	0.69
Monthly precipitation (mm)	-	-	-	0.00	0.00	0.11	0.00	0.00	0.13
Latitude (degrees)	-	-	-	0.00	0.01	0.74	0.00	0.01	0.80
Parental education (< high school)	-	-	-	0.02	0.08	0.83	0.03	0.08	0.72
Parental education (high school/some college)	-	-	-	0.06	0.06	0.32	0.06	0.06	0.34
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	0.04	0.03	0.23
Collective efficacy score	-	-	-	-	-	-	0.02	0.04	0.66
*Deviance statistic (model fit)**	9824.29	-	1.00	9423.06	-	<0.01	9316.15	-	<0.01
Girls									
Intercept	**0.39**	**0.08**	**<0.01**	**0.35**	**0.09**	**<0.01**	**0.35**	**0.09**	**<0.01**
Outdoor time (hours/day)	0.01	0.02	0.42	0.01	0.02	0.48	0.01	0.02	0.56
Daylight (min/day)	-	-	-	0.00	0.00	0.24	0.00	0.00	0.21
Mean daily temperature (degrees)	-	-	-	0.00	0.01	0.79	0.00	0.01	0.72
Annual minimum temperature (degrees)	-	-	-	0.00	0.01	0.69	0.00	0.01	0.72
Annual maximum temperature (degrees)	-	-	-	0.03	0.02	0.20	0.03	0.02	0.22
Monthly precipitation (mm)	-	-	-	0.00	0.00	0.34	0.00	0.00	0.39
Latitude (degrees)	-	-	-	0.00	0.00	0.58	0.00	0.00	0.54
Parental education (< high school)	-	-	-	0.04	0.07	0.59	0.01	0.07	0.88
Parental education (high school/some college)	-	-	-	0.08	0.05	0.10	0.07	0.05	0.17
Parental education (≥ undergraduate degree)	-	-	-	Ref	-	-	Ref	-	-
Accessibility to neighborhood recreation facilities score	-	-	-	-	-	-	0.03	0.03	0.29
Collective efficacy score	-	-	-	-	-	-	-0.05	0.03	0.07
*Deviance statistic (model fit)**	11200.64	-	1.00	10816.14	-	<0.01	10603.97	-	<0.01

Note: BMI Z-scores are based on the World Health Organization growth references (de Onis et al., 2007). Note: regression coefficients represent the effect of each additional hour of outdoor time per day. Bold text indicates statistical significance. Model 1 is unadjusted. Model 2 is adjusted for climate variables and parental education. Model 3 is adjusted for climate variables, parental education, and the accessibility to neighborhood recreation facilities and collective efficacy scales. School-level intra-class correlation coefficient (ICC): boys = 0.067; girls = 0.044. Site-level ICC: boys = 0.019; girls = 0.034. *Improvement in fit for Model 1 was assessed by comparing its deviance to that of an “empty model” without fixed effects.