# Joint associations between weekday and weekend physical activity or sedentary time and childhood obesity

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**ABSTRACT**

**Objective** To evaluate the single and joint associations of objectively measured moderate-to-vigorous physical activity (MVPA) and sedentary time on week and weekend days with obesity in children from 12 countries across all inhabited continents.

**Methods** A multinational, 12-country cross-sectional study of 5,779 children aged 9-11 years was conducted. Time spent in MVPA and sedentary behaviors was assessed by waist-worn accelerometry. Logistic regression was used to examine the independent and joint associations of MVPA and sedentary time on weekdays and weekend with the odds of obesity.

**Results** After adjustment for all confounding factors, the odds ratios (ORs) of childhood obesity were the highest among children with a low level of MVPA on both weekdays and weekend (OR 4.67), high among children with a high level of MVPA on weekdays and a low level of MVPA on weekend (OR 1.99) and among children with a low level of MVPA on weekdays and a high levels of MVPA on weekend (OR 2.20), compared to those with a high level of MVPA on both weekdays and weekend. Similarly, the ORs of childhood obesity were significantly higher among children with a high level of sedentary time on both weekdays and weekend (OR 1.87) compared with those with a low level of sedentary time on both weekdays and weekend.

**Conclusions** Lower levels of MVPA or higher levels of sedentary time on either weekdays or weekend were positively associated with increased odds of obesity in 9–11 years old children in 12 countries.

**Keywords:** Children; Moderate-to-vigorous physical activity; Obesity; Accelerometry

## INTRODUCTION

Global physical activity guidelines call for a minimum of 60 minutes per day of moderate-to-vigorous physical activity (MVPA) and reductions in sedentary time for health benefits in school-aged children.[1] Physical inactivity[2] and obesity are classified as the fourth and fifth leading causes of global mortality, and two of the greatest health challenges and determinants for various chronic diseases.[3, 4] Levels of physical inactivity are rising in many countries with major implications for the general health of people worldwide and for the prevalence of non-communicable diseases such as cardiovascular disease, diabetes and cancer and their risk factors such as raised blood pressure, raised blood sugar, and obesity.[5]

MVPA is a key determinant of childhood obesity and health disparities throughout the life course. The available evidence indicates that lower levels of MVPA are associated with higher odds of obesity in children, independent of sedentary behavior.[6] Children with overweight/obesity accumulated significantly fewer minutes of MVPA (average weekday and weekends) as compared to normal/underweight children.[7] Children's physical activity (PA) behaviors vary in bout frequency, duration, and intensity depending on the setting where they occur. Several studies have suggested that PA varies considerably throughout the week, such as lower PA and sedentary time during the weekend and higher PA and sedentary during weekdays among young adults and children.[8-11] Previous studies have focused mainly on the association between PA both in school and out of school and the risk of obesity,[6, 12] and found that the risk of obesity is higher when children are out of school than when they are in school, especially during summer school vacation .[13-15] There are limited data on the association of

weekdays and weekend PA with the risk of obesity. Furthermore, the association between PA and the risk of obesity among countries with different economic development levels is unclear. Therefore, the aim of the present study was to examine the joint and separate associations of objectively measured MVPA or sedentary time on weekdays and weekend days with the odds of obesity in 9-11 years old children from 12 countries.

## METHODS

### Study Design

ISCOLE is a multi-national cross-sectional study conducted in 12 countries (Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, United Kingdom, United States) from five major geographic regions of the world (Europe, Africa, the Americas, South-East Asia and the Western Pacific). According to World Bank classifications, ISCOLE countries span low income (Kenya), lower-middle income (India), upper-middle income (Brazil, China, Colombia, South Africa) and high-income economies (Australia, Canada, Finland, Portugal, USA, United Kingdom). Further, the ISCOLE countries also span a continuum of the Human Development Index (HDI), which is a composite score based on life expectancy, gross national income, literacy and school participation.[16] These countries were divided into low-to-high groups according to the Human Development Index (low: Kenya; medium: Brazil, Colombia, China, India, South Africa; high: Australia, Canada, Finland, Portugal, United Kingdom, United States).[16] One study compared data collected in ISCOLE to data collected via nationally representative studies in all ISCOLE study sites.[17] This study reported that the data from the ISCOLE study appear to be relatively similar to the

country-level data, and there were no systematic differences across countries or variables.

The Institutional Review Board at the Pennington Biomedical Research Center (coordinating center) approved the overarching protocol, and the Institutional/Ethical Review Boards at each participating institution also approved the local protocol. Written informed consent was obtained from parents or legal guardians, and child assent was also obtained as required by local Institutional/Ethical Review Boards before participation in the study. The standardization of the study protocol across sites, a rigorous system of training and certification of study personnel, the use of a web-based data entry system, and centralized data management and analysis at the coordinating center ensured the quality of data collected.[16] A detailed account of the study protocol has been published elsewhere.[16]

**Participants**

A total of 7,372 children aged 9-11 years participated in ISCOLE, of whom 5,779 remained in the analytical sample for the present study after excluding participants who did not have valid data/information on accelerometry of MVPA (n = 919), sleep time (n = 395), diet scores (n = 127), or other information (sex, BMI, highest parental education, n = 152). Participants who were excluded from the present analysis did not differ in BMI z-scores, but the excluded sample had a higher proportion of boys (51.5%) than those who were included in the analysis. Data were collected from September 2011 through December 2013.

**Accelerometry**

Time spent in MVPA and sedentary behavior was obtained from a 24-hour, waist worn accelerometer. An Actigraph GT3X+ accelerometer (ActiGraph, LLC, Pensacola, FL, USA) was worn at the waist on an elasticized belt on the right mid-axillary line. Participants were encouraged to wear the accelerometer for 24 hours per day (removing only for water-related activities) on at least 7 days (plus an initial familiarization day and the morning of the final day), including weekend days. The minimal amount of accelerometer data that was considered acceptable for inclusion in the sample was 4 days with at least 10 hours of wear time per day, including at least one weekend day. Nocturnal sleep duration was estimated from the accelerometer data using a fully automated algorithm for 24-h waist-worn accelerometers that was validated for ISCOLE.[18, 19] The weekly total sleep time averages were calculated using only days where valid sleep was accumulated (total sleep-period time ≥160 min) and only for participants with at least 3 nights of valid sleep, including one weekend day.[20] After exclusion of the total sleep episode time and non-wear time (any sequence of at least 20 consecutive minutes of zero activity counts), MVPA was defined as all activity ≥574 counts per 15 seconds, and sedentary time was defined as all movement <25 counts per 15 seconds.[21] On the basis of the average MET (Metabolite equivalent) level of the study, some activities such as brisk walking, treadmill walking, basketball, and running were considered as MVPA.[21] High level of MVPA was defined as the average of MVPA ≥60 minutes per day, and high level of sedentary was defined as the average of sedentary time ≥ 482 minutes per day.[22-26] MVPA or sedentary time on weekdays was calculated using the mean duration of MVPA or sedentary time per weekday, and MVPA or sedentary time on weekend was calculated using the mean duration of MVPA or sedentary time per weekend

day.

**Anthropometry**

Height and weight were measured using standard procedures across all study sites. Height was measured without shoes using a Seca 213 portable stadiometer (SECA, Hamburg, Germany), with the participant's head in the Frankfurt plane. Weight was measured using a portable Tanita SC-240 Body Composition Analyzer (Arlington Heights, IL, USA) after all outer clothing, heavy pocket items, shoes and socks were removed. Two measurements were obtained, and the average was used in the analysis (a third measurement was obtained if the first two measurements were >0.5 cm or ≥0.5 kg apart for height and weight, respectively, and the average of the two closest measurements was used in the analysis). Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters. BMI z-scores were computed using age- and sex-specific reference data from the World Health Organization.[27] Participants were classified as obese (BMI-for-age z-score >+2 SD) or non-obese (BMI-for-age z-score ≤ +2 SD).

**Demographics and family health history**

A demographic and family health history questionnaire was completed by parents. The questionnaire collected information on the child's age, sex, and highest parental education. The highest parental education variable was computed based on the highest education level of the mother or father and categorized as 'less than high school', 'completed high school or some college', and 'completed a bachelor or postgraduate degree'. If one of the parents'

responses to this question was missing, the highest education level attained would be that of the other parent.[28]

**Dietary patterns**

A Food Frequency Questionnaire adapted from the Health Behaviour in School-aged Children Survey (HBSC)[29] was administered to all ISCOLE participants. The questionnaire asks the participants about their 'usual' consumption of 23 food categories, with response categories including 'never', 'less than once per week', 'once per week', '2-4 days per week', '5-6 days per week', 'once a day every day' and 'more than once a day'. Two diet scores which represented an 'unhealthy diet pattern' (with positive loadings for fast food, hamburgers, soft drinks, sweets, fried food, and so on) and a 'healthy diet pattern' (with positive loadings for vegetables, fruit, whole grains, low fat milk, and so on) were obtained using principal components analyses.[30]

**Statistical Analysis**

Means and standard deviations (SD) were computed for variables by study site and by sex for participants with complete measurements. Differences between boys and girls were determined using unpaired t-tests for continuous variables. Associations of MVPA or sedentary time on weekdays and weekend days with the odds of obesity were assessed by using multilevel logistic regression models. We defined child as Level 1, school as Level 2, and study site as Level 3. Study site and school were considered to have random effects. The analyses were adjusted for age, sex, highest parental education, unhealthy diet pattern scores,

healthy diet pattern scores, and sleeping time on weekdays and weekend days. The criterion for statistical significance was $p < 0.05$. All statistical analyses were performed with SPSS for Windows, version 21.0 (SPSS, IBM, USA) or SAS for Windows, version 9.4 (SAS Institute, Cary, NC, USA).

**RESULTS**

A total of 5,779 children (2,601 boys and 3,178 girls) were included in the present study. The descriptive characteristics of the study sample are provided in Tables 1 and 2. The mean (SD) age of the total sample was 10.4 (0.6) years, and the mean time spent in MVPA and sedentary behavior was 60.2 (24.9) minutes/day or 515.8 (67.9) minutes/day, respectively. The mean MVPA time ranged from 44.8 minutes/day in China to 72.1 minutes/day in Kenya and mean sedentary time ranged from 479.5 minutes/day in Australia to 569.4 minutes/day in China. The mean time spent in MVPA on weekdays and weekend days was 62.1 (25.9) minutes/day and 55.4 (31.9) minutes/day, respectively. Overall, 44.1% of children had an average of ≥60 minutes of MVPA per day, and 68.3% of children had an average of ≥ 482 minutes of sedentary per day. The overall prevalence of obesity was 12.1%, which ranged from 5.3% in Finland to 24.3% in China.

Table 3 presents the descriptive characteristics of boys and girls. Overall, boys and girls did not show significant differences in the mean values of weight and BMI. Boys had significantly greater mean values for BMI z-scores and spent more time in MVPA during weekdays (71.9 (27.0) minutes/day) and weekend days (64.1 (34.8) minutes/day) than girls

(weekdays, 54.1 (21.8) minutes/day; weekend days, 48.2 (27.4) minutes/day). Girls spent more time in sedentary during weekdays (Girls, 536.9 (70.6) minutes/day; Boys, 514.3 (73.1) minutes/day) and more time sleeping during weekdays and weekend days than boys.

We first analyzed the single association of MVPA or sedentary time during weekdays and weekend with the odds of childhood obesity (Table 4). After adjustment for age, sex, highest parental education, unhealthy diet pattern scores, healthy diet pattern scores, and sleeping time, odds ratios (ORs) for obesity were significantly higher among children with low levels of MVPA during weekdays (OR 2.92, 95% CI: 2.44-3.51) or weekend (OR 2.77, 95% CI: 2.28-3.38) compared with children with high levels of MVPA during weekdays or weekend, respectively. Similarly, the multivariable-adjusted ORs of obesity were significantly higher among children with high levels of sedentary behaviors during weekdays (OR 1.48, 95% CI: 1.21-1.80) or weekend (OR 1.44, 95% CI 1.21-1.71) compared with children with lows level of sedentary behaviors during weekdays or weekend, respectively.

Table 5 shows the joint association of MVPA or sedentary time during weekdays and weekend with the odds of obesity. In these analyses, the children were classified into four groups: high level of MVPA (reference group) or sedentary time during both weekdays and weekend (high-high), a high level of MVPA or sedentary time during weekday and a low level MVPA or sedentary time during weekend (high-low), a low level of MVPA or sedentary time during weekday and a high level MVPA or sedentary time during weekend (low-high), and low levels of MVPA or sedentary time (reference group) during both weekdays and

weekend (low-low). The odds ratios (ORs) for obesity were the highest among children at the low-low MVPA group (OR 4.67, 95% CI 3.66-5.97), higher among children at the low-high MVPA group (OR: 2.20, 95% CI: 1.54-3.14) and among children at the high-low MVPA group (OR 1.99, 95% CI 1.51-2.65) compared with children at the high-high MVPA group. There was no difference in OR for obesity between children at the high-low MVPA group and children at the low-high MVPA group (OR: 1.16, 95% CI: 0.81-1.65, *P*=0.427).

The odds of obesity was the highest among children at the high-high sedentary time group (OR 1.87, 95% CI 1.45-2.42), higher among children at the high-low sedentary time group (OR 1.43, 95% CI 1.09-1.87) and among children at the low-high sedentary time group (OR 1.46, 95% CI 1.02-2.08) compared with children at the low-low sedentary time group. There was no difference in OR for obesity between children at the high-low sedentary time group and children at the low-high sedentary time group (OR: 0.95, 95% CI: 0.67-1.35, *P*=0.777).

When stratified by the HDI, the inverse associations of MVPA during weekdays and weekend with the odds of obesity, and the positive associations of sedentary time during weekdays and weekend and the odds of obesity were still present in high, medium and low HDI countries with the exception of the association of sedentary time during weekdays and weekend with the odds of obesity in the low HDI countries, which were not significant.

## DISCUSSION

This study demonstrated that low levels of MVPA or high levels of sedentary behaviors

during weekdays and weekend were associated with higher odds of obesity in 9–11 year old children in 12 countries. In our study, more than half of children had low level of MVPA (55.9%) or high level of sedentary (68.3%) per day.

There are limited data on the association of weekday and weekend PA with childhood obesity. In the present study, children who had low levels of MVPA on both weekdays and weekend days showed 4.6-fold higher odds of obesity, and those who had a low level of MVPA on weekday and a high level of MVPA on weekend or those who had a high level of MVPA on weekday and a low level of MVPA on weekend showed about 2-hold higher odds of obesity, compared with children with high levels of MVPA on both weekdays and weekend days. We also found that a low of MVPA on either weekdays or weekend was associated with higher odds of obesity. Overall, only 44.1% of children met the guidelines for 60 minutes of MVPA per day in the 12 study sites. In addition, the mean time spent in MVPA on weekdays was significantly higher than that on weekend days in 9 of the 12 study sites, which is similar to the results of some previous studies.[8, 9] However, a cross-sectional survey showed opposite results that children aged 6–8 years in Hong Kong seemed to be more physically active during weekend days than weekdays.[31] Children usually sleep longer and get up later on weekend days, so they may spend less MVPA time during the weekend. Our study also showed that children had significantly longer night sleep time during weekend days than weekdays.

Previous studies assessing sedentary behaviors (i.e. watching television, movies, or playing

video games) with childhood obesity risk have found a positive correlation of sedentary behaviors with childhood weight status.[32, 33] Moreover, the study by Yen *et al.* found that higher BMI were associated with a high television viewing only in adolescents who exercised less than one hour a day.[32] Most studies reported weekend PA to be lower than on weekdays, but seldom have examined sedentary time during weekday and weekend days. Similar to MVPA findings, our study also found that children had significantly longer sedentary time during weekdays than weekend days. Longer sleep time or more family activities on weekend days may explain lower weekend MVPA and sedentary time. The writing while sitting in the chair was considered light activity.[21] The children spent more time sitting in class during weekdays, which may explain this observation. Moreover, the study by Moore *et al.* [34]found that Sunday was not only associated with reduced odds of meeting the recommendation for PA, but also with reduced odds of engaging in high levels of sedentary behavior. Similarly, children were most likely to meet recommendations for PA and engage in lower levels of sedentary behaviors on Saturdays. Although activities on weekends may be different among different countries, the results of our study found less MVPA and less sedentary time on weekends than weekdays in most countries in our samples. The current results suggest that the children should reduce the sedentary time during weekdays to meet the recommendation1 of 60 minutes of MVPA.

An observational study conducted by Drenowatz et al. examined the association between weekly PA patterns and weight changes in generally healthy young adults. Results from this work indicated that weekend behaviors appeared to be of particular importance even though

overall PA levels were similar between weekdays and weekend.[35] This study found that a 30-minute increase in vigorous physical activity (VPA) on Sundays was associated with a loss of 0.6 kg body weight or 0.6% body fat over a 1-year period, however, a 60-minute increase in sedentary time on weekend was associated with a 0.5% gain in body fat. These results suggest that weekend PA plays an important role in long-term weight management. For the youth, increasing MVPA and decreasing sedentary time daily for obesity prevention may be more effective than increasing VPA. So, in our study, we did not analyze the difference between VPA and MVP. The present study did not find any differences in odds for obesity between children with a high level of MVPA (sedentary time) on weekdays and a low level of MVPA (sedentary time) on weekend and those with a low level of MVPA (sedentary time) on weekdays and high levels of MVPA (sedentary time) on weekend. More effort to target interventions during both weekdays and weekends, such as in the family and community, appears important.

There are several strengths to the present study including the recruitment of a large multinational sample of children from low- to high-income countries across several regions of the world, the highly standardized measurement protocol, the use of direct measurements whenever possible and the rigorous quality-control program. In addition, our study assessed the single and joint associations of weekdays and weekend PA with the risk of obesity in 9–11 years old children. There are also a number of limitations to the present study. First, the cross-sectional study precludes us from making causal inferences. It is not known whether lower levels of physical activity are the cause or the consequence of obesity. Second, we

objectively assessed physical activity and sedentary time using accelerometry; however, a limitation of this approach is the inability to quantify some physical activities such as cycling and swimming. Third, food consumption was assessed using a 23-item Food Frequency Questionnaire (FFQ) in ISCOLE. However, dietary patterns on weekdays or on weekends have not been obtained. The potential difference in dietary factors between weekdays and weekends may still confound the study findings.

In conclusion, lower levels of MVPA and high levels of sedentary behaviors during weekdays and weekends were significantly associated with higher odds of obesity in 9–11 year old children in 12 countries. These children were more physically active or longer sedentary time on weekdays than on weekends. In light of the SDH,[36] consistent evidence demonstrates the structured environment of weekdays may help to protect children by regulating obesogenic behaviors, most likely through compulsory physical activity opportunities, restricting caloric intake, reducing screen time occasions, and regulating sleep schedules. Weekend days is emerging as the critical period where childhood obesity prevention efforts need to be focused. Adhering to public health recommendations for both PA and sedentary time is associated with better weight outcomes. Since children have more discretionary time during weekend days than weekdays, children should be encouraged to increase PA during weekend days, especially a high level of MVPA.

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**Table 1. Descriptive characteristics of participants stratified by study sites**

| Country (Site) | No. of participants | | | Mean (SD) | | | | % |
|---|---|---|---|---|---|---|---|---|
| | Total | Boys | Girls | Age (years) | Height (cm) | Weight (kg) | Body mass index (kg/m$^2$) | Obesity (%)[a] |
| Australia (Adelaide) | 433 | 202 | 231 | 10.7 (0.4) | 144.7 (7.3) | 39.8 (9.4) | 18.8 (3.3) | 10.6 |
| Brazil (Sao Paulo) | 435 | 211 | 224 | 10.5 (0.5) | 143.8 (7.4) | 41.3 (11.9) | 19.8 (4.5) | 21.8 |
| Canada (Ottawa) | 496 | 203 | 293 | 10.5 (0.4) | 143.9 (7.1) | 38.2 (9.3) | 18.3 (3.4) | 12.1 |
| China (Tianjin) | 460 | 238 | 223 | 9.9 (0.5) | 141.3 (7.1) | 38.3 (11.0) | 18.9 (4.1) | 24.3 |
| Colombia (Bogota) | 820 | 403 | 417 | 10.5 (0.6) | 137.7 (7.0) | 33.6 (7.0) | 17.6 (2.5) | 5.6 |
| Finland (Helsinki, Espoo & Vantaa) | 433 | 196 | 237 | 10.5 (0.4) | 144.4 (6.5) | 37.3 (7.4) | 17.8 (2.6) | 5.3 |
| India (Bangalore) | 526 | 237 | 289 | 10.4 (0.5) | 141.2 (7.0) | 36.0 (8.6) | 17.9 (3.3) | 10.8 |
| Kenya (Nairobi) | 453 | 206 | 247 | 10.2 (0.7) | 139.0 (7.4) | 33.5 (8.3) | 17.2 (3.1) | 6.4 |
| Portugal (Porto) | 563 | 234 | 329 | 10.4 (0.3) | 143.3 (6.9) | 39.9 (9.0) | 19.3 (3.3) | 15.6 |
| South Africa (Cape Town) | 365 | 141 | 224 | 10.2 (0.7) | 138.6 (7.5) | 34.8 (9.2) | 17.9 (3.6) | 10.7 |
| United Kingdom (Bath & NE Somerset) | 374 | 160 | 214 | 10.9 (0.4) | 145.3 (7.2) | 39.2 (8.6) | 18.4 (3.0) | 8.8 |
| United States (Baton Rouge) | 421 | 170 | 251 | 9.9 (0.6) | 140.8 (7.7) | 37.6 (10.2) | 18.8 (3.8) | 16.4 |
| Total | 5779 | 2601 | 3178 | 10.4 (0.6) | 141.7 (7.6) | 37.3 (9.4) | 18.4 (3.4) | 12.1 |

Data are shown as means (SDs) or percentages.

[a] Obesity defined as BMI z-score >2 from the WHO reference.

**Table 2. Comparisons of moderate-to-vigorous physical activity and sedentary time between weekdays and weekend by study sites**

| Country (Site) | Moderate-to-vigorous physical activity (minutes/day) | | | | | Sedentary Time (minutes/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Weekdays | Weekend | Total | *P* | High level (%) | Weekdays | Weekend | Total | *P* | High level (%) |
| Australia (Adelaide) | 69.6 (24.0) | 55.7 (30.3) | 65.7 (23.1) | <0.001 | 56.1 | 480.8 (62.7) | 475.8 (89.0) | 479.5 (60.0) | 0.228 | 48.7 |
| Brazil (Sao Paulo) | 61.4 (26.9) | 54.3 (35.0) | 59.3 (26.3) | <0.001 | 44.0 | 509.6 (72.0) | 483.1 (97.9) | 502.3 (67.1) | <0.001 | 61.9 |
| Canada (Ottawa) | 62.0 (21.2) | 49.5 (24.3) | 58.5 (19.5) | <0.001 | 43.1 | 512.3 (63.7) | 519.7 (86.0) | 514.1 (60.5) | 0.040 | 69.8 |
| China (Tianjin) | 46.0 (17.0) | 41.7 (21.4) | 44.8 (15.7) | <0.001 | 15.2 | 588.3 (71.8) | 521.7 (83.1) | 569.4 (66.0) | <0.001 | 92.8 |
| Colombia (Bogota) | 70.8 (26.1) | 62.0 (32.3) | 68.2 (24.9) | <0.001 | 59.5 | 516.5 (70.9) | 466.0 (85.5) | 502.2 (66.1) | <0.001 | 59.5 |
| Finland (Helsinki, Espoo & Vantaa) | 75.0 (27.6) | 61.0 (34.3) | 70.5 (26.7) | <0.001 | 62.9 | 536.9 (67.2) | 519.5 (89.3) | 531.0 (65.4) | <0.001 | 76.7 |
| India (Bangalore) | 49.1 (20.5) | 47.0 (27.5) | 48.5 (20.7) | 0.020 | 24.5 | 531.0 (70.3) | 488.2 (83.2) | 518.1 (65.0) | <0.001 | 71.9 |
| Kenya (Nairobi) | 70.9 (31.8) | 74.9 (40.9) | 72.1 (31.6) | <0.001 | 58.3 | 515.6 (74.9) | 454.0 (91.1) | 496.1 (65.3) | 0.008 | 55.8 |
| Portugal (Porto) | 59.7 (23.3) | 43.7 (25.2) | 55.1 (21.5) | <0.001 | 34.3 | 560.5 (63.0) | 543.5 (81.8) | 555.7 (57.4) | <0.001 | 90.1 |
| South Africa (Cape Town) | 63.8 (25.3) | 62.5 (33.4) | 63.4 (25.4) | 0.326 | 49.6 | 509.8 (67.0) | 444.5 (88.8) | 491.3 (66.9) | <0.001 | 54.8 |
| United Kingdom (Bath & NE Somerset) | 66.9 (23.7) | 58.1 (29.4) | 64.4 (22.7) | <0.001 | 52.0 | 507.1 (57.7) | 483.6 (85.4) | 500.8 (55.9) | <0.001 | 60.0 |
| United States (Baton Rouge) | 47.5 (17.3) | 56.0 (30.3) | 50.0 (19.0) | <0.001 | 26.1 | 544.5 (64.3) | 462.2 (91.5) | 521.1 (61.4) | <0.001 | 73.9 |
| Total | 62.1 (25.9) | 55.4 (31.9) | 60.2 (24.9) | <0.001 | 44.1 | 526.8 (72.6) | 489.2 (92.3) | 515.8 (67.9) | <0.001 | 68.3 |

Sedentary time and moderate-to-vigorous physical activity were measured with accelerometers and were defined as time spent at <100 counts per minute, and ≥574 counts/15 seconds, respectively.

**Table 3. Descriptive characteristics of participants stratified by sex**

| | Boys (n=2601) | Girls (n=3178) | Total (n=5779) | *P* |
|---|---|---|---|---|
| Age (years) | 10.4 (0.6) | 10.4 (0.6) | 10.4 (0.6) | 0.001 |
| Body weight (kg) | 37.2 (9.4) | 37.3 (9.5) | 37.3 (9.4) | 0.540 |
| Body height (cm) | 141.5 (7.3) | 141.9 (7.8) | 141.7 (7.6) | 0.055 |
| Body mass index (kg/m$^2$) | 18.4 (3.4) | 18.3 (3.4) | 18.4 (3.4) | 0.843 |
| Body mass index z-scores[a] | 0.53 (1.3) | 0.38 (1.2) | 0.45 (1.26) | <0.001 |
| Unhealthy diet pattern score | -0.05 (1.00) | -0.04(0.99) | -0.0001 (0.99) | 0.001 |
| Healthy diet pattern score | 0.01 (0.99) | -0.13 (0.88) | -0.07 (0.93) | <0.001 |
| Duration of night sleep (minutes/day) | | | | |
| Weekdays | 517.3 (59.9) | 520.5 (61.1) | 519.1 (60.6) | 0.041 |
| Weekend | 538.8 (80.7) | 554.8 (78.5) | 547.6 (79.9) | <0.001 |
| Total | 524.1 (52.1) | 531.7 (52.9) | 528.3 (52.7) | <0.001 |
| Duration of moderate-to-vigorous physical activity per day (minutes/day) | | | | |
| Weekdays | 71.9 (27.0) | 54.1 (21.8) | 62.1 (25.8) | <0.001 |
| Weekend | 64.1 (34.8) | 48.2 (27.4) | 55.4 (31.9) | <0.001 |
| Total | 69.7 (26.0) | 52.4 (21.0) | 60.2 (24.9) | <0.001 |
| Duration of sedentary per day (minutes/day) | | | | |
| Weekdays | 514.3 (73.1) | 536.9 (70.6) | 526.8 (72.6) | <0.001 |
| Weekend | 488.7 (96.1) | 489.6 (89.1) | 489.2 (92.3) | 0.702 |
| Total | 506.9 (68.5) | 522.1 (66.5) | 515.8 (67.9) | <0.001 |
| Body mass index category (%)[b] | | | | <0.001 |
| Non-obesity | 85.0 | 90.3 | 87.9 | |
| Obesity | 15.0 | 9.7 | 12.1 | |
| Parental education (%) | | | | 0.688 |
| Less not complete high school | 19.2 | 19.9 | 19.6 | |
| Completed high school/some college | 42.9 | 41.8 | 42.3 | |
| Bachelor’s degree or postgraduate degree | 37.9 | 38.2 | 38.1 | |

**Table 4 Odd ratios (95% confidence intervals) of obesity by single levels of MVPA and sedentary during weekdays and weekend**

| | Weekdays | | P | Weekend | | P |
|---|---|---|---|---|---|---|
| | High level | Low level | | High level | Low level | |
| MVPA | | | | | | |
| Australia (Adelaide) | 1.00 | 3.03 (1.51-6.08) | 0.002 | 1.00 | 1.90 (0.92-3.91) | 0.084 |
| Brazil (Sao Paulo) | 1.00 | 2.35 (1.37-4.02) | 0.002 | 1.00 | 2.50 (1.43-4.38) | 0.001 |
| Canada (Ottawa) | 1.00 | 2.14 (1.14-3.99) | 0.017 | 1.00 | 2.32 (1.08-4.99) | 0.032 |
| China (Tianjin) | 1.00 | 1.74 (0.96-3.17) | 0.068 | 1.00 | 2.80 (1.41-5.55) | 0.003 |
| Colombia (Bogota) | 1.00 | 3.00 (1.58-5.72) | 0.001 | 1.00 | 1.84 (0.96-3.53) | 0.068 |
| Finland (Helsinki, Espoo & Vantaa) | 1.00 | 2.58 (1.03-6.47) | 0.044 | 1.00 | 1.84 (0.72-4.72) | 0.204 |
| India (Bangalore) | 1.00 | 2.81 (1.28-6.19) | 0.010 | 1.00 | 2.52 (1.08-5.85) | 0.032 |
| Kenya (Nairobi) | 1.00 | 16.50 (4.32-63.01) | <0.001 | 1.00 | 4.04 (1.55-10.54) | 0.004 |
| Portugal (Porto) | 1.00 | 1.19 (0.70-2.02) | 0.528 | 1.00 | 1.36 (0.75-2.46) | 0.309 |
| South Africa (Cape Town) | 1.00 | 4.21 (1.78-9.95) | 0.001 | 1.00 | 2.80 (1.24-6.34) | 0.014 |
| United Kingdom (Bath & NE Somerset) | 1.00 | 2.73 (1.19-6.25) | 0.018 | 1.00 | 1.90 (0.80-4.53) | 0.148 |
| United States (Baton Rouge) | 1.00 | 2.18 (1.03-4.62) | 0.043 | 1.00 | 2.54 (1.35-4.75) | 0.004 |
| Total | 1.00 | 2.92 (2.44-3.51) | <0.001 | 1.00 | 2.77 (2.28-3.38) | <0.001 |
| Sedentary | | | | | | |
| Australia (Adelaide) | 2.11 (1.07-4.17) | 1.00 | 0.031 | 1.65 (0.84-3.23) | 1.00 | 0.146 |
| Brazil (Sao Paulo) | 1.24 (0.73-2.10) | 1.00 | 0.429 | 1.13 (0.69-1.86) | 1.00 | 0.633 |
| Canada (Ottawa) | 0.96 (0.51-1.83) | 1.00 | 0.909 | 0.87 (0.46-1.67) | 1.00 | 0.678 |
| China (Tianjin) | 0.59 (0.27-1.30) | 1.00 | 0.190 | 1.08 (0.64-1.83) | 1.00 | 0.774 |
| Colombia (Bogota) | 1.60 (0.76-3.36) | 1.00 | 0.217 | 1.69 (0.90-3.15) | 1.00 | 0.102 |
| Finland (Helsinki, Espoo & Vantaa) | 2.03 (0.56-7.36) | 1.00 | 0.281 | 1.99 (0.69-5.71) | 1.00 | 0.201 |

| | | | | | | |
|---|---|---|---|---|---|---|
| India (Bangalore) | 0.95 (0.46-1.99) | 1.00 | 0.900 | 0.78 (0.42-1.42) | 1.00 | 0.411 |
| Kenya (Nairobi) | 0.80 (0.33-1.92) | 1.00 | 0.617 | 1.20 (0.53-2.72) | 1.00 | 0.666 |
| Portugal (Porto) | 1.38 (0.64-2.97) | 1.00 | 0.405 | 0.94 (0.52-1.67) | 1.00 | 0.824 |
| South Africa (Cape Town) | 1.35 (0.61-2.98) | 1.00 | 0.452 | 1.34 (0.63-2.86) | 1.00 | 0.450 |
| United Kingdom (Bath & NE Somerset) | 1.50 (0.62-3.63) | 1.00 | 0.364 | 1.87 (0.82-4.28) | 1.00 | 0.140 |
| United States (Baton Rouge) | 1.45 (0.63-3.34) | 1.00 | 0.388 | 1.66 (0.96-2.87) | 1.00 | 0.070 |
| Total | 1.48 (1.21-1.80) | 1.00 | <0.001 | 1.44 (1.21-1.71) | 1.00 | <0.001 |
| MVPA | | | | | | |
| HDI -high | 1.00 | 2.15 (1.65-2.79) | <0.001 | 1.00 | 2.01 (1.51-2.67) | <0.001 |
| -medium | 1.00 | 2.97 (2.26-3.89) | <0.001 | 1.00 | 2.90 (2.16-3.87) | <0.001 |
| -low | 1.00 | 16.50 (4.32-63.01) | <0.001 | 1.00 | 4.04 (1.55-10.54) | 0.004 |
| Sedentary | | | | | | |
| HDI -high | 1.50 (1.11-2.05) | 1.00 | 0.009 | 1.32 (1.02-1.72) | 1.00 | 0.038 |
| -medium | 1.42 (1.07-1.89) | 1.00 | 0.016 | 1.38 (1.08-1.76) | 1.00 | 0.010 |
| -low | 0.80 (0.33-1.92) | 1.00 | 0.617 | 1.20 (0.53-2.72) | 1.00 | 0.666 |

Adjusted for child age, sex, highest parental education, unhealthy diet pattern scores, healthy diet pattern scores, and sleeping time on weekdays and weekend.

**Table 5. Odd ratios (95% confidence intervals) of obesity by joint levels of moderate-to-vigorous physical activity (minutes/day) and sedentary time during weekdays and weekend by study site and human development index**

| | Weekday-Weekend | | | | P for trend |
|---|---|---|---|---|---|
| | High-High | High-Low | Low-High | Low-Low | |
| MVPA | | | | | |
| Australia (Adelaide) | 1.00 | 0.99 (0.39-2.48) | 0.95 (0.11-8.08) | 3.38 (1.46-7.85) | 0.008 |
| Brazil (Sao Paulo) | 1.00 | 2.17 (1.03-4.59) | 2.13 (0.77-5.93) | 3.87 (1.92-7.78) | 0.002 |
| Canada (Ottawa) | 1.00 | 1.66 (0.64-4.30) | 1.22 (0.22-6.88) | 3.21 (1.30-7.92) | 0.043 |
| China (Tianjin) | 1.00 | 2.51 (0.77-8.14) | 1.36 (0.38-4.87) | 3.50 (1.27-9.59) | 0.022 |
| Colombia (Bogota) | 1.00 | 1.18 (0.46-3.06) | 2.31 (0.75-7.15) | 3.56 (1.60-7.93) | 0.007 |
| Finland (Helsinki, Espoo & Vantaa) | 1.00 | 1.71 (0.53-5.52) | 3.56 (0.61-20.73) | 3.35 (1.03-10.85) | 0.197 |
| India (Bangalore) | 1.00 | 2.31 (0.60-8.92) | 3.07 (0.69-13.76) | 4.62 (1.48-14.44) | 0.049 |
| Kenya (Nairobi) | 1.00 | 6.17 (0.50-76.8) | 27.6 (2.88-263.9) | 43.5 (5.19-364.8) | 0.001 |
| Portugal (Porto) | 1.00 | 1.09 (0.52-2.25) | 0.63 (0.16-2.43) | 1.35 (0.65-2.78) | 0.578 |
| South Africa (Cape Town) | 1.00 | 0.80 (0.15-4.15) | 1.80 (0.42-7.78) | 4.75 (1.77-12.8) | 0.004 |
| United Kingdom (Bath & NE Somerset) | 1.00 | 1.84 (0.58-5.81) | 3.92 (0.80-19.2) | 3.85 (1.25-11.9) | 0.096 |
| United States (Baton Rouge) | 1.00 | 1.74 (0.39-7.73) | 1.39 (0.49-3.93) | 3.27 (1.32-8.10) | 0.021 |
| Total | 1.00 | 1.99 (1.51-2.65) | 2.20 (1.54-3.14) | 4.67 (3.66-5.97) | <0.001 |
| | | 1.00 | 1.16 (0.81-1.65) | | 0.427 |
| Sedentary | | | | | |
| Australia (Adelaide) | 2.72 (1.13-6.56) | 2.11 (0.79-5.64) | 1.52 (0.53-4.34) | 1.00 | 0.146 |
| Brazil (Sao Paulo) | 1.42 (0.72-2.82) | 1.63 (0.79-3.37) | 1.69 (0.71-4.03) | 1.00 | 0.539 |
| Canada (Ottawa) | 0.75 (0.33-1.74) | 0.65 (0.23-1.82) | 0.57 (0.20-1.62) | 1.00 | 0.732 |
| China (Tianjin) | 1.05 (0.35-3.16) | 1.05 (0.33-3.32) | 4.06 (0.80-20.6) | 1.00 | 0.206 |
| Colombia (Bogota) | 2.07 (0.86-4.96) | 1.25 (0.48-3.24) | 1.24 (0.31-5.05) | 1.00 | 0.318 |
| Finland (Helsinki, Espoo & Vantaa) | 2.25 (0.48-10.6) | 1.09 (0.17-7.04) | 0.88 (0.07-10.9) | 1.00 | 0.475 |
| India (Bangalore) | 0.81 (0.32-2.06) | 1.08 (0.41-2.82) | 0.88 (0.25-3.10) | 1.00 | 0.866 |
| Kenya (Nairobi) | 0.90 (0.30-2.78) | 0.61 (0.20-1.82) | 0.77 (0.18-3.42) | 1.00 | 0.797 |

| | | | | | |
|---|---|---|---|---|---|
| Portugal (Porto) | 1.31 (0.36-4.69) | 1.44 (0.38-5.49) | 0.95 (0.20-4.37) | 1.00 | 0.850 |
| South Africa (Cape Town) | 1.54 (0.60-3.97) | 1.11 (0.44-2.78) | 0.67 (0.08-5.95) | 1.00 | 0.736 |
| United Kingdom (Bath & NE Somerset) | 1.86 (0..66-5.24) | 0.76 (0.21-2.76) | 0.79 (0.14-4.45) | 1.00 | 0.303 |
| United States (Baton Rouge) | 2.28 (0.84-6.18) | 1.50 (0.57-3.97) | 3.31 (0.50-21.7) | 1.00 | 0.254 |
| Total | 1.87 (1.45-2.42) | 1.43 (1.09-1.87) | 1.46 (1.02-2.08) | 1.00 | <0.001 |
| | | 0.95 (0.67-1.35) | 1.00 | | 0.777 |
| MVPA | | | | | |
| HDI -high | 1.00 | 1.47 (1.002-2.15) | 1.44 (0.84-2.49) | 2.96 (2.08-4.21) | <0.001 |
| -medium | 1.00 | 2.08 (1.34-3.21) | 2.24 (1.33-3.78) | 4.73 (3.29-6.81) | <0.001 |
| -low | 1.00 | 6.17 (0.50-76.8) | 27.6 (2.88-263.9) | 43.5 (5.19-364.8) | 0.001 |
| Sedentary | | | | | |
| HDI -high | 1.74 (1.17-2.59) | 1.39 (0.90-2.14) | 1.18 (0.69-2.03) | 1.00 | 0.028 |
| -medium | 1.82 (1.27-2.61) | 1.55 (1.06-2.67) | 1.78 (1.07-2.98) | 1.00 | 0.011 |
| -low | 0.92 (0.30-2.78) | 0.61 (0.20-1.82) | 0.77 (0.18-3.42) | 1.00 | 0.797 |

Adjusted for child age, sex, highest parental education, unhealthy diet pattern scores, healthy diet pattern scores, and sleeping time on weekdays and weekend.

HDI, human development index; high: Australia, Canada, Finland, Portugal, United Kingdom, United States; medium: Brazil, Colombia, China, India, South Africa; low: Kenya.