Are participant characteristics from ISCOLE study sites comparable to the rest of their country?

Short title: Generalizability of ISCOLE

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Abstract (max = 300 words, currently = 263)

The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) provides robust, multi-national information on physical activity, diet and weight status in 9-11 year-old children around the world. The purpose of this analysis was to examine the similarities and differences between participant characteristics from ISCOLE sites and data from nationally representative surveys from ISCOLE countries (Australia, Brazil, Canada, China, Colombia, Finland, Kenya, India, Portugal, South Africa, the United Kingdom, and the United States). Variables of comparison included body mass index (BMI), physical activity (accelerometer-determined steps per day), and screen time (child-report). Distributions of characteristics were assessed within each ISCOLE country-level database, and compared to published data from national or regional surveys, where available. Of twelve countries, data on weight status (BMI) were available in eight countries, data on measured physical activity (steps per day) were available in five countries, and data on self-reported screen time were available in nine countries. The five ISCOLE countries that were part of the Health Behaviors in School-aged Children survey (i.e., Canada, Finland, Portugal, United Kingdom (England), and United States) also provided comparable data on self-reported physical activity. Available country-specific data often used different measurement tools or cut-points, making direct comparisons difficult. Where possible, ISCOLE data were re-analysed to match country-level data, but this step limited between-country comparisons. From the analyses performed, the ISCOLE data do not seem to be systematically biased; however, due to limitations in data availability, data from ISCOLE should be used with appropriate caution when planning country-level population health interventions. This work highlights the need for harmonized measurement tools around the world while accounting for culturally specific characteristics, and the need for collaboration across study centres and research groups.

Introduction

The prevalence of paediatric obesity and related lifestyle behaviors have been examined in many countries; however, the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) represents the most up-to-date, directly measured, harmonized study of several countries ranging widely in level of human development.[1] Previous multi-national studies have focused on one geographic region (e.g., HELENA in Europe [Healthy Lifestyle in Europe by Nutrition in Adolescents][2]), or limited their inclusion to developed, or high income countries (e.g., HBSC [Health Behavior in School-aged Children][3]). ISCOLE aimed to recruit study sites with diverse geographical distribution from around the world, and drawn from low-, middle-, and high-income countries. Further, many previous studies have been limited by small sample sizes, indirect measurements, and/or the inability to generalize their findings to larger populations. With so many small, isolated, and non-representative studies, it becomes difficult to inform population health interventions, especially on a global scale.

The primary aim of ISCOLE was to determine the relationships between lifestyle behaviors and obesity in a multi-national study of 10-year-old children.[1] Further, ISCOLE aimed to investigate the influence of higher-order characteristics such as behavioral settings, and the physical, social and policy environments, on the observed relationships within and between countries. However, to better inform public health strategies and policies, the representativeness of ISCOLE participants needs to be examined.

ISCOLE participants were primarily recruited through convenience samples, thus the within-site samples were not designed to be nationally representative. However, to understand how to better interpret results from ISCOLE, and to make informed recommendations, it is important to understand if ISCOLE participants are comparable to their country as a whole, or if they represent a unique subset of the larger population. The purpose of this paper was to determine if data collected at ISCOLE study sites was representative of their site country. This work may be used to better understand the limitations, potential bias and generalizability of results of ISCOLE, and to understand current gaps in health and obesity-related knowledge in countries that participated in ISCOLE. Although availability of nationally representative data

differed across countries, comparisons were made when possible. If no nationally representative data were available, other large studies were used when appropriate, or no comparisons were made.

Methods

International Study of Childhood Obesity, Lifestyle and the Environment

To ensure that ISCOLE participants represented diverse backgrounds and circumstances, study sites were chosen from diverse geographic regions around the world (i.e., Europe, Africa, the Americas, South Asia, and the Western Pacific) and across different levels of socio-economic indicators (i.e., World Bank classification, Human Development Index, and the Gini Index). World Bank classifications include low income (Kenya), lower-middle income (India), upper-middle income (Brazil, China, Colombia, South Africa), and high income (Australia, Canada, Finland, Portugal, the United Kingdom (U.K.), and the United States (U.S.)). Human Development Index is a composite score based on life expectancy, gross national income, literacy, and school participation. Countries included in ISCOLE were classified as low (Kenya), medium (China, India, and South Africa), high (Brazil and Colombia) and very high (Australia, Canada, Finland, Portugal, the U.K., and the U.S.) in their Human Development Index. Finally, the Gini Index reflects unequal distribution of income within a country, with 0 representing perfect equality, and 100 representing perfect inequality. ISCOLE countries range from 26.9 (Finland) to 63.1 (South Africa).

Details on participant recruitment and sampling strategy can be found in the ISCOLE methods paper.[1] In brief, data collection occurred from September 2011 through to December 2013 with a goal of recruiting at least 500 participants, aged 9-11 years, from each study site. Data collection strategies varied slightly by ISCOLE site; details on site-specific recruitment strategies can be found in the ISCOLE methods paper.[1] Sites made an effort to stratify their sample by indicators of socio-economic status to maximize variability, and generally had a goal of including at least 20 schools, with approximately 25-30 children per school.[1] Many countries included both private and public schools, although all sites limited their data collection to large cities, and urban or suburban schools (i.e., no country collected data from participants living in remote or rural areas, or attending rural schools). The ISCOLE coordinating center, located at the Pennington Biomedical Research Center in Baton

Rouge, Louisiana, was responsible for overall administration of the study. This project was approved by the relevant research ethics boards at Pennington Biomedical Research Center, at each ISCOLE study site, and at the respective school boards. Written informed parental consent and child assent were obtained for all participants.

ISCOLE variables used for the present analysis were limited to those common in national surveys and surveillance systems, including: body mass index (BMI), household income, physical activity and screen time. Anthropometric variables (height, weight, BMI) were collected and calculated following standard procedures and measurement tools.[1] Height (to the nearest 0.1cm) was measured using a Seca213 portable stadiometer (Hamburg, Germany); weight (to the nearest 0.1kg) was measured using a portable TanitaSC-240 Body Composition Analyzer (Arlington Heights, IL, USA). BMI was calculated and weight status was determined using various cut-points (e.g., World Health Organization, Center for Disease Control and Prevention) to maximize comparability with nationally representative data.

Accelerometer derived variables (light-, moderate- and vigorous-intensity physical activity, and step counts) were obtained via 24-hour wear protocol using the hip-worn ActiGraph GT3X+ triaxial accelerometer (ActiGraph LLC, Pensacola, FL, USA).[4] Data reduction strategies limited the analytical dataset to participants who provided at least four days of valid measurements (including at least one weekend day), with at least 10 hours per day of waking wear time.[5,6] Data were collected at a sampling rate of 80Hz, downloaded in 1-second epochs, and aggregated to 15-second epochs for analysis.[7] Step counts were calculated using the default filter. To maximize within country comparisons, accelerometer cut-points were matched to the country-level data.

Data on behavioral characteristics (i.e., self-reported physical activity, and screen time) were obtained via a child-report questionnaire. Child-reported screen time was determined from a Diet and Lifestyle Questionnaire, with questions taken from the U.S. Youth Risk Behavior Surveillance System.[1,8] Children were asked how many hours they typically watched TV, and how many hours they played video games and/or used the computer during their discretionary time, per weekday, and per weekend day. Children were also asked to self-report the number of days they engaged in at least 60 minutes of moderate- to vigorous-intensity physical

activity. Socio-economic status was measured via parent-reported household income. Further details on all measurement procedures and questionnaires used in ISCOLE can be found elsewhere.[1] For the purpose of this work, physical activity guidelines were defined as ≥60 minutes of daily moderate- to vigorous-intensity physical activity and sedentary behavior guidelines were defined as ≤2 hours of self-reported recreational screen time per day. These guidelines are consistent with those from many countries, including Australia,[9] Canada,[10,11] the U.K.,[12] the U.S.,[13] and the World Health Organization.[14]

Nationally representative data

To gain access to nationally representative data, and to understand the intricacies of the datasets, the primary investigator from each ISCOLE study site was asked to provide information for their respective country. As the primary investigators for ISCOLE were chosen based on their expertise in paediatric obesity research, it was believed that they would be aware of relevant studies and data sources. They were asked to use their best judgement when identifying information; however, some of the available nationally representative data may be considered to be out of date. The writing group for this paper agreed that it was more important to have comparable and well-collected data (e.g., similar age group, directly measured variables) than to necessarily have the most recent data. Furthermore, methods for data collected in other studies may differ from methods for data collection in ISCOLE. Summaries of the studies used for comparison in the present analysis can be found in Additional File 2. Where possible, reviews and/or summary papers were used to help inform our comparisons.

When no data were available, cells were left blank. It is important to note that all variables included in this paper were identified *a priori* and deemed the most relevant to the ISCOLE project and most likely to be captured in other studies. Therefore, some countries have a greater number of empty cells than other countries, and this may highlight a paucity of robust data in certain areas.

Results

ISCOLE data were available for 9-11-year-old children from Australia (n=516), Brazil (n=541), Canada (n=541), China (n=537), Colombia (n=905), Finland (n=525), India (n=584), Kenya (n=563), Portugal (n=724),

South Africa (n=513), the U.K. (n=508), and the U.S. (n=554). Characteristics of ISCOLE countries can be found in Table 1, and characteristics of participants from each ISCOLE country can be found in Table 2. As per ISCOLE study design, included countries vary considerably in their population size, and socio-economic status. The proportion of children overweight or obese, accelerometer-determined steps per day, and the proportion of children exceeding current screen time guidelines are presented in Figures 1-3, respectively. Figure 4 shows the proportion of children that self-reported meeting physical activity guidelines (i.e. 60 minutes of moderate- to vigorous-intensity physical activity per day) in ISCOLE, and in the HBSC.

Initially, this study aimed to compare household income between ISCOLE study participants, and their representative country data (or representative city, within the country); however, because ISCOLE included household income as a categorical variable, it was impossible to determine a sample mean, and therefore impossible to deduce a value that was comparable to what was commonly obtained in other studies. We have presented the most common income category for each site (Table 2).

Europe *(Finland, Portugal, United Kingdom)*

All of the ISCOLE site countries in Europe were classified as high-income countries. They were also all part of the HBSC survey,[3] and Finland and the U.K. (England) were able to provide a summary of comparable data for physical activity and screen time via their 2014 Report Card on Physical Activity in Children and Youth.[15,16]

Based on the results from HBSC, Finland provided self-reported data showing that 24% of Finnish children aged 11-15 years met physical activity guidelines,[3] which is very similar to 25.8% of ISCOLE children who self-reported that they met physical activity guidelines. Additional data from Tammelin et al., and the Foundation for Sport and Health Science, found that Finnish children (aged 9-10 years) accumulated 10,506 steps per day, compared to 10,485 steps per from ISCOLE participants. Data looking at screen time came from the 2010 HBSC, which reported that 61% of 11 year-old boys, and 58% of 11 year-old girls self-reported that they exceeded screen time recommendations on weekdays. This was lower than in ISCOLE, which showed that 84% of boys, and 74% of girls exceeded the recommendation. We were unable to find any comparable data

reporting the proportion of Finnish children considered overweight or obese. Therefore, data from ISCOLE Finland are consistent with previous data for physical activity, provide slightly higher estimates for screen time, and inconclusive with respect to weight status.

Portugal was able to provide data from the HBSC study. According to HBSC self-reported behaviors, 23% of boys, and 14% of girls are meeting physical activity guidelines, a proportion that is much higher than self-report data from ISCOLE (8.9% of boys and 4.3% of girls).[3] Reports from HBSC suggest children are watching more TV (61% of boys and 60% of girls exceed screen time guidelines) compared to ISCOLE participants (55.3% of boys and 43.0% of girls exceed screen time guidelines). Regarding weight status, Portugal was able to provide comparable data from the Plataforma Contra a Obesidade.[17] This showed similar proportions of children considered overweight or obese for boys (50.0% compared to 51.4% in ISCOLE) and girls (45.3 versus 42.3% in ISCOLE). Overall, participants from ISCOLE Portugal reported lower levels of physical activity, but similar levels of screen time, and a similar proportion of children were considered overweight or obese compared to other surveys.

Because the ISCOLE site in the U.K. was based in England, we aimed to obtain comparable data from England, rather than across the U.K.. Data from England came primarily from the Millennium Cohort Study (MCS), with additional data coming from HBSC. According to the MCS, boys averaged 10,739 steps/day and girls averaged 9,699 steps per day.[18] This was very similar to what was seen in ISCOLE with boys averaging 10,675 steps per day and girls averaging 9,435 steps per day. Self-reported data from HBSC showed that 33% of boys and 20% of girls met physical activity guidelines,[3] whereas in ISCOLE, only 19% of boys and 11% of girls self-reported that they met the guidelines. With respect to sedentary behavior, results from the HBSC showed that 64% of boys, and 60% of girls exceeded screen time guidelines on week days;[3] results from ISCOLE show that 86% of boys, and 80% of girls exceeded the guidelines. Compared to data from the National Child Measurement Programme, there was a lower proportion of children considered overweight or obese in ISCOLE (33.3% versus 21.7% respectively).[19] Data from ISCOLE seem to be comparable with respect to physical activity levels, but with higher levels of screen time. However, even if ISCOLE participant characteristics are

comparable to characteristics of children from the rest of England, it can be assumed that there are variations in the socio-cultural environment across the rest of the U.K and it is recommended that generalizations to a wider population are made only with appropriate caution.

Africa *(Kenya, South Africa)*

Kenya was the only study included in ISCOLE considered to be a low-income country; South Africa is considered to be an upper-middle income country. Neither Kenya, nor South Africa identified any nationally representative, or large datasets for comparison. Summaries of the best available evidence for each country was presented in their 2014 Report Card on Physical Activity in Children and Youth and included primarily early results from ISCOLE, suggesting future studies are critically needed.[20,21]

Comparisons for ISCOLE Kenya came from two systematic reviews examining obesity and physical activity transitions in Sub-Saharan Africa.[22,23] One systematic review reported a range of 35-72% of children meeting physical activity guidelines,[22] which is higher than the 11.4% of children who self-reported meeting the guidelines in ISCOLE. The only data we could identify that examined screen time was from and showed that 53.6 % of children exceeded screen time guidelines. However, this may be due to the fact that ISCOLE only sampled from urban and suburban areas as previous research on Kenyan children suggests that screen time is much lower in rural areas.[24] The systematic review examining the overweight and obesity transition included studies that reported proportions of overweight/obesity between 3.2-12.0%,[23] which is lower than 16% found in ISCOLE. Even though there were little comparable data available in Kenya, Nairobi is an urban hub, with a population of over 3 million people, and one could assume that children from urban Nairobi may not be representative of their rural peers.

Although South Africa was notable to provide any nationally representative data, information from smaller studies, summarized in their Report Card suggest that 50-59% of children are meeting physical activity guidelines, and <50% of children are meeting screen time guidelines.[21] These values are more promising than what was shown in ISCOLE, which found that 26.4% of children self-reported meeting physical activity guidelines, and 36.7% reported meeting screen time guidelines. Data from the 2010 Survey of Time of Use

suggest that on average, children aged 10-17 years watched 3 hours of TV per day.[25] In ISCOLE, children were asked to self-report habitual TV, video game, and computer use with the highest possible value being "≥5 hours per day". Therefore for analysis, self-reported screen time was presented as a score, rather than total hours of screen time since after 5 hours per day, we could not ascertain the participant's actual amount of screen time. Although ISCOLE can only provide an approximate value for daily screen time, it did appear to be similar to what was reported in the Time of Use survey with children averaging approximately 3.1 hours of screen time and 2.0 hours of TV time per day. We were not able to find any comparable data with respect to weight status. Therefore, overall, children from ISCOLE seem to be slightly less active than reported in other studies, but seem to engage in similar amounts of screen time.

The Americas *(Brazil, Canada, Colombia, and the United States)*

Canada and the U.S. are both considered high-income countries; whereas Colombia and Brazil are both considered upper-middle-income countries. The Americas, especially Canada and the U.S., were able to provide a significant amount of comparable and nationally representative data. Canada and the U.S. are both included in the HBSC, and both have directly measured, nationally representative surveys (CHMS: Canadian Health Measures Survey[26], NHANES: National Health and Nutrition Examination Survey (U.S.)).

Brazil provided comparable data for weight status from the Brazilian Institute of Geography and Statistics (BIGS),[27] but was unable to provide comparable data for physical activity, or screen time. BIGS reported that 33.1% of their children were considered overweight or obese, compared to a much higher 45.7% of children considered overweight or obese in ISCOLE.

Comparable data for Canada came primarily from the CHMS (with custom analysis for their Report Card[28]) and showed that only 5% of school-aged children met current Canadian physical activity guidelines.[10,29]Self-reported data from HBSC showed 31% of boys, and 21% of girls met the physical activity guidelines, which was similar to data from ISCOLE, with 26% of boys, and 18% of girls self-reporting they met guidelines. With respect to screen time, data came from the 2007-2009 CHMS and showed that 31% of children aged 5-11 years exceed screen time guidelines.[30] This was slightly lower than what was seen in ISCOLE Canada,

with 54.4% of boys, and 40.2% of girls exceeding guidelines. There was a slightly lower proportion of children considered overweight or obese in ISCOLE (21.9% of boys and 21.7% of girls), compared to reports from the CHMS (31% for boys and 26% for girls). In Canada, ISCOLE participants engaged in similar amounts of physical activity, greater amounts of screen time, and had a lower proportion of children considered overweight or obese.

Comparable data for levels of physical activity in Colombia came from the ENSIN study (Encuesta Nacional de la Situación Nutricional (National Survey of Nutritional Status)),[31] and showed that 26% of children self-reported that they met physical activity guidelines, which is higher than what was seen in ISCOLE (12% meeting guidelines). The ENSIN study also provided comparable data with respect to screen time and weight status. For screen time, ENSIN showed that fewer children (59.4% of boys, and 56.3% of girls) exceeded screen time guidelines than children from ISCOLE (71.6% of boys, and 60.4% of girls).[32] ENSIN also reported a lower proportion of children being overweight or obese than ISCOLE (17.5% in ENSIN compared to 23.3% in ISCOLE).[32] Overall, it appears that children in ISCOLE engage in less physical activity, more screen time, and are more likely to be overweight or obese than other Colombian children.

Comparable data for U.S. physical activity levels came primarily from the 2003-2004 NHANES (National Health and Nutrition Examination Survey). Accelerometer data showed that 42.0% of children aged 6-11 years were meeting physical activity guidelines,[33,34] and on average, boys were accumulating approximately 13,000 steps per day, and girls were accumulating approximately 12,000 steps per day. This was substantially higher than what was seen in ISCOLE, with boys accumulating only 9,261 steps per day, and girls accumulating only 8,078 steps per day. With respect to screen time, data were presented from the 2009-2010 NHANES and showed that 47.8% of children aged 9-11 years self-reported that they exceeded screen time guidelines.[35] The proportion of children meeting guidelines was lower in ISCOLE, and in HBSC for both boys and girls (Figure 2). In ISCOLE, 68.3% of boys exceeded screen time guidelines, and 56.2% of girls exceeded screen time guidelines. Compared to NHANES, we saw a similar proportion of children considered overweight or obese in ISCOLE (NHANES: boys = 33.2%, girls = 35.2%; ISCOLE boys = 32.4%, girls = 35.6%). In the U.S. sample of ISCOLE,

children were less active, and were less likely to meet screen time guidelines, but had similar weight status to children from across the country.

South Asia *(India)*

India is the only study site in South Asia, and is considered a lower-middle-income country. We could not identify any nationally representative or large datasets for comparison with ISCOLE data. Data collected in ISCOLE show that 28.4% of Indian children are meeting physical activity guidelines, 30.8% are meeting screen time guidelines, and 33.7% are considered overweight or obese.

Western Pacific *(Australia, China)*

Australia is considered a high-income country and China is considered an upper-middle-income country. Australia provided comparable data via the ANCNPAS (Australian National Children's Nutrition and Physical Activity Survey),[36] the National Health Services,[37] and a summary of current evidence via their 2014 Report Card on Physical Activity in Children and Youth.[38] China was able to provide comparable data via the China Health and Nutrition Survey (CHNS).

Comparable data from Australia came primarily from the Australian Bureau of Statistics. This data showed that 20% of children aged 5-17 years self-reported that they met physical activity guidelines.[37] This is consistent with self-reported data from ISCOLE. Australia was also able to provide information from the ANCNPAS showing higher values for number of steps per day (12,230 in ANCNPAS compared to 10,262 in ISCOLE).[36] With respect to screen time, data from the Australian Bureau of Statistics showed that 70% of children aged 5-17 years old exceeded screen time guidelines. This was higher than what was seen in ISCOLE, with only 56% of children exceeding the guidelines. Data from ANCNPAS reported 28.4% of children to be overweight or obese, which is similar to 26.7% of children considered overweight or obese in ISCOLE. Overall, participants from ISCOLE accumulated similar amounts of physical activity, had lower screen time, and had more favourable weight status than their Australian peers.

China provided comparable data on physical activity, screen time, and weight status via the CHNS (China Health and Nutrition Survey).[39,40] For 6-11 year-olds, the CHNS reported children averaged 60 minutes

(boys), and 48 minutes (girls) of physical activity per day, compared to lower levels in ISCOLE (49.5 minutes for boys and 40.5 minutes for girls). Results for screen time showed that 24.9% of boys and girls exceeded screen time guidelines, compared to 35.1% in ISCOLE. However, it is interesting to note that these data came from 2004, and in a longitudinal analysis, the proportion of children who reported >2 hours of screen time per day rose from 5.8% in 1997, to 24.9% in 2004, suggesting data from present day may be more comparable. With respect to weight status, the proportion of children considered overweight or obese was much higher in ISCOLE than in the CHNS (ISCOLE boys = 50.1%, ISCOLE girls = 30.6%, versus CHNS boys = 16.6% and HBSC boys = 10.9%). ISCOLE China participants accumulated slightly less physical activity and slightly more screen time than other estimates; however, the difference (in screen time at least), may be because ISCOLE data collection has occurred more recently, and may not reflect a true difference. The proportion of ISCOLE participants considered overweight or obese was much higher than previous estimates. It should be noted that data for ISCOLE China came from one large city and all participants came from only six separate schools. This was the fewest number of schools included in any ISCOLE site and could contribute to the differences seen between ISCOLE children and their peers.

Discussion

This study aimed to compare data collected in ISCOLE to data collected via nationally representative studies in all ISCOLE study sites. Of the 12 ISCOLE countries, eight provided data on weight status (BMI), five provided data on objectively measured physical activity (steps per day), and nine provided data on self-reported screen time. The five ISCOLE countries that were part of the HBSC survey provided additional data for self-reported physical activity (meeting physical activity guidelines). When data were available, mean data from ISCOLE study appears to be relatively similar to country-level data; however, this varied with data availability and quality, and there were no systematic differences across countries or variables. Few countries used the same cut-points or measurement tools in their national studies as ISCOLE when analysing participant characteristics. Where possible, the ISCOLE data were re-analysed to match other country-level data, but this limited the possibility to make comparisons across countries.

Initially, the aim of this study was to compare data from ISCOLE sites to nationally representative data in the site country, to get a crude evaluation of the potential bias in the ISCOLE sample. However, it quickly became apparent that many countries do not collect nationally representative data on physical activity, screen time, or weight status. When data were available, it was collected using different tools or with different methods. For example, we aimed to compare accelerometer measured daily moderate- to vigorous-intensity physical activity (minutes per day); however, after scoping the literature for comparable country level data, this was not possible. Due to the range of different models of accelerometers, and the different cut-points used to distinguish activity intensity, only two countries (the U.S., and Canada) were able to provide comparable data. No countries that could provide nationally representative accelerometer measured physical activity data used common cut-points. Therefore, we opted to examine physical activity via steps per day, which can be measured using an accelerometer, or a pedometer. The added benefit of examining steps per day is that the cost of pedometers is quite low, making it more feasible to use them in large, population based studies, or in times where resources are limited. This work highlights the need for standardized measurement tools around the world while accounting for cultural specific characteristics, and the need for collaboration across study centres and research groups. Even with standardized measurement tools, it is important to remember that technology is constantly evolving and expanding our abilities to monitor human movement behavior. This technology should be embraced, while at the same time trying to ensure consistency with previous work.

This work has several strengths and limitations. The initial aim of this paper was to compare results from ISCOLE study sites to data from representative study samples in each ISCOLE country; however, many countries could not provide any comparable data. This meant that many comparisons could not be made, and nothing could be said about the comparability or generalizability of ISCOLE findings. Further, in most cases we did not have access to the raw data from nationally representative surveys and could not complete any formal statistical analysis. This leaves our comparisons open interpretation, and our judgement on similarities (or differences) in the data open to criticism. However, we believe this also highlights an important limitation of international research programs – the inconsistencies in measurement tools and cut points across different

research centres, and countries, and the unavailability of raw data. Most of the studies included in this work used different methodologies, and different cut points to assess similar health variables. For example, BMI is a common measure of adiposity in children, yet there are four different cut points used, all of which provide different prevalence of overweight/obesity.[41] ISCOLE recruitment was also limited to urban and suburban schools, and therefore we cannot account for populations living in rural areas. Previous work has consistently shown differences in obesity and lifestyle habits between these two groups, and that these differences may be most important in developing areas.[42–44]

Finally, results of many of the surveys included here have not been included in the peer-reviewed literature; some have been included in governmental reports, and some have only been disseminated via online websites. Governments should ensure that there is sufficient budget for researchers to publish and disseminate the results of their studies after the data have been collected, or at the very least, provide open-access to the raw data so researchers are able to analyse it themselves. This may require continued funding for some studies that require complex statistical analysis or content experts to interpret the findings.

A major strength of this paper is with the information it provides to researchers about current gaps in knowledge. From this work, countries can see where they are leading (or lagging), and where they need to focus more resources in pediatric research. This provides a valuable tool when developing future research programs and can help inform public health interventions. Another strength of this work is related to the rigour of the ISCOLE data collection and management procedures.[1] The ISCOLE framework and coordinating center ensured all study sites, and all ISCOLE researchers, completed mandatory training for all aspects of the study. ISCOLE represents the most culturally and geographically diverse, up-to-date, and robust study on lifestyles associated with obesity-related health in children.

Conclusions

This manuscript was designed as a methodological and ecological comparison study that may be used to provide evidence of the potential bias from each ISCOLE country sample, facilitating future intra- and inter-country comparisons. Due to the limited availability of country-level data, it is suggested that ISCOLE data be

used with appropriate caution when planning countrywide population health interventions. However, for many countries ISCOLE currently provides the most up-to-date and most robust data on obesity and physical activity in children. This work has identified the paucity of comparable country data around the world and highlighted the importance of large, multi-national studies like ISCOLE. Moving forward, we recommend that researchers harmonize procedures for data collection and analysis. It is important to use the momentum, and collaborations that were built in ISCOLE to inform public health interventions, as well as other cross-sectional, surveillance surveys.

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Table 1: ISCOLE country characteristics

Country	National population*	ISCOLE site location	Population of ISCOLE site location**	World bank classification§	Large and/or National study/studies
Europe					
Finland	5,442,322	Helsinki, Espoo, Vantaa	1,060,701	High-income	HBSC
United Kingdom	63,705,000	Bath, North East Somerset	177,700	High-income	ENERGY, HBSC¥, HELENA, IDEFICS, MCS
Portugal	10,562,178	Porto	237,584	High-income	EYHS[j], HBSC,
Africa					
Kenya	44,354,000	Nairobi	3,138,369	Low-income	None available
South Africa	52,981,991	Cape Town	3,497,097	Upper-middle-income	Time of Use survey
The Americas					
Canada	35,158,304	Ottawa	883,391	High-income	CHMS, HBSC
United States	316,783,000	Baton Rouge	802,484	High-income	CHBSC, NHANES, YRBS
Colombia	47,262,816	Bogotá	7,674,366	Upper-middle-income	ENSIN
Brazil	201,032,714	Sao Caetano do Sul	149,263	Upper-middle-income	BIGS
South Asia					
India	1,242,456,566	Bangalore	9,588,910	Lower-middle-income	None available
Western Pacific					
China	1,362,620,526	Tianjin	10,290,987	Upper-middle-income	CNNS
Australia	23,235,207	Adelaide	1,212,982	High-income	AHS, ANCNPAS

AHS: Australian Health Survey; ANCNPAS: Australian National Children's Nutrition and Physical Activity Survey; BIGS: Brazilian Institute of Geography and Statistics; CNNS: China National Nutrition Survey; CHMS: Canadian Health Measures Survey; ENERGY: EuropeaN Energy balance Research to prevent excessive weight Gain among Youth; ENSIN: Encuesta Nacional de la Situación Nutricional (National Survey of Nutritional Status); IDEFICS: identification and prevention of dietary- and lifestyle induced health effects in children and infants; HBSC: Health Behavior in School-aged Children; HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescents; MCS: Millennium Cohort Study; NHANES: National Health and Nutrition Examination Survey.

*Population estimate accessed October 2014.

**Represents the population size of the city or general area where children were sampled.

§ World Bank classification represents.

¥Since the U.K. ISCOLE site was in England, the corresponding HBSC data was taken from HBSC England site.

Table 2: ISCOLE participant characteristics

Study site	Participants (*n*, % boys)	Age (years) (mean, SD)	Weight status (%)*	Combined annual household income**	Approximate equivalent in U.S. dollars
Europe					
Finland	536 (47.2%)	10.0 (0.4)	Normal weight: 74.6 Overweight/obese: 23.7	Less than 20,000€: 5.5% 80,000€ and above: 40.9%	$26,000: 5.5% $104,000 and above: 40.9%
United Kingdom	525 (45.1%)	10.4 (0.5)	Normal weight: 68.5 Overweight/obese: 30.3	Less than £10,000: 9.4% £10,000 - £19,999: 17.3% £90,000 and above: 8.1%	Less than 16,500: 9.4% $16,500-$32,998: 17.3% $148,500 and above: 8.1%
Portugal	777 (46.1%)	10.0 (0.3)	Normal weight: 52.5 Overweight/obese: 47.2	Under €6,000: 20.5% € 6,000 - € 11,999: 30.9% €42,000 and above: 5.5%	Under $7,800: 20.5% $7,800-15,599: 30.9% $54,6000 and above: 5.5%
Africa					
Kenya	563 (46.5%)	9.8 (0.7)	Normal weight: 75.1 Overweight/obese: 21.1	Less than Ksh. 121,980: 23.2% Ksh 6,000,000 and above: 3.5%	Less than $1,342: 23.2% $66,000 and above: 3.5%
South Africa	550 (40.1%)	9.8 (0.7)	Normal weight: 71.2 Overweight/obese: 26.4	Less than R11,500: 47.8% More than R500,000: 7.6%	Less than $1,081: 47.8% $47,000 and above: 7.6%
The Americas					
Canada	565 (42.2%)	10.0 (0.4)	Normal weight: 68.7 Overweight/obese: 30.8	Less than $14,999: 2.9% $140,000 and above: 38.4%	Less than $13,799: 2.9% $128,800 and above: 38.4%
United States	651 (43.2%)	9.5 (0.6)	Normal weight: 58.4 Overweight/obese: 41.3	Less than $10,000: 20.4% $ 140,000 and above: 21.6%	N/A
Colombia	919 (49.4%)	10.0 (0.6)	Normal weight: 75.7 Overweight/obese: 22.9	$0-$1.200.000: 0.7% $ 4.800.000 - $ 8.400.000: 29.4% $36.000.000 and above: 8.8%	$0-$624: 0.7% $2,496-$4,368: 29.4% $18,720 and above: 8.8%
Brazil	584 (49.1%)	10.1 (0.5)	Normal weight: 52.8 Overweight/obese: 45.2	Under R 6.54,00: 3.1% R$6.540,00 - R$19.620,00: 35.1% R: 85.020,01 and above: 4.4%	Less than $2,943: 3.1% $2,943-$8,829: 35.1% $38,259 and above: 4.4%
South Asia					
India	620 (47.1%)	10.0 (0.6)	Normal weight: 61.5 Overweight/obese: 33.7	Less than Rs 60000: 2.8% Rs720000 – and above: 37.6%	Less than $1,020: 2.8% $12,240 and above: 37.6%
Western Pacific					
China	552 (53.1%)	9.4 (0.5)	Normal weight: 56.3 Overweight/obese: 41.2	Less than ¥20,000: 18.1% ¥20,000 - ¥39,999: 18.1% ¥ 150,000 and above: 10.4%	Less than $3,200: 18.1% $3,200-$6,400: 18.1% $24,000 and above: 10.4%
Australia	528 (46.0%)	10.3 (0.5)	Normal weight: 61.4 Overweight/obese: 37.9	Less than $10,000: 2.1% $70,000 to $89,999: 17.0% $140,000 and above: 21.7%	Less than $9,300: 2.1% $65,100-$83,699: 17.0% $130,200 and above: 21.7%

* Weight status defined by World Health Organization cut-points[41]

** Presented as percent of participants in the lowest, highest, and median income categories. If the median income category was also the lowest, or the highest, only two income categories are presented see Figure 5 for income distribution and Additional file 1 for additional information.

Figure legends

Figure 1

Title: Proportion of children considered overweight or obese from ISCOLE study sites and their representative countries.

Legend: Dark grey bars indicate data from ISCOLE participants; white bars represent country-level data. If no white bar, then country level data are not available. Where available, data are presented for both boys and girls. Data were analyzed as per BMI cut-points available in each country as follows. World Health Organization: Portugal, Colombia, Brazil; International Obesity Task Force: Canada, Australia; Center for Disease Control and Prevention: United States; other: United Kingdom (British 1990 growth reference[19]), China (China BMI criteria, overweight ≥19.4, obese ≥22.2).[45] Country level datasets included: U.K.: National Child Measurement Programme;[19] Portugal: Plataforma Contra a Obesidade;[46] Canada: Canadian Health Measures Survey;[47] U.S., National Health and Nutrition Examination Survey; Colombia: Encuesta Nacional de la Situación Nutricional; Brazil: Brazilian Institute of Geography and Statistics;[27] China: China Health and Nutrition Survey;[45] Australia: Australian National Children's Nutrition and Physical Activity Survey.[36] BMI: Body Mass Index. See Additional file 3 for additional study details for country level data.

Figure 2

Title: Daily physical activity (steps per day) from ISCOLE study sites and their representative countries

Legend: Dark grey bars indicate data from ISCOLE participants; white bars represent country-level data. If no white bar, then country level data were not available. Where available, data are presented for both boys and girls. Horizontal black line represents mean steps per day for all ISCOLE participants; horizontal dashed line represents target of 12,000 steps per day recommended to meet current physical activity guidelines.[48] Data were included if it was collected via pedometer or accelerometer, and presented as sample mean. Country level datasets included: Finland: Physical Activity of School Aged Children;[49] United Kingdom: Millennium Cohort Study;[18] Canada: Canadian Health Measures Survey;[30] U.S.: National Health and Nutrition Examination

Survey;[50] Australia:Australian National Children's Nutrition and Physical Activity Survey.[36] The Millennium Cohort Study also provided data for England: 10,147 steps per day compared to 9982 steps per day in ISCOLE.See Additional file 4 for additional study details for country level data.

Figure 3

Title: Proportion of children exceeding screen time guidelines (>2 hours per day) from ISCOLE sites and their representative countries.

Legend: Dark grey bars indicate data from ISCOLE participants; white bars represent country-level data. If no white bar, then country level data were not available. Where available, data are presented for both boys and girls. Horizontal black like represents mean proportion of all ISCOLE participants who exceed screen time guidelines. Country level datasets included: Canada, Finland, the U.K., and the U.S.: Healthy Behaviors in School-aged Children;[3] South Africa: Time of Use survey;[25] Colombia: Instituto Colombiano de Bienestar Familiar (ICBF); China: China Health and Nutrition Survey;[51]Australia: Australian Bureau of Statistics.[37]See Additional file 5 for additional study details for country level data.

Figure 4

Title: Proportion of girls (Panel A) and boys (Panel B) who self-reported that they engage in at least 60 minutes of moderate- to vigorous-intensity physical activity every day of the week.

Legend: Dark grey bars indicate data from ISCOLE participants; white bars represent data that were adapted from the HBSC survey.[3] MVPA: moderate- to vigorous-intensity physical activity.

Figure 1

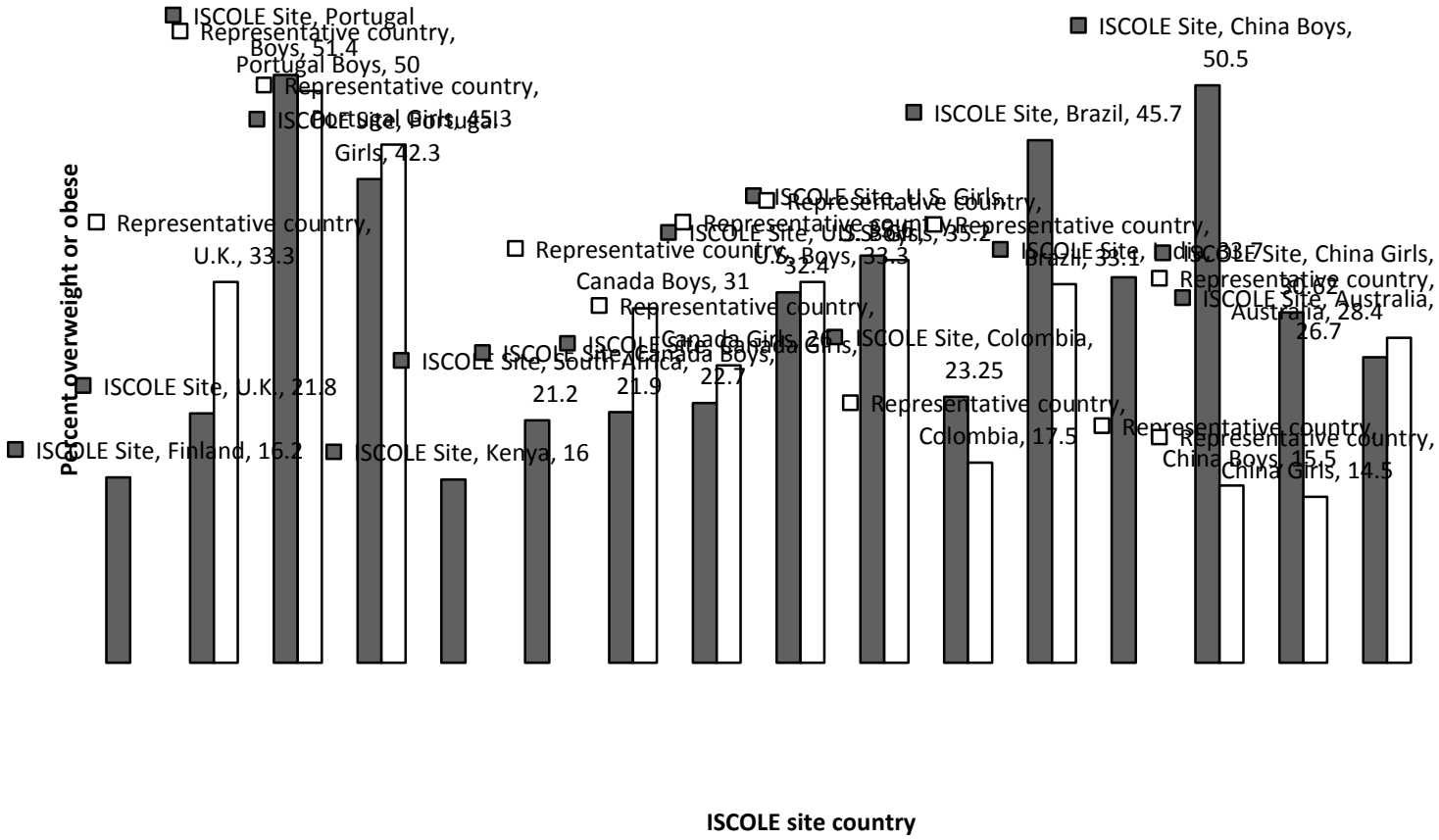

Percent overweight or obese
ISCOLE site country
ISCOLE Site, Portugal
Representative country, Portugal Boys, 50
ISCOLE Site, Portugal Girls, 42.3
Representative country, U.K., 33.3
ISCOLE Site, U.K., 21.8
ISCOLE Site, Finland, 16.2
ISCOLE Site, Kenya, 16
ISCOLE Site, South Africa, 21.2
Representative country, Canada Boys, 31
ISCOLE Site, Canada Girls, 21.9
ISCOLE Site, U.S. Girls, 32.4
ISCOLE Site, Colombia, 23.25
Representative country, Colombia, 17.5
ISCOLE Site, Brazil, 45.7
ISCOLE Site, China Boys, 50.5
Representative country, China Boys, 15.5
ISCOLE Site, China Girls, 14.5
ISCOLE Site, Australia, 26.7

Figure 2

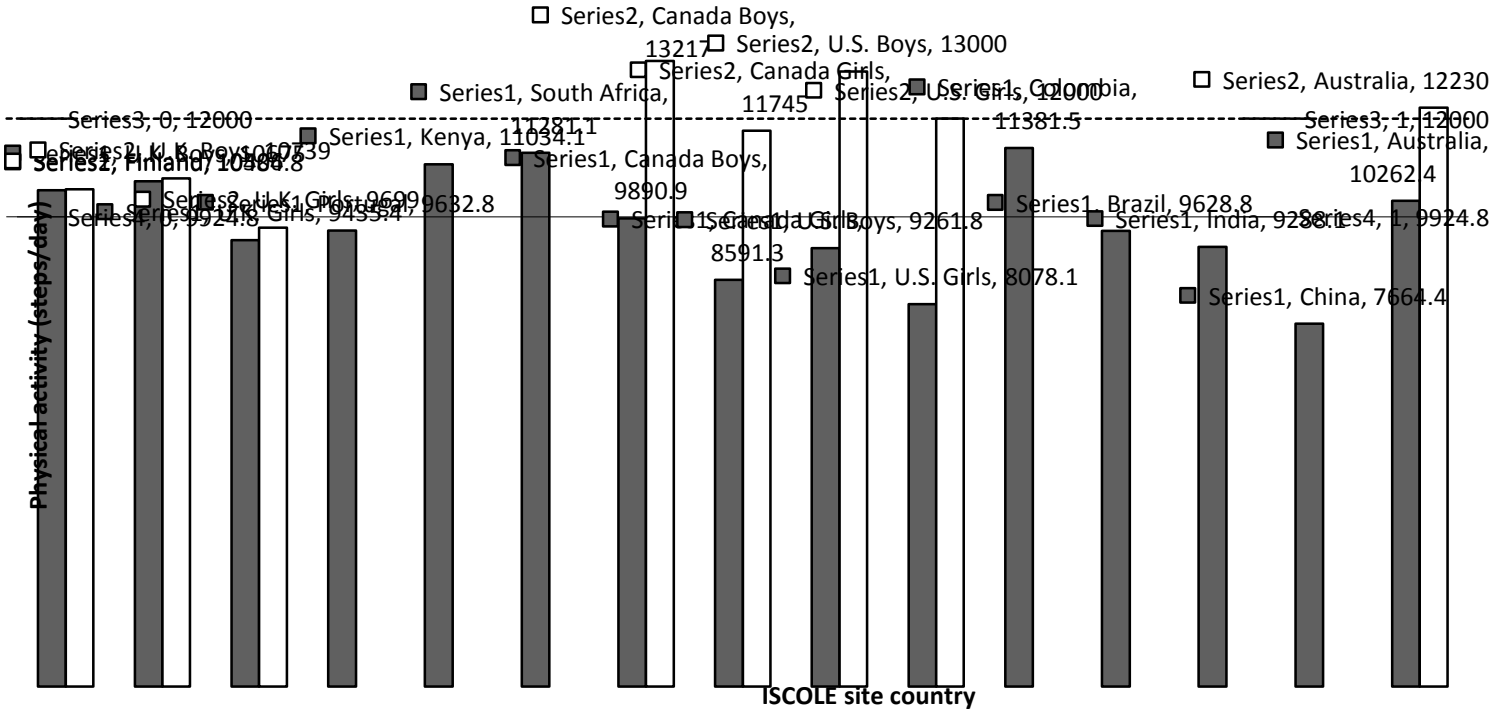

Series2, Canada Boys, 13217
Series2, U.S. Boys, 13000
Series2, Canada Girls, 11745
Series2, U.S. Girls, 12000
Series2, Australia, 12230
Series1, South Africa, 11281.1
Series1, Colombia, 11381.5
Series3, 0, 12000
Series3, 1, 12000
Series1, Kenya, 11034.1
Series1, Australia, 10262.4
Series1, Canada Boys, 9890.9
Series1, Brazil, 9628.8
Series1, India, 9238.1
Series4, 1, 9924.8
Series1, Canada Girls, 9261.8
8591.3
Series1, U.S. Girls, 8078.1
Series1, China, 7664.4
Physical activity (steps/day)
ISCOLE site country

Figure 3

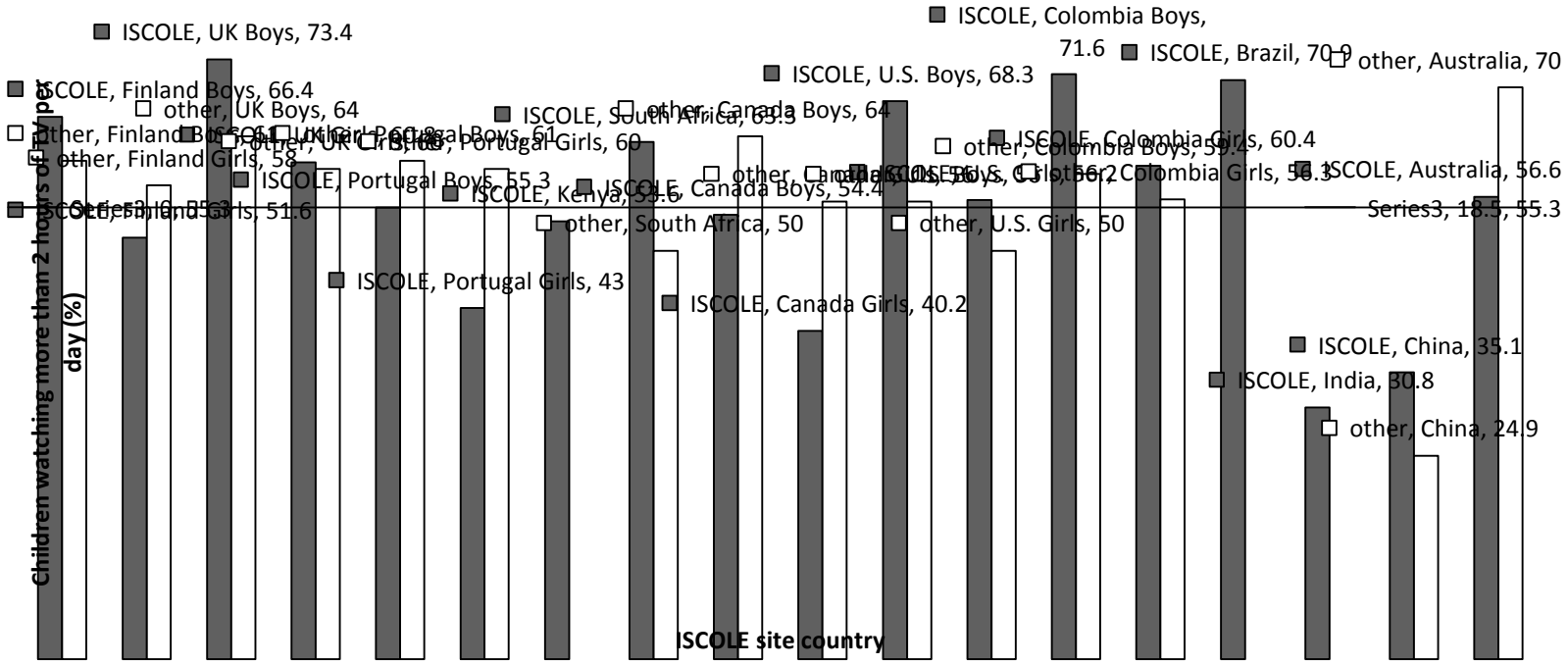
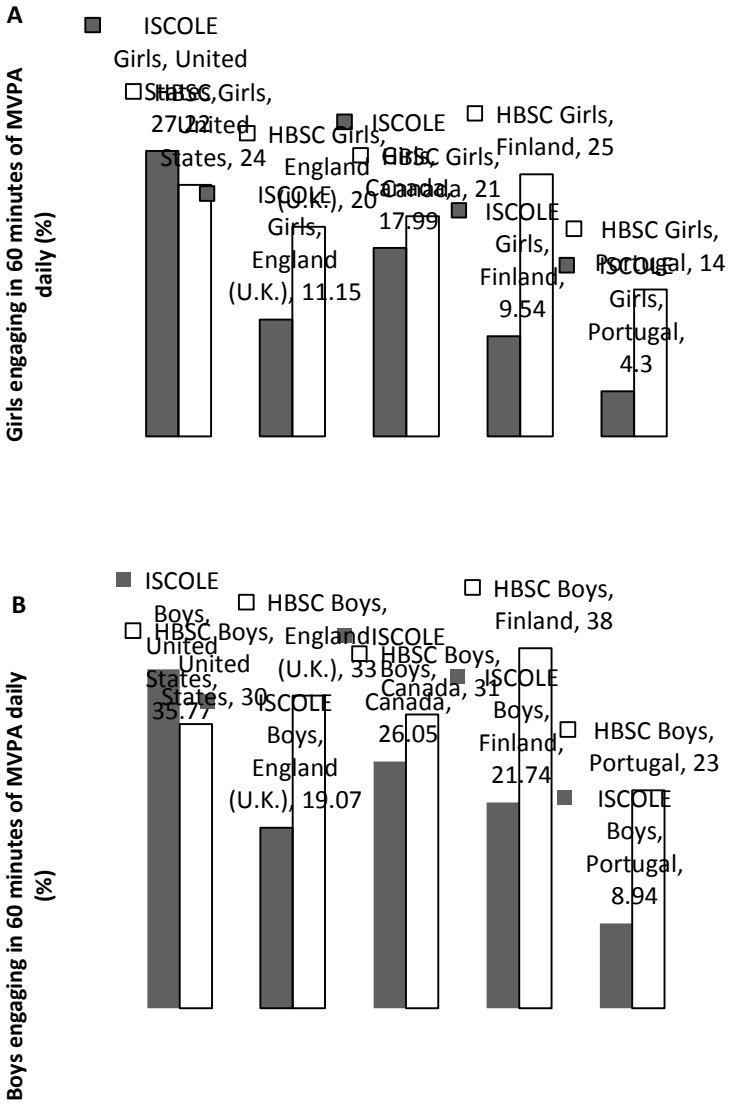

ISCOLE, UK Boys, 73.4
ISCOLE, Finland Boys, 66.4
other, UK Boys, 64
ISCOLE, Portugal Boys, 55.3
other, Finland Girls, 58
ISCOLE, Finland Girls, 51.6
ISCOLE, Portugal Girls, 43
ISCOLE, South Africa, 65.3
other, Canada Boys, 64
other, Portugal Girls, 60
ISCOLE, Kenya, 53.6
other, South Africa, 50
ISCOLE, Canada Girls, 40.2
ISCOLE, U.S. Boys, 68.3
ISCOLE, Canada Boys, 54.4
other, U.S. Girls, 50
ISCOLE, Colombia Boys, 71.6
ISCOLE, Brazil, 70.9
other, Australia, 70
other, Colombia Boys, 59.4
ISCOLE, Colombia Girls, 60.4
ISCOLE, Australia, 56.6
Series3, 18.5, 55.3
ISCOLE, China, 35.1
ISCOLE, India, 30.8
other, China, 24.9
Children watching more than 2 hours of TV per day (%)
ISCOLE site country

Figure 4


A
Girls engaging in 60 minutes of MVPA daily (%)
ISCOLE Girls, United States, 27.22
HBSC Girls, United States, 24
ISCOLE Girls, England (U.K.), 11.15
HBSC Girls, England (U.K.), 20
ISCOLE Girls, Canada, 17.99
HBSC Girls, Canada, 21
ISCOLE Girls, Finland, 9.54
HBSC Girls, Finland, 25
ISCOLE Girls, Portugal, 4.3
HBSC Girls, Portugal, 14
B
Boys engaging in 60 minutes of MVPA daily (%)
ISCOLE Boys, United States, 35.77
HBSC Boys, United States, 30
ISCOLE Boys, England (U.K.), 19.07
HBSC Boys, England (U.K.), 33
ISCOLE Boys, Canada, 26.05
HBSC Boys, Canada, 31
ISCOLE Boys, Finland, 21.74
HBSC Boys, Finland, 38
ISCOLE Boys, Portugal, 8.94
HBSC Boys, Portugal, 23

References

1 Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput J-P, Fogelholm M *et al.* The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE): design and methods. *BMC Public Health* 2013; **13**: 900.

2 Healthy Lifestyle in Europe by Nutrition in Adolescence. http://www.helenastudy.com/.

3 Currie C, Gabhainn SN, Godeau E, Roberts RS, Currie O, Picket W *et al.* Inequalities in Young People's Health: Health Behavior in School-aged Children. International Report from the 2005 2006 Survey Health Policy for Children and Adolescents. 2008.

4 Barreira TV, Schuna JM, Mire EF, Katzmarzyk PT, Chaput J-P, Leduc G *et al.* Identifying Children's Nocturnal Sleep Using 24-h Waist Accelerometry. *Med Sci Sports Exerc* 2014. doi:10.1249/MSS.0000000000000486.

5 Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of Accelerometer Cut Points for Predicting Activity Intensity in Youth: *Med Sci Sports Exerc* 2011; **43**: 1360–1368.

6 Colley RC, Connor Gorber S, Tremblay MS. Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Rep* 2010; **21**: 63–69.

7 Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008; **26**: 1557–1565.

8 Youth Risk Behavior Surveillance System (YRBSS). US Cent. Dis. Control Prev. 2012.

9 Okely AD, Salmon J, Trost SG, Hinkley T. Discussion paper for the development of physical activity recommendations for children under 5 years. Australian Government Department of Health and Ageing: Australia, 2008.

10 Tremblay MS, Warburton DER, Janssen I, Paterson DH, Latimer AE, Rhodes RE *et al.* New Canadian Physical Activity Guidelines. *ApplPhysiolNutrMetab* 2011; **36**: 36–46.

11 Tremblay MS, LeBlanc AG, Janssen I, Kho ME, Hicks A, Murumets K *et al.* Canadian Sedentary Behavior Guidelines for Children and Youth. *ApplPhysiolNutrMetab* 2011; **36**: 59–64.

12 Bull FC, Expert Working Group. Physical activity guidelines in the U.K.: review and recommendations. School of Sport, Exercise, and Health Sciences, Loughborough University: Leichestershire, United Kingdom, 2010.

13 Pate RR PM. Physical activity and public health: A recommendation from the centers for disease control and prevention and the american college of sports medicine. *JAMA* 1995; **273**: 402–407.

14 World Health Organization. Global recommendations on physical activity for health. 2010http://www.who.int/dietphysicalactivity/publications/9789241599979/en/index.html (accessed 28 Feb2013).

15 Dept of Sport Sciences, University of Jyväskylä, Finland., Liukkonen J, Jaakkola T, Kokko S, Gråstén A, Yli-Piipari S *et al.* Results From Finland's 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health* 2014; **11**: S51–S57.

16 Dept for Health, University of Bath., Standage M, Wilkie HJ, Jago R, Foster C, Goad MA *et al.* Results From England's 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health* 2014; **11**: S45–S50.

17 Plataforma Contra aObesidade. http://www.plataformacontraaobesidade.dgs.pt/PresentationLayer/homepage_institucional.aspx?menuid=113.

18 Griffiths LJ, Cortina-Borja M, Sera F, Pouliou T, Geraci M, Rich C *et al.* How active are our children? Findings from the Millennium Cohort Study. *BMJ Open* 2013; **3**: e002893.

19 Lifestyle Statistics Team. National Child Measurement Programme: England, 2012/2013 school year. Health and Social Care Information Centre, Public Health England, 2013.

20 Kenyatta University, Nairobi, Kenya., Wachira L JM, Muthuri SK, Tremblay MS, Onywera VO. Results From Kenya's 2014 Report Card on the Physical Activity and Body Weight of Children and Youth. *J Phys Act Health* 2014; **11**: S69–S73.

21 MRC/UCT Research Unit for Exercise Science and Sports Medicine, Dept of Human Biology, University of Cape Town, Draper C, Basset S, de Villiers A, Lambert EV, Writing Group H. Results From South Africa's 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health* 2014; **11**: S98–S104.

22 Muthuri SK, Wachira L-JM, Leblanc AG, Francis CE, Sampson M, Onywera VO *et al.* Temporal Trends and Correlates of Physical Activity, Sedentary Behavior, and Physical Fitness among School-Aged Children in Sub-Saharan Africa: A Systematic Review. *Int J Environ Res Public Health* 2014; **11**: 3327–3359.

23 Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO *et al.* Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS ONE* 2014; **9**: e92846.

24 Onywera VO, Adamo KB, Sheel AW, Waudo JN, Boit MK, Tremblay M. Emerging Evidence of the Physical Activity Transition in Kenya. *J Phys Act Health* 2012; **9**: 554–562.

25 Statistics South Africa. A time of use. Statistics South Africa: Pretoria, South Africa, 2013.

26 Giroux S. Canadian Health Measures Survey: sampling strategy overview. *Health Rep* 2006; **18 Suppl**: 31–36.

27 Brazilian Institute of Geography and Statistics (InstitutoBrasileiro de Geografia e Estatística). http://www.ibge.gov.br/english/.

28 Healthy Active Living and Obesity Research Group, Gray CE, Barnes JD, Cowie Bonne J, Cameron C, Chaput JP *et al.* Results From Canada's 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health* 2014; **11**: S26–S32.

29 Active Healthy Kids Canada. Are we driving our kids to unhealthy habits? The 2013 Active Healthy Kids Canada Report Card on Physical Activity for children and youth. 2013.

30 Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep* 2011; **22**: 15–23.

31 InstitutoColombiano de Bienestar Familiar ICBF. Encusesta Nacional de la SituacionNutricionalen Colombia ENSIN. InsitutoColombiano de Bienestar Familiar, Ed: Bogota, 2005.

32 Gomez LF, Parra DC, Lobelo F, Samper B, Moreno J, Jacoby E *et al.* Television viewing and its association with overweight in Colombian children: results from the 2005 National Nutrition Survey: A cross sectional study. *Int J BehavNutrPhys Act* 2007; **4**: 41.

33 Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008; **40**: 181–188.

34 Pennington Biomedical Research Center, Dentro KN, Beals K, Crouter SE, Eisenmann JC, McKenzie TL *et al.* Results From the United States' 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health* 2014; **11**: S105–S112.

35 Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents. Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents: Summary Report. *Pediatrics* 2011; **128**: S213–S256.

36 Department of Health and Ageing. Australian National Children's Nutrition and Physical Activity Survey (ANCNPAS): main findings. Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the University of South Australia: Canberra, Australia, 2008.

37 Australian Bureau of Statistics. Australian Health Survey: Physical Activity, 2011–12. 2013.http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4364.0.55.001main+features12011-12 (accessed 10 Oct2014).

38 University of South Australia., Schranz N, Olds T, Cliff D, Davern M, Engelen L *et al.* Results From Australia's 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health* 2014; **11**: S21–S25.

39 Zhang J, Seo D-C, Kolbe L, Middlestadt S, Zhao W. Associated Trends in Sedentary Behavior and BMI Among Chinese School Children and Adolescents in Seven Diverse Chinese Provinces. *Int J Behav Med* 2011; **19**: 342–350.

40 Yao N. Weight status in Chinese children: maternal perceptions and child self-assessments. *World J Pediatr* 2012; **8**: 129–135.

41 Shields M, Tremblay MS. Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J PediatrObes* 2010; **5**: 265–273.

42 Joens-Matre RR, Welk GJ, Calabro MA, Russell DW, Nicklay E, Hensley LD. Rural–Urban Differences in Physical Activity, Physical Fitness, and Overweight Prevalence of Children. *J Rural Health* 2008; **24**: 49–54.

43 Plotnikoff RC, Mayhew A, Birkett N, Loucaides CA, Fodor G. Age, gender, and urban–rural differences in the correlates of physical activity. *Prev Med* 2004; **39**: 1115–1125.

44 Onywera VO. Adiposity and physical activity among children in countries at different stages of the physical activity transition : Canada, Mexico and Kenya. 2013.http://reference.sabinet.co.za/sa_epublication_article/ajpherd_v19_n1_a12 (accessed 25 Apr2015).

45 He W, Li Q, Yang M, Jiao J, Ma X, Zhou Y *et al.* Lower BMI cutoffs to define overweight and obesity in China: Chinese BMI Cutoffs. *Obesity* 2015; : n/a–n/a.

46 Sardinha LB, Santos R, Vale S, Silva AM, Ferreira JP, Raimundo AM *et al.* Prevalence of overweight and obesity among Portuguese youth: a study in a representative sample of 10-18-year-old children and adolescents. *Int J PediatrObes* 2011; **6**: e124–128.

47 Tremblay M, Shields M, Laviolette M, Craig C, Janssen I, Connor Gorber S. Fitness of Canadian children and youth: results from the 2007-2009 Canadian Health Measures Survey. *Health Rep* 2010; **21**: 7–20.

48 Colley RC, Janssen I, Tremblay MS. Daily Step Target to Measure Adherence to Physical Activity Guidelines in Children. *Med Sci Sports Exerc*; **44**: 977–982.

49 Tammelin T, Laine K, Turpeinen S. Oppilaidenfyysinenaktiivisuus. [Physical Activity of School-aged children]. Liikunnanjakansanterveydenedistämissäätiö LIKES [Sport and Health LIKES]: Jyväskylä, 2013.

50 Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-Determined Steps per Day in US Children and Youth: *Med Sci Sports Exerc* 2010; **42**: 2244–2250.

51 Cao H, Qian Q, Weng T, Yuan C, Sun Y, Wang H *et al.* Screen time, physical activity and mental health among urban adolescents in China. *Prev Med* 2011; **53**: 316–320.