Physical Activity, Sedentary Time, and Obesity in an International Sample of Children

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Running Head: Physical Activity and Obesity in Children
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ABSTRACT

Purpose: To determine the relationships between moderate-to-vigorous physical activity (MVPA), vigorous physical activity (VPA), sedentary time and obesity in children from 12 countries representing a wide range of human development. Methods: The sample included 6,539 children aged 9-11 years. Time in MVPA, VPA and sedentary behaviors were assessed by accelerometry. The body mass index (BMI; kg/m²) was used to classify children as obese based on z-scores (>+2 SD) from World Health Organization reference data. Results: The mean (SD) times spent in MVPA, VPA and sedentary behavior were 60 (25) min/day, 18 (11) min/day and 513 (69) min/day, respectively. The overall proportion of the sample that was obese ranged from 5.2% to 24.6% across sites. The odds ratios for obesity were significant for MVPA (0.49; 95% CI: 0.44 - 0.55), VPA (0.41; 0.37 - 0.46) and sedentary time (1.19; 1.08 - 1.30) in the overall sample. The associations of MVPA and VPA with obesity were significant in all 12 sites, whereas the association between sedentary time and obesity was significant in 5 of the 12 sites. There was a significant difference in BMI z-scores across tertiles of MVPA (P<0.001) but not across tertiles of sedentary time in a mutually adjusted model. The results of receiver operating characteristic curve analyses for obesity indicated that the optimal thresholds for MVPA (AUC = 0.64), VPA (AUC = 0.67) and sedentary behavior (AUC = 0.57) were 55 (95% CI: 50-64) min/day, 14 (11-16) min/day and 482 (455-535) min/day, respectively. Conclusions: Greater MVPA and VPA were both associated with lower odds of obesity, independent of sedentary behavior. Sedentary time was positively associated with obesity, but not independent of MVPA. Attaining at least 55 min/day of MVPA is associated with lower obesity in this multi-national sample of children, which supports current guidelines. KEY WORDS: overweight; pediatrics; epidemiology; lifestyle; international
INTRODUCTION

Global physical activity guidelines as well as those for the United States call for a minimum of 60 minutes per day of moderate-to-vigorous physical activity (MVPA) for health benefits in school-aged children (32,33). These guidelines are largely based on evidence linking physical activity and outcomes such as physical fitness, bone health, and markers of cardiovascular and metabolic health in childhood (32,33). Recent reviews indicate that the cross-sectional association between physical activity and adiposity is modest in children (11,22), and that further research is required to determine the amount of physical activity needed to prevent the development of excess adiposity during childhood (22).

In addition to the health-enhancing effects of physical activity, recent studies have shown a negative association between sedentary behaviors (sitting, TV viewing, etc.) and health outcomes in adults (9,25). The available evidence also indicates an association between sedentary behavior, especially TV viewing, and health in children and youth (18,26). Given that only a weak association exists between MVPA and sedentary behavior (20), it is important to better understand the independent effects of these behaviors on obesity in children.

The majority of existing evidence on associations between physical activity, sedentary behavior and health in children has relied on subjective (self-reported) measures of the exposure variable (11). Although largely limited to North America and Europe, the objective assessment of physical activity and sedentary behavior using accelerometry has recently allowed for large-scale studies to examine associations with health status in children (1,6).

Given the lack of comparative objective data on the relationship between physical activity, sedentary behavior and obesity in international samples, the purpose of this study was to examine the associations of MVPA, vigorous physical activity (VPA) and sedentary behavior
with obesity in 9-11 year old children from countries that differ in stages of epidemiologic transition, and to identify the optimal thresholds of MVPA, VPA and sedentary time that are associated with obesity.

METHODS

Study Design

ISCOLE is a cross-sectional, multi-national study designed to determine the relationships between lifestyle behaviors and obesity in children in 12 study sites located in Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, United Kingdom and United States. These countries represent a range of economic development (low to high income) and human development index (0.509 in Kenya to 0.929 in Australia) (12). 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 (12). Data were collected from September 2011 through December 2013.

Participants

The ISCOLE study includes 7,372 children aged 9-11 years. However, a total of 31 participants were missing data on BMI and a further 802 participants were missing data from
accelerometry, resulting in an analytic sample size of 6,539. Participants with missing BMI or accelerometry data did not differ in age from the analytic sample, but those missing accelerometry had a higher average BMI z-score (0.62) compared to the analytic sample (0.46).

The primary sampling frame was schools, and this sampling frame was typically stratified by an indicator of socio-economic status in order to maximize variability within sites (12). By design, the within-site samples were not intended to be nationally representative.

**Measurements**

Time spent in MVPA, VPA and sedentary behavior was obtained from 24-hour, waist worn accelerometry. An Actigraph GT3X+ accelerometer (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 24 hours per day (removing only for water-related activities) for at least 7 days (plus an initial familiarization day and the morning of the final day), including weekend days. We have previously shown that this protocol increases wear-time compliance compared to previous studies, and overall the average wear time at the U.S. ISCOLE site was 22.6 hours/day (30). The minimal amount of accelerometer data that was considered acceptable for inclusion in the sample was 4 days with at least 10 hours of waking wear time per day, including at least one weekend day. After exclusion of the total sleep episode time (2,29) and non-wear time (any sequence of at least 20 consecutive minutes of zero activity counts)(16), MVPA was defined as all activity ≥574 counts per 15 seconds, VPA was defined as activity ≥1003 counts per 15 seconds, and sedentary time was defined as all movement ≤25 counts per 15 seconds (8,28).

Body height and body mass were measured using standard procedures across all study sites. Body height was measured without shoes using a Seca 213 portable stadiometer (Hamburg, Germany), with the head in the Frankfurt Plane. Body mass was determined with a portable
Tanita SC-240 scale (Arlington Heights, IL, USA), after all outer clothing and shoes were removed. Each measurement was repeated and the average was used for analysis (a third measurement was obtained if the first two measurements were greater than 0.5 cm or 0.5 kg apart for height and body mass, respectively, and the average of the two closest measurements was used in analyses). Body mass index (BMI; kg/m$^2$) was calculated, and BMI z-scores were computed using age- and sex-specific reference data from the World Health Organization (4). Participants were classified as obese (BMI z-score > +2 SD) or non-obese (BMI z-score ≤ +2 SD).

**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 between MVPA, VPA, sedentary time and obesity (0 = no, 1 = yes) were assessed in terms of odds ratios calculated using generalized linear mixed models (SAS version 9.3, PROC GLMMIX). Study sites were considered to have fixed effects, and schools nested within study sites were viewed as having random effects. The denominator degrees of freedom for statistical tests pertaining to fixed effects were calculated using the Kenward and Roger approximation (13). Times in MVPA, VPA and sedentary time were standardized, such that odds ratios are expressed per SD of each variable (MVPA = 25 min, VPA = 10 min, sedentary time = 70 min). Mean daily waking wear time was included as a covariate in all models, and in all models that included both boys and girls, sex was also included as a covariate. A subsequent linear mixed model (PROC MIXED) was used to examine the combined effects of MVPA and sedentary time on BMI z-scores, with both MVPA and sedentary time categorized into sex-specific tertiles.
Receiver Operating Characteristic (ROC) curves were used to select thresholds of MVPA, VPA, and sedentary time associated with obesity. The area under the curve (AUC) is considered a measure of the utility of the predictor variable and represents the trade-off between the correct identification of high-risk (obese) individuals (sensitivity) and the correct identification of low-risk (non-obese) individuals (specificity). An AUC of 1 indicates the ability to perfectly distinguish between obese and non-obese participants, while an AUC of 0.5 indicates no greater predictive ability than chance alone.

The optimal threshold was determined from the Youden index \( J \), which is the maximum value of \( J = \text{sensitivity} + \text{specificity} - 1 \).

Statistical significance of differences in AUCs between MVPA, VPA and sedentary time was assessed by using the nonparametric approach of DeLong et al. (5).

In addition to the primary analyses, two sets of sensitivity analyses were conducted. First, the associations were re-analyzed using the MVPA threshold of Treuth et al. (27) (3000 counts/min) rather than the Evenson et al. (8) threshold used in the primary analysis. Previous work has shown that the prevalence of obesity is similar among children when comparing the WHO growth reference versus the U.S. Centers for Disease Control and Prevention (CDC) cut-points (24). However, as an additional sensitivity analysis, the associations in the present study were re-analyzed after reclassifying participants as obese and non-obese using the CDC age- and sex-specific BMI thresholds (≥ 95th percentile)(14).

Data management and calculations for statistical inferences were conducted using SAS version 9.3 (SAS Institute, Cary, NC). The ROC analyses and comparisons of ROC curves were
performed using MedCalc Statistical Software Version 13 (MedCalc Software bvba, Ostend, Belgium). The level of significance was set at $P < 0.05$.

RESULTS

The mean (SD) waking wear time in the sample was 14.8 (0.9) hours/day, which ranged from 14.1 to 15.2 hours/day across the 12 sites. The descriptive characteristics of the study sample are provided in TABLE 1, stratified by study site. The mean age of the total sample was 10.4 (0.6) years, and the mean time spent in MVPA, VPA and sedentary behavior was 60 (25) min/day, 18 (11) min/day and 513 (69) min/day, respectively. The mean MVPA time ranged from 45 min/day in China to 71 min/day in Kenya and Finland, mean VPA time ranged from 13 min/day in India and China to 23 min/day in Finland, and mean sedentary time ranged from 477 min/day in Australia to 565 min/day in China. The overall proportion of obese participants was 12.4%, and ranged from 5.2% to 24.6% across sites. TABLE 2 presents descriptive characteristics of boys and girls. Overall, boys and girls did not significantly differ in mean height, body mass or BMI; however, BMI z-scores were significantly greater in boys than girls. Further, boys spent significantly more time in MVPA and VPA; whereas girls spent significantly more time in sedentary behaviors.

FIGURE 1 presents the combined associations of MVPA and sedentary time with BMI z-scores. In both boys and girls, there was a significant decreasing trend for BMI z-scores across increasing tertiles of MVPA ($p<0.001$), but the trend across tertiles of sedentary behavior was not significant. Similar trends in BMI z-score were observed across tertiles of VPA and sedentary time (results not shown).
FIGURE 2 shows odds ratios for assessing the associations of MVPA and sedentary behavior with obesity across study sites. The odds ratios for obesity were significant for MVPA (0.49; 95% CI: 0.44 - 0.55), VPA (0.41; 95% CI: 0.37 - 0.46) and sedentary time (1.19; 95% CI 1.08 - 1.30) in the overall sample. The negative associations of MVPA and VPA with obesity were significant in all of the 12 study sites, whereas the positive association between sedentary time and obesity was significant in only 5 (Australia, Canada, Colombia, South Africa and United States) of the 12 study sites.

The results of the ROC curve analyses are presented in TABLE 3. In the total sample and in both boys and girls, the AUC for sedentary behavior was significantly lower than the AUC for both MVPA and VPA (p<0.001), and the AUC for MVPA was significantly lower than the AUC for VPA (p<0.001). The overall threshold for MVPA was 55 min/day (95% C.I.: 50 - 64) and the threshold was higher in boys (65 min/day; 95% C.I.: 55 - 75) compared to girls (49 min/day; 95% C.I.: 43 – 62). The overall threshold for VPA was 14 min/day (95% C.I.: 11 - 16), and the threshold was higher in boys (20 min/day; 95% C.I.: 16 - 22) compared to girls (11 min/day; 95% C.I.: 9 - 13). The overall threshold for sedentary time was 482 min/day (95% C.I.: 455 - 535), and was similar in girls (497 min/day; 95% C.I.: 449 - 534) and boys (482 min/day; 95% C.I.: 455 - 554). In country-specific analyses (results not shown), the thresholds ranged from 39 to 72 min/day for MVPA in 10 sites where the AUC was significant, from 8 to 22 min/day for VPA in 12 sites where the AUC was significant, and from 475 to 609 min/day for sedentary behavior in 8 sites where the AUC was significant.

In sensitivity analyses conducted using the Treuth et al. (27) thresholds for MVPA, the associations between MVPA and obesity were similar. The odds ratio for obesity was similar (0.27; 95% CI: 0.23 – 0.33), and the association between MVPA and obesity remained
significant in all 12 study sites. The AUC for the ROC curve analysis was also significant when using the Treuth et al. (27) MVPA threshold (AUC = 0.66; 95% CI: 0.65 – 0.67). The associations observed when using the WHO BMI thresholds (4) were also maintained when using the CDC BMI thresholds (14). For example, the odds ratios (per SD) for obesity were similar for MVPA (0.47; 95% CI: 0.42 - 0.53), VPA (0.38; 95% CI: 0.34 - 0.43), and sedentary time (1.18; 95% CI 1.07 - 1.32) in the overall sample when applying the CDC thresholds. Further, the associations of MVPA and VPA with obesity remained significant in all 12 sites, and the association between sedentary time and obesity remained significant in 4 of 12 sites, respectively.

**DISCUSSION**

Time spent in MVPA and VPA was consistently associated with obesity in this multinational sample of children, and the optimal threshold of 55 min/day of MVPA supports global recommendations which call for 60 min/day of physical activity for children and youth (33). The robust, standardized data collection procedures employed across all world regions in this study, and the consistency of the relationship across countries at different stages of economic and epidemiologic transition, strongly indicate that physical activity is a robust correlate of obesity across different cultures, races and geographical settings. The relationship between sedentary time and obesity is weaker, not independent of MVPA, and less consistent across study sites.

The results support the conclusion of the 2008 *Physical Activity Recommendations for Americans* that “Regular physical activity in children and adolescents promotes a healthy body weight and body composition” (32). Indeed, results from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development demonstrated that
time spent in MVPA was negatively associated with changes in BMI from 9 to 15 years of age (19). The results of the present study confirm the association between MVPA and obesity in U.S. children, and extend the results to other world regions. Accelerometers are now ubiquitous in physical activity research as well as in “real world” settings, as smart phones and other commercial devices such as wrist band physical activity monitors have proliferated in the marketplace (15). Whereas current physical activity recommendations were largely informed by studies relying on self-reported measures of physical activity, objective data such as those reported in the present study have the potential to inform future physical activity guidelines with real world significance. However, there is a need for independent validation of new devices as they come into the market to ensure they are measuring what they purport to measure.

The results of the present study also support data from regional multi-national studies that have objectively measured physical activity by accelerometry. Although limited to European children, time spent in MVPA was significantly inversely associated with body fatness (sum of skinfolds) in 1,292 9-10 year old children from four countries in the European Youth Heart Study. (7) Results of cluster-analyses among 766 10- to 12-year-old European children participating in the ENERGY study indicated that both higher MVPA and lower sedentary time in girls was associated with lower BMI; however, MVPA was the dominant correlate in boys (3). Further, ROC curve analyses among 2,094 adolescents from the HELENA study in Europe identified an optimal threshold of 55 min/day for differentiating obese from normal weight youth, and their thresholds were similarly higher in boys (56 min/day) compared to girls (49 min/day)(17). This sex difference in physical activity levels associated with obesity has also been reported when using steps/day as a metric (31). The underlying mechanism for this sex difference is not understood; however, girls tend to have higher levels of percent body fat for a
given BMI percentile (10), which could influence the associations with physical activity. The results of the present multi-national study extend those of these smaller studies that were limited to the European context, and confirm that MVPA is a robust correlate of obesity in multiple economic and geographic settings.

The finding in the present study that time spent in MVPA was more consistently related to obesity than time spent in sedentary behavior supports results from the International Children’s Accelerometry Database (ICAD; n = 20,871) which indicated that MVPA, but not sedentary time, was associated with cardiometabolic risk factors, including waist circumference (6). The ICAD analysis provides a wealth of important information, although it is limited to data from studies conducted in the United States, Europe and Brazil using different protocols (6). The present study expands upon these data by the use of a standardized protocol across 12 sites from 5 different world regions, and confirms that MVPA is more strongly related to obesity than sedentary behavior among 9-11 year old children. The reason for the lack of association between sedentary time and obesity in some countries is not known. Television viewing is one type of sedentary behavior that has been more strongly associated with obesity in children than global measures of overall sedentary time (26). Television viewing may be a more prominent activity in the developed countries where an association was found (Australia, Canada, Colombia, South Africa and United States), which may partially explain the greater associations observed in these countries. However, more research is required to better understand associations among indicators of specific sedentary behaviors and health outcomes such as obesity.

The results of the sensitivity analyses indicate that similar associations with obesity are obtained when using different MVPA thresholds or different definitions of obesity. We chose to use the Evenson et al. (8) MVPA threshold for our primary analysis as a 15-second epoch may
be more appropriate than a 60-second epoch to capture the sporadic nature of children’s activity, and it provides the best classification accuracy among the currently available thresholds for sedentary, light-, moderate-, and vigorous-intensity activity in children and adolescents (28). Further, we chose to use the WHO BMI thresholds given that this is an international study of children from 5 world regions. However, the consistency of the results when using the CDC BMI thresholds is encouraging, and suggests that our results may be comparable to other studies that have used the CDC thresholds.

This study has several strengths and limitations that warrant discussion. A marked strength is the large diverse sample of children from study sites from every world region which varied in their prevalence of obesity, MVPA, VPA and sedentary behavior. This served to increase the variability among the dependent and independent variables, and increased the generalizability of the results. Hence, the results strongly indicate that the associations seen between physical activity and obesity are robust and not related to certain types of cultures, races or geographical settings. An additional strength is the rigorous standardization of the protocol across all study sites, which included the use of the same anthropometric equipment and the same model of accelerometer to objectively monitor physical activity and sedentary behavior at all study sites. Further, all data management and analysis was centrally conducted at the coordinating center, which assured consistency in data handling and interpretation.

The cross-sectional design of this study limits conclusions regarding cause-and-effect relationships and the direction of the associations observed. Further, we cannot exclude the possibility that unmeasured confounding variables may explain some of the observed relationships. The results for MVPA and VPA were very consistent across study sites, but it is not known whether lower levels of physical activity are the cause or the consequence of obesity
in this sample of children. We objectively assessed physical activity and sedentary behavior using accelerometry; however, a limitation of this approach is the inability to quantify some physical activities such as cycling and swimming. It should be noted that the optimal threshold (identified as 55 min/day MVPA in this study) may vary according to the method and algorithm used in classifying physical activity intensity and hence the threshold should be regarded as showing the approximate magnitude rather than an exact value. Finally, we used a threshold of ≤25 counts per 15 seconds to quantify time spent in sedentary behavior. Although this is commonly used threshold that is related to sitting in children during school hours (23), it does not measure “sitting” *per se* nor time spent in specific sedentary behaviors such as TV viewing, rather it captures non-movement and time spent in low intensity movements. Further research using devices that capture posture in addition to intensity is required to better quantify sedentary behavior in children.

In conclusion, higher levels of MVPA and VPA were associated with lower odds of obesity in this multi-national sample of children, independent of sedentary behavior. Attaining at least 55 min/day of MVPA appears to be associated with lower obesity which supports guidelines that call for 60 min/day of MVPA in childhood. The implementation of a standardized protocol across countries that vary widely in economic and epidemiologic transition highlights the robustness of the relationship between physical activity and obesity in children.
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**CONFLICT OF INTEREST:** Dr. Church receives honoraria for lectures from scientific, educational, and lay groups. Dr. Church has a book entitled “Move Yourself: The Cooper Clinic Medical Director’s Guide to All the Healing Benefits of Exercise.” Dr. Church is a member of the Jenny Craig/Curves Medical Advisory Board as well as the Utilifit/FIX Corporate advisory board. Dr. Church has consulted for Medscape, Vivus and Takada, and he serves as the Senior Medical Advisor for Catapult Health and the Chief Medical Officer at ACAP health. Dr. Fogelholm has received a research grant from Fazer Finland. Dr. Kurpad is a member of the Advisory Board of McCain Foods. Dr. Matsudo is a member of the Scientific Advisory Board of Actigraph. The authors reported no other potential conflicts of interest. The results of the present study do not constitute endorsement by ACSM.
REFERENCES


Figure Legends

Figure 1. Combined associations between moderate-to-vigorous physical activity (MVPA), sedentary time and body mass index (BMI) z-scores in 2,985 boys and 3,554 girls. P<0.001 for differences across tertiles of MVPA in both boys and girls and P = 0.20 in boys and P = 0.73 in girls for differences across tertiles of sedentary time. The results are from multi-level mixed models including both variables simultaneously. Error bars represent standard errors.

Figure 2. Associations between moderate-to-vigorous physical activity (MVPA), vigorous physical activity (VPA), sedentary time and obesity in 6,539 9-11 year old children from 12 study sites around the world. Odds ratios are expressed per 25 minutes of daily MVPA, 10 minutes of daily VPA, and 70 minutes of sedentary behavior, adjusted for sex and waking wear time. Error bars represent 95% confidence intervals.
Figure 1
Figure 2

Moderate-to-Vigorous Physical Activity

Vigorous Physical Activity

Sedentary Behavior

Australia
Brazil
Canada
China
Colombia
Finland
India
Kenya
Portugal
South Africa
United Kingdom
United States
Total

Odds Ratio for Obesity

Odds Ratio for Obesity

Odds Ratio for Obesity
Table 1. Descriptive Characteristics of Participants Stratified by Study Site (n = 6,539).

<table>
<thead>
<tr>
<th>Country (Site)</th>
<th>No. of Participants</th>
<th>Mean (SD)</th>
<th>Sedentary Time (min/day)</th>
<th>MVPA (min/day)</th>
<th>VPA (Min/day)</th>
<th>Obesity(^a) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Age (y)</td>
<td>Height (cm)</td>
<td>Mass (kg)</td>
<td>BMI (kg/m(^2))</td>
</tr>
<tr>
<td>Australia (Adelaide)</td>
<td>225</td>
<td>266</td>
<td>10.7 (0.4)</td>
<td>144.7 (7.2)</td>
<td>39.8 (9.3)</td>
<td>18.8 (3.3)</td>
</tr>
<tr>
<td>Brazil (Sao Paulo)</td>
<td>241</td>
<td>252</td>
<td>10.5 (0.5)</td>
<td>143.7 (7.3)</td>
<td>41.1 (11.9)</td>
<td>19.7 (4.4)</td>
</tr>
<tr>
<td>Canada (Ottawa)</td>
<td>216</td>
<td>306</td>
<td>10.5 (0.4)</td>
<td>143.7 (7.1)</td>
<td>38.1 (9.2)</td>
<td>18.3 (3.3)</td>
</tr>
<tr>
<td>China (Tianjin)</td>
<td>261</td>
<td>240</td>
<td>9.9 (0.5)</td>
<td>141.3 (7.1)</td>
<td>38.2 (11.0)</td>
<td>18.9 (4.2)</td>
</tr>
<tr>
<td>Colombia (Bogota)</td>
<td>422</td>
<td>435</td>
<td>10.5 (0.6)</td>
<td>137.7 (7.0)</td>
<td>33.6 (7.0)</td>
<td>17.6 (2.5)</td>
</tr>
<tr>
<td>Finland (Helsinki, Espoo &amp; Vantaa)</td>
<td>231</td>
<td>269</td>
<td>10.5 (0.4)</td>
<td>142.4 (6.6)</td>
<td>37.1 (7.3)</td>
<td>17.7 (2.6)</td>
</tr>
<tr>
<td>India (Bangalore)</td>
<td>254</td>
<td>299</td>
<td>10.4 (0.5)</td>
<td>141.2 (6.8)</td>
<td>36.1 (8.5)</td>
<td>18.0 (3.3)</td>
</tr>
<tr>
<td>Kenya (Nairobi)</td>
<td>232</td>
<td>267</td>
<td>10.2 (0.7)</td>
<td>139.1 (7.4)</td>
<td>33.7 (8.3)</td>
<td>17.2 (3.1)</td>
</tr>
<tr>
<td>Portugal (Porto)</td>
<td>305</td>
<td>381</td>
<td>10.4 (0.3)</td>
<td>143.5 (6.8)</td>
<td>40.4 (9.2)</td>
<td>19.5 (3.4)</td>
</tr>
<tr>
<td>South Africa (Cape Town)</td>
<td>184</td>
<td>284</td>
<td>10.3 (0.7)</td>
<td>138.2 (7.4)</td>
<td>34.7 (9.0)</td>
<td>18.0 (3.6)</td>
</tr>
<tr>
<td>United Kingdom (Bath &amp; NE Somerset)</td>
<td>211</td>
<td>267</td>
<td>10.9 (0.5)</td>
<td>145.0 (7.2)</td>
<td>39.2 (8.6)</td>
<td>18.5 (3.0)</td>
</tr>
<tr>
<td>United States (Baton Rouge)</td>
<td>203</td>
<td>288</td>
<td>9.9 (0.6)</td>
<td>140.9 (7.5)</td>
<td>37.9 (10.3)</td>
<td>18.9 (3.9)</td>
</tr>
</tbody>
</table>

BMI: body mass index; MVPA: moderate-to-vigorous physical activity; VPA: vigorous physical activity.

Data are shown as mean (SD).

Sedentary time, MVPA and VPA were measured with accelerometry and were defined as time spent at ≤25 counts/15 s, ≥574 counts/15 s, and ≥1003 counts/15 s, respectively.

\(^a\)Obesity defined as BMI z-score >+2 from the WHO reference (4).
Table 2. Descriptive Characteristics of Participants Stratified by Sex (n = 6,539).

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 2,985)</th>
<th>Girls (n = 3,554)</th>
<th>Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>10.4 (0.6)</td>
<td>10.4 (0.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body Height, cm</td>
<td>141.6 (7.3)</td>
<td>141.8 (7.7)</td>
<td>0.29</td>
</tr>
<tr>
<td>Body Mass, kg</td>
<td>37.4 (9.5)</td>
<td>37.3 (9.4)</td>
<td>0.87</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>18.4 (3.5)</td>
<td>18.4 (3.5)</td>
<td>0.47</td>
</tr>
<tr>
<td>BMI z-scoreb</td>
<td>0.55 (1.31)</td>
<td>0.39 (1.21)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Obesity, %c</td>
<td>15.5</td>
<td>9.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MVPA, min/day</td>
<td>70 (26)</td>
<td>52 (21)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VPA, min/day</td>
<td>22 (12)</td>
<td>15 (9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sedentary Time, min/day</td>
<td>504 (70)</td>
<td>521 (68)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

BMI: body mass index; MVPA: moderate-to-vigorous physical activity; VPA: vigorous physical activity.

Data are shown as mean (SD) unless otherwise stated. Sedentary time, MVPA and VPA were measured with accelerometry and were defined as time spent at ≤25 counts/15 s, ≥574 counts/15 s, and ≥1003 counts/15 s, respectively.

aP value for differences between sexes (unpaired t-test for continuous variables, chi-square for obesity).

bBMI z-score computed from WHO growth reference (4).

cObesity defined as BMI z-score >+2 from WHO reference (4).
Table 3. Results of Receiver Operating Characteristic (ROC) Curve Analyses for the Associations Among Moderate-to-Vigorous Physical Activity, Vigorous Physical Activity, Sedentary Time and Obesity in 6,539 9-11 Year Old Children.

<table>
<thead>
<tr>
<th></th>
<th>AUC (95% C.I.)*</th>
<th>Youden Index</th>
<th>Threshold, min/day (95% CI)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moderate-to-Vigorous Physical Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys (n = 2,985)</td>
<td>0.68 (0.67 - 0.70)</td>
<td>0.267</td>
<td>65 (55 - 75)</td>
<td>70</td>
<td>57</td>
</tr>
<tr>
<td>Girls (n = 3,554)</td>
<td>0.66 (0.64 - 0.68)</td>
<td>0.246</td>
<td>49 (43 - 62)</td>
<td>70</td>
<td>55</td>
</tr>
<tr>
<td>Total (n = 6,539)</td>
<td>0.64 (0.63 - 0.65)</td>
<td>0.207</td>
<td>55 (50 - 64)</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td><strong>Vigorous Physical Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys (n = 2,985)</td>
<td>0.72 (0.70 - 0.73)</td>
<td>0.327</td>
<td>20 (16 - 22)</td>
<td>80</td>
<td>52</td>
</tr>
<tr>
<td>Girls (n = 3,554)</td>
<td>0.68 (0.67 - 0.70)</td>
<td>0.280</td>
<td>11 (9 - 13)</td>
<td>62</td>
<td>66</td>
</tr>
<tr>
<td>Total (n = 6,539)</td>
<td>0.67 (0.66 - 0.68)</td>
<td>0.247</td>
<td>14 (11 - 16)</td>
<td>63</td>
<td>62</td>
</tr>
<tr>
<td><strong>Sedentary Time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys (n = 2,985)</td>
<td>0.58 (0.56 - 0.60)</td>
<td>0.126</td>
<td>482 (455 - 554)</td>
<td>72</td>
<td>41</td>
</tr>
<tr>
<td>Girls (n = 3,554)</td>
<td>0.57 (0.56 - 0.59)</td>
<td>0.113</td>
<td>497 (449 - 534)</td>
<td>74</td>
<td>38</td>
</tr>
<tr>
<td>Total (n = 6,539)</td>
<td>0.57 (0.56 - 0.58)</td>
<td>0.101</td>
<td>482 (455 - 535)</td>
<td>75</td>
<td>35</td>
</tr>
</tbody>
</table>

AUC, area under the curve; CI, confidence interval.
*AUC significantly lower for sedentary time versus both vigorous physical activity and moderate-to-vigorous physical activity, and AUC significantly lower for moderate-to-vigorous physical activity versus vigorous physical activity in boys, girls, and the total sample (all p<0.001). Comparison of ROC curves following methods of DeLong et al.(5)