Leisure-time sedentary behavior and obesity among 116,762 adolescents aged 12-15 years from 41 low- and middle-income countries

Running title: Sedentary behavior and obesity in adolescents

Submission to Obesity

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Study Importance Questions:

What is already known about this subject?

- Rates of obesity are rising steeply in low- and middle-income countries
- Sedentary behavior is associated with various physical health conditions

What does your study add?

- Sedentary behavior for ≥3 hours/day was associated with higher odds for obesity in 32 of the 41 included countries.
- This relationship was strongest among low-income countries.
- These results were found among more than 115,000 adolescents from 41 countries

Abstract

Objective: Rates of adolescent obesity are increasing worldwide, with steeper increases being observed in low- and middle-income countries (LMICs). Sedentary behavior (SB), is associated with various physical and mental health conditions. Little is known about the association between SB and obesity among adolescents in LMICs. This cross-sectional study explored the associations between SB and obesity in adolescents from 41 LMICs. **Methods:** Obesity was measured using BMI; SB was assessed through self-report and considered for all times except when at school or doing homework. **Results:** Data from the Global school-based Student Health Survey were analyzed in 116,762 adolescents [mean (SD) age 13.8 (1.0) years; 48.6% female]. The overall prevalence of obesity was 4% and the prevalence of ≥3 hours/day of SB was 26%. The prevalence of obesity and SB were lowest in low-income countries and highest in upper middle-income countries. SB for ≥3 hours/day was associated with higher odds for obesity in 32 countries. This relationship was strongest among low-income countries. **Conclusions:** Being sedentary for ≥3 hours/day is associated with increased odds of obesity in adolescence. Future longitudinal data are required to confirm these findings and to inform interventions targeting SB among adolescents in LMICs, thereby reduce the prevalence of obesity.

Introduction

There have been sustained concerns about obesity levels in youth in developed countries, however rates of obesity are also increasing in low- and middle-income countries (LMICs). Indeed, LMICs have even seen a steeper increase in preschool overweight and obesity levels from 1990-2010 compared to developed countries (1). Specifically, during this time period, the relative percentage change in overweight and obesity in developing countries was 65%, whereas in developed countries, it was 48% (2). Obesity can have detrimental effects on adolescents' physical, mental, and psychosocial health (3,4,5). Since obesity in adolescence is a key predictor of obesity in adulthood, this timeframe represents an essential window to prevent lifelong increased weight and the associated health issues (6). Consequently, there is a global movement with accompanying (inter)national guidelines that stipulate the need to prevent and manage obesity in adolescents (7, 8).

Currently, there is increasing recognition that sedentary behavior (SB) is a risk factor for childhood weight gain, although almost all of this research is derived from high-income countries (9). SB is usually defined as an energy expenditure ≤1.5 metabolic equivalents of task (METs) while in a sitting or reclining posture during waking hours. This is now being considered as a contributing factor to unhealthy weight gain and obesity **(**10), potentially through increased obesogenic behaviors such as snacking, decreased energy expenditure and increase abdominal fat (11-13). In a systematic review examining this relationship among children in developed countries, SB was generally positively associated with weight status, though this relationship varied by gender for some studies (9).

However, the review only examined the relationships of SB in the USA and other developed countries, and did not identify any relevant studies looking at health outcomes of SB in LMICs, showing a severe under-representation of literature for these regions. As such, further research is warranted to examine how these relationships may differ in such countries, especially given that SB levels have been reported to be high among adolescents in LMICs (14), and childhood obesity is increasing in this setting. Exploring the SB-obesity association in LMICs is particularly important as there may be different sociocultural attitudes towards obesity (e.g., obesity may be viewed as a sign of wealth or beauty), or different access to devices (e.g., television, computers) associated with SB, compared with high-income countries. Furthermore, most of the previous studies exploring the associations between SB and obesity have not adjusted for physical activity levels or nutrition, despite the established influence of these factors on obesity (6). Finally, multinational studies exploring the associations between SB and obesity in LMICs are to the best of our knowledge absent. Multinational studies allow the associations between SB and obesity to be explored independent of national policies and other possible contributing factors, while also allowing comparisons between countries to investigate the roles of these policies and factors in different countries.

Given the current gaps in the literature, the aim of the current study was to assess whether higher levels of SB are associated with greater levels of obesity among adolescents in 41 LMICs. Given the previously reported links between SB and obesity among adolescents in developed countries, we hypothesized that greater time spent in SB would be associated with higher levels of obesity, even after adjusting for physical activity and nutritional intake.

Methods

The survey

Publicly available data from GSHS were analyzed. Details on this survey can be found at http://www.who.int/chp/gshs and http://www.cdc.gov/gshs. Briefly, the GSHS was jointly developed by the WHO and the US Centers for Disease Control and Prevention (CDC), and other UN allies. The core aim of this survey was to assess and quantify risk and protective factors of major non-communicable diseases. The survey draws content from the CDC Youth Risk Behavior Survey (YRBS) for which test-retest reliability has been established (15). The survey used a standardized two-stage probability sampling design for the selection process within each participating country. For the first stage, schools were selected with probability proportional to size sampling. The second stage involved the random selection of classrooms which included students aged 13-15 years within each selected school. All students in the selected classrooms were eligible to participate in the survey regardless of age. Data collection was performed during one regular class period. The questionnaire was translated into the local language in each country and consisted of multiple choice response options; students recorded their response on computer scannable sheets. All GSHS surveys were approved, in each country, by both a national government administration (most often the Ministry of Health or Education) and an institutional review board or ethics committee. Student privacy was protected through anonymous and voluntary participation, and informed consent was obtained as appropriate from the students, parents and/or school officials. Data were weighted for non-response and probability selection.

From all publicly available data, we selected all nationally representative datasets that included the variables pertaining to this analysis. High-income countries were excluded to focus on LMICs. We also excluded countries for which more than 20% of the data on body mass index (BMI) were missing. If there were more than two datasets from the same country, we chose the most recent dataset. Thus, a total of 41 LMICs were included in the current study. The characteristics of each country or survey are provided in **Table 1**. For the included countries, the survey was conducted between 2003 and 2015, and consisted of 5 low-income, 26 lower middle-income, and 10 upper middle-income countries based on the World Bank classification at the time of the survey for the respective countries.

Obesity *(dependent variable)*

Trained survey staff conducted measurement of weight and height. BMI was calculated as weight in kilograms divided by height in meters squared. Obesity was defined as >2 SDs above the median for age and sex based on the 2007 WHO Child Growth reference (16).

Sedentary behavior (SB) *(independent variable)*

SB was assessed with the question "How much time do you spend during a typical or usual day sitting and watching television, playing computer games, talking with friends, or doing other sitting activities?" with six response options: <1, 1-2, 3-4, 5-6, 7-8, and >8 hours/day. This excluded time at school and when doing homework. This variable was used as a five-category variable (5-6 and 7-8 hours/day were merged as the proportion of those who replied 7-8 hours/day was small) or a dichotomized variable (≥3 hours/day or not) (17). This question was based on the National Health And Nutrition Examination Survey (NHANES) questionnaire from 1999-2000, and modified for use in children. This measure of SB has been used in multiple published papers (i.e. 14).

Control variables

These included age, sex, food insecurity (proxy of socioeconomic status), physical activity, and low fruit/vegetable consumption. As in a previous GSHS study, food insecurity was used as a proxy for socioeconomic status as there were no variables on socioeconomic status in the GSHS (18). Specifically, this was assessed by the question "During the past 30 days, how often did you go hungry because there was not enough food in your home?" Answer options were categorized as 'never', 'rarely/sometimes', and 'most of the time/always' (19). To assess levels of physical activity, questions that represented the PACE+ Adolescent Physical Activity Measure (20) were asked. This measure has been tested for validity and reliability

(20). The questions asked about the number of days with physical activity of at least 60 minutes during the past 7 days. This did not include physical activity during physical education or gym classes. Those who engaged in ≥5 days of at least 60 minutes of physical activity in a week were considered to have a sufficient amount of physical activity (17). Low fruit and vegetable intake was defined as intake of fruit and vegetables less than five times per day (< 400g of fruits and vegetables/day) during the past 30 days (16).

Statistical analysis

Statistical analyses were performed with Stata 14.1 (Stata Corp LP, College station, Texas). As in previous studies using the same dataset (16, 21), we restricted the analysis to those aged 12-15 years as most students were within this age range and data on the exact age out of this age range was not provided. We used multivariable logistic regression analysis to estimate the association between SB (independent variable) and obesity (dependent variable) using the overall and country-wise samples. The exposure variable was the five-category SB variable when the overall sample was used. However, for country-wise analyses, we used the dichotomized SB variable to obtain stable estimates, as the sample size in each country was small. In order to assess between-country heterogeneity in the association between SB and obesity, we calculated the Higgin's I^2 which represents the degree of heterogeneity that is not explained by sampling error with a value of <25%, 25-50%, and over 50% considered as small, moderate and high heterogeneity, respectively (22). A pooled estimate was obtained by combining the estimates for each country into a fixed effect meta-analysis (overall and by country-income level). Heterogeneity between groups was tested by Cochran's Q tests. We also tested for interaction by sex by including the product term of sex X SB in the model using the overall sample.

All regression analyses were adjusted for age, sex, food insecurity (proxy of socioeconomic status), physical activity, and low fruit/vegetable consumption. The analysis using the overall sample additionally adjusted for country by using fixed effects models as in a previous GSHS study (19). All variables were included in the regression analysis as categorical variables with the exception of age (continuous variable). Under 1.7% of the data were missing for the variables included in the study with the exception of BMI (7.3%). Complete case analysis was done. Sampling weights and the clustered sampling design of the surveys were taken into account to obtain nationally representative estimates. Results from the logistic regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The level of statistical significance was set at $p<0.05$.

Results

The final sample comprised 116,762 adolescents aged 12-15 years [mean (SD) age 13.8 (1.0) years; 48.6% female]. The overall prevalence of obesity was 4.0% [range 0.4% (Cambodia) to 21.9% (Tonga)], while the corresponding figure for ≥3 hours/day of SB was 26.2% [range 8.2% (Pakistan) to 50.7% (Thailand)] (**Table 1**). The prevalence of obesity and SB were lowest in low-income countries and highest in upper middle-income countries. The prevalence of SB was: <1 hour/day 38.4%; 1-2 hours/day 35.4%; 3-4 hours/day 15.6%; 5-8 hours/day 7.3%; and >8 hours/day 3.4%. The prevalence of obesity increased with greater time spent sedentary per day, from 3.5% in <1 hour/day to 5.5% in >8 hours/day (**Figure 1**). This was also confirmed in the multivariable logistic regression analysis where >8 hours/day of SB was associated with 1.40 (95%CI=1.06-1.86) times higher odds of obesity compared to <1 hour/day (**Figure 2**). A significant interaction by sex in this association was not found. The country-wise associations between ≥3 hours/day of SB and obesity based on multivariable logistic regression are shown in **Figure 3**. SB of ≥3 hours/day was associated with increased odds of obesity relative to <3 hours/day in 32 of the 41 included countries. Strong significant associations between obesity and SB were observed in countries such as Solomon Islands (OR=3.45; 95%CI=1.69-7.04), Laos (OR=3.07; 95%CI=1.33-7.08), and Namibia (OR=2.08; 95%CI=1.17-3.69). The pooled estimate was 1.18 (95%CI=1.10-1.25) with a moderate level of heterogeneity (I^2=40.3%). The association was strongest in low-income countries (pooled OR=1.87; 95%CI=1.08-3.25), followed by lower middle-income countries (OR=1.28; 95%CI=1.17-1.41), and upper middle-income countries (OR=1.08; 95%CI=0.99-1.18). This between group heterogeneity was statistically significant (P=0.008).

Discussion

To the best of our knowledge, this is the first multinational LMIC study to investigate the relationship between SB and obesity in adolescence. We found consistent evidence that adolescents who engaged in SB, excluding time at school and when doing homework, for 3 or more hours a day, were more likely to be obese. We also found some evidence to suggest a dose-dependent association between SB and obesity where compared to those who were sedentary for <1 hour/day, individuals who were sedentary for >8 hours/day (excluding time at school and when doing homework) were 1.40 times more likely to be obese. The results remained evident even after adjusting for physical activity.

The overall prevalence of obesity in our sample was 4%, which is relatively low compared to previous studies, which may be explained by the fact that our sample was based on LMICs, and only included those aged 12-15. For example, among children and adolescents worldwide (including high-income countries), 6% of girls and 8% of boys are obese (23). The rates of obesity increased by country-income level, with the highest rates of obesity present in upper middle-income countries, which is in line with previous literature (23). The country with the highest rate of obesity was Tonga (21.9%), and this is in line with the extremely high adult obesity rate in Tonga, where 52% of males and 67% of females are either overweight or obese (2). It may also be that geographical locations of countries play an important role alongside economic status, such that island nations in the Pacific and the Caribbean and certain countries in the Middle East and Central America have very high rates of obesity, while most countries in Asia and Africa do not (2). This was seen in our results. For example, Vietnam (0.6%) and Namibia (1.9%) had very low rates of obesity. Overall, just over a quarter of adolescents engaged in SB for ≥3 hours/day, which is considered sedentary for children (17), while 38.4% engaged in SB for less than 1 hour/day. Rates of SB increased by country-income level, with the highest rates of SB present in upper middle-income countries. These results are difficult to compare against other results, as the examination of SB in the realm of public health has only gained momentum in the past 10 years, and thus standardized instruments are still lacking (24).

SB was related to obesity, with the relationship being strongest in low-income countries. This is in line with the results of Lear et al., 2014 (25), who found stronger relationships between the ownerships of household devices (television, car, computer) and obesity among adults from low-income countries, compared with those from middle- and high-income countries. However, a study examining this relationship among 9- to 11-year olds from 12 low-, medium- and high-income countries found that the significant association between TV viewing (as a proxy for SB) and obesity were consistent across country income levels (26). The fact that this study did not take into account of other types of SB could have led to the discrepant results. Furthermore, in a study among adolescents in a high-income country (England), those with low socio-economic position spent more time watching television compared to their higher socio-economic position counterparts, while the reverse was true for all other type of SB (i.e. homework, drawing, time spent on the computer) (accelerometer-measured, 27). This suggests that family-income level may affect types of SB differently, which may in turn affect the SB and obesity relationship.

Interestingly, in our study, the countries with the strongest relationship between SB and obesity (i.e. low-income countries) were also those that had the lowest rates of both SB and obesity. Lear et al. (25) posited that one reason for this could be because a plateau effect of exposure to such devices (television, car, computer) might be present in higher income countries, such that the negative effects have already occurred and are represented in higher obesity prevalence. Conversely, in lower-income countries in which exposure to such devices might be a recent development, their negative effects may still be acute, and may increase as the rates of ownership increases (25). This may explain the current study’s findings of SB being particularly strongly related to obesity in low-income countries, as among young people, ownership of devices such as televisions and game consoles has been linked to SB (28, 29). As such, it may be that in low-income countries, SB may be a sign of wealth and is observed through obesogenic activities like snacking, whereas in middle-income countries, it is already common to snack such that obesity is no longer strongly associated with SB.

The reasons that underpin the relationship between SB and obesity are likely complex, and the direction of the relationship remains unclear. It is possible that SB leads to obesity, or that obesity leads to SB, but it is likely to be a combination of both. One possible reason for this relationship may be that SBs such as watching television have been associated with obesogenic behaviors such as snacking (11). Interestingly, a recent systematic review emphasized the fact that while there have been many studies examining the relationship between SB and adiposity in adolescents, there is no evidence to confirm a causal association (30). However, a small dose-response between levels of SB and levels of adiposity has been reported (30). An alternative mechanism by which SB may lead to obesity may be through a reduction in energy expenditure, leading to increased accumulation of abdominal fat (12,13).

Regardless of whether SB and obesity are causally related, their mere co-existence is deleterious to health. SB and obesity both exert negative effects on cardiometabolic markers, and in turn increase risk of developing metabolic diseases such as type 2 diabetes and cardiovascular diseases (31). For example, one study found that regardless of PA, increased sedentary time was detrimentally associated with levels of 2h plasma glucose, triacylglycerol and HDL-cholesterol (32). Individuals with obesity also have higher levels of these circulating biomarkers (31). The detrimental effects of increased levels of such markers highlight the important need for solutions to prevent and treat both SB and obesity.

Whilst this study is novel, includes a large number of countries and participants, is multinational, and took into account various confounders (e.g. physical activity and nutrition), it is important to note some limitations. First, the study is cross sectional and directionality cannot be inferred. Thus, future longitudinal research is required to explore the direction of causation and temporal relationships. Second, SB was captured using self-report measures that included only one item. This is a limitation as more items could have been used to examine the content and context of SBs (e.g., television watching, playing computer games) and thereby create a greater understanding of sedentary patterns and modalities. Furthermore, SB was assessed subjectively in our study and this measure has not been validated against objective measures. The accuracy of measuring SB with self-reporting among pediatric populations has been questioned, and thus objective techniques such as accelerometry are warranted in the future (33). Furthermore, the GSHS measure on nutrition was insufficient as it was only based on fruit and vegetable intake. In addition, the GSHS data only includes adolescents in schools, thus information from adolescents who were unable to attend school or who had dropped out were not included. This could be a direction for future research, as socio-economic factors may affect these individuals differently. Measuring time spent being sedentary while at school and completing homework may also be a direction of future research, as it may affect obesity and health outcomes differently than leisure-time SB. A related limitation is the use of an SB measure that is not validated. However, asking about sedentary time in a similar way is routinely done and there are numerous published papers that use this SB measure. Finally, there was a lack of data regarding depression, which has been linked to both obesity and SB, which warrants further investigation (14).

Conclusion

The present study found that among adolescents in LMICs, rates of obesity and SB were highest among higher income countries, while the relationship between obesity and SB was strongest among the lowest income countries. These results suggest that different strategies may be needed in countries of different income levels to reduce SB and obesity among adolescents. Specifically, as the relationship is strongest in low-income countries, those which may be the least prepared to deal with the effects of obesity such as hypertension and diabetes, it may be particularly important to find ways in which to target SB (34). Future research is needed to confirm the causal and longitudinal aspects of this relationship.

References

1. de Onis, M., Blossner, M., & Borghi, E. (2010). Global prevalence and trends of overweight and obesity among preschool children. The American Journal of Clinical Nutrition, 92, 1257–1264.

2. Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., ... & Abraham, J. P. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The lancet*, *384*(9945), 766-781.

3. Pulgaron ER. Childhood obesity: a review of increased risk for physical and psychological comorbidities. Clin Ther. 2013;35(1):A18–A32.

4. Sanders RH, Han A, Baker JS, Cobley S. Childhood obesity and its physical and psychological co-morbidities: a systematic review of Australian children and adolescents. Eur J Pediatr.

5. Rankin, J., Matthews, L., Cobley, S., Han, A., Sanders, R., Wiltshire, H. D., & Baker, J. S. (2016). Psychological consequences of childhood obesity: psychiatric comorbidity and prevention. *Adolescent Health, Medicine and Therapeutics*, *7*, 125–146.

http://doi.org/10.2147/AHMT.S101631

6. Solmi, M., Köhler, C. A., Stubbs, B., Koyanagi, A., Bortolato, B., Monaco, F., ... & Firth, J. (2018). Environmental risk factors and non-pharmacological, non-surgical interventions for obesity: An umbrella review of meta-analyses of cohort studies and randomized controlled trials. *European Journal of Clinical Investigation*, e12982.

7. National Institute for Health and Care Excellence. (2013). *Weight management: lifestyle services for overweight or obese children and young people*. Retrieved from https://www.nice.org.uk/guidance/ph47.

8. Styne, D. M., Arslanian, S. A., Connor, E. L., Farooqi, I. S., Murad, M. H., Silverstein, J. H., & Yanovski, J. A. (2017). Pediatric obesity—assessment, treatment, and prevention: an Endocrine Society Clinical Practice guideline. *The Journal of Clinical Endocrinology & Metabolism*, *102*(3), 709-757.

9. Prentice-Dunn, H., & Prentice-Dunn, S. (2012). Physical activity, sedentary behavior, and childhood obesity: a review of cross-sectional studies. *Psychology, health & medicine*, *17*(3), 255-273.

10. Sedentary Behaviour Research Network, E. Stamatakis, J. Henson, T. Yates, S. Biddle, C. Edwardson, K. Khunti, E. Wilmot, L. Gray, T. Gorely, M. Nimmo, M. Davies, M. Tremblay, J. Chau, A. Grunseit, T. Chey, E. Stamatakis, W. Brown, C. Matthews, A. Bauman, H. van der Ploeg, A. Chomistek, J. Manson, M. Stefanick, B. Lu, M. Sands-Lincoln, S. Going, L. Garcia, M. Allison, S. Sims, M. LaMonte, K. Johnson, C. Eaton, H. van der Ploeg, T. Chey,

R. Korda, E. Banks, A. Bauman, N. Brodersen, A. Steptoe, S. Williamson, J. Wardle, W. Greene, E. Stamatakis, M. Hamer, K. Tilling, D. Lawlor, S. Biddle, N. Cavill, T. Gorely, M. Griffiths, R. Jago, J. Oppert, M. Raats, J. Salmon, G. Stratton, G. Vicente-Rodríguez, B. Butland, L. Prosser,

11. Popkin BM. 2001. The nutrition transition and obesity in the developing world. J. Nutr. 131(3):871S–3S

12. Stephens, B. R., Granados, K., Zderic, T. W., Hamilton, M. T., & Braun, B. (2011). Effects of 1 day of inactivity on insulin action in healthy men and women: interaction with energy intake. *Metabolism*, *60*(7), 941-949.

13. Olsen, R. H., Krogh-Madsen, R., Thomsen, C., Booth, F. W., & Pedersen, B. K. (2008). Metabolic responses to reduced daily steps in healthy nonexercising men. *J A M A: The Journal of the American Medical Association*, *299*(11), 1261-3

14. Vancampfort, D., Stubbs, B., Firth, J., Van Damme, T., & Koyanagi, A. (2018). Sedentary behavior and depressive symptoms among 67,077 adolescents aged 12–15 years from 30 low-and middle-income countries. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1), 73.

15. Brener, ND, Collins JL, Kann L, Warren CW & Williams BI (1995). Reliability of the Youth Risk Behavior Survey Questionnaire. *Am J Epidemiol* 141, 575-80.

16. Caleyachetty, R, Echouffo-Tcheugui JB, Tait CA, Schilsky S, Forrester T & Kengne AP (2015). Prevalence of behavioural risk factors for cardiovascular disease in adolescents in low-income and middle-income countries: an individual participant data meta-analysis. *Lancet Diabetes Endocrinol* 3, 535-44.

17. Guthold, R, Cowan MJ, Autenrieth CS, Kann L & Riley LM (2010). Physical activity and sedentary behavior among schoolchildren: a 34-country comparison. *J Pediatr* 157, 43-49.e1.

18. Balogun, O, Koyanagi A, Stickley A, Gilmour S & Shibuya K (2014). Alcohol consumption and psychological distress in adolescents: a multi-country study. *J Adolesc Health* 54, 228-34.

19. McKinnon, B, Gariepy G, Sentenac M & Elgar FJ (2016). Adolescent suicidal behaviours in 32 low- and middle-income countries. *Bull World Health Organ* 94, 340-350f.

20. Prochaska, JJ, Sallis JF & Long B (2001). A physical activity screening measure for use with adolescents in primary care. *Arch Pediatr Adolesc Med* **155**, 554-9.

21. Xi B, Liang Y, Liu Y, et al. Tobacco use and second-hand smoke exposure in young adolescents aged 12-15 years: data from 68 low-income and middle-income countries. *Lancet Glob Health.* 2016;4(11):e795-e805.

22. Higgins, JP & Thompson SG (2002). Quantifying heterogeneity in a meta-analysis. *Stat Med* 21, 1539-58.

23. Abarca-Gómez, L., Abdeen, Z. A., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., ... & Agyemang, C. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128· 9 million children, adolescents, and adults. *The Lancet*, *390*(10113), 2627-2642.

24. Bauman, A., Ainsworth, B. E., Sallis, J. F., Hagströmer, M., Craig, C. L., Bull, F. C., ... & IPS Group. (2011). The descriptive epidemiology of sitting: a 20-country comparison using the International Physical Activity Questionnaire (IPAQ). *American journal of preventive medicine*, *41*(2), 228-235.

25. Lear, S. A., Teo, K., Gasevic, D., Zhang, X., Poirier, P. P., Rangarajan, S., … Yusuf, S. (2014). The association between ownership of common household devices and obesity and diabetes in high, middle and low income countries. *CMAJ : Canadian Medical Association Journal*, *186*(4), 258–266. http://doi.org/10.1503/cmaj.131090

26. Katzmarzyk, P. T., Barreira, T. V., Broyles, S. T., Champagne, C. M., Chaput, J. P., Fogelholm, M., ... & Lambert, E. V. (2015). Relationship between lifestyle behaviors and obesity in children ages 9–11: Results from a 12-country study. *Obesity*, *23*(8), 1696-1702.

27. Coombs, N., Shelton, N., Rowlands, A., & Stamatakis, E. (2013). Children's and adolescents' sedentary behaviour in relation to socioeconomic position. *J Epidemiol Community Health*, *67*(10), 868-874.

28. Roberts, J. D., Rodkey, L., Ray, R., Knight, B., & Saelens, B. E. (2017). Electronic media time and sedentary behaviors in children: Findings from the Built Environment and Active Play Study in the Washington DC area. *Preventive Medicine Reports*, *6*, 149–156. http://doi.org/10.1016/j.pmedr.2017.02.021

29. Sandercock, G. R. H., Alibrahim, M., & Bellamy, M. (2016). Media device ownership and media use: Associations with sedentary time, physical activity and fitness in English youth. *Preventive Medicine Reports*, *4*, 162–168. http://doi.org/10.1016/j.pmedr.2016.05.013

30. Biddle, S. J. H., García Bengoechea, E., & Wiesner, G. (2017). Sedentary behaviour and adiposity in youth: a systematic review of reviews and analysis of causality. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*, 43. http://doi.org/10.1186/s12966-017-0497-8

31. Da Costa, L. A., Arora, P., García-Bailo, B., Karmali, M., El-Sohemy, A., & Badawi, A. (2012). The association between obesity, cardiometabolic disease biomarkers, and innate

immunity-related inflammation in Canadian adults. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *5*, 347–355. http://doi.org/10.2147/DMSO.S35115

32. Henson, J., Yates, T., Biddle, S. J., Edwardson, C. L., Khunti, K., Wilmot, E. G., ... & Davies, M. J. (2013). Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health. *Diabetologia*, *56*(5), 1012-1020.

33. Adamo, K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S., & Tremblay, M. (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: a systematic review. *International Journal of Pediatric Obesity*, *4*(1), 2-27.

34. NCD Risk Factor Collaboration. (2016). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19· 2 million participants. *The Lancet*, *387*(10026), 1377-1396.

Table 1 Survey characteristics and prevalence of obesity and sedentary behavior by country

Country income[a]	Country	Year	Response rate (%)[b]	Unweighted N[c]	Obesity (%) SE[d]	Sedentary ≥3h/day (%) SE[d]
Low	Afghanistan	2014	79	1,493	2.3 (0.6)	23.3 (3.4)
	Benin	2009	90	1,170	0.5 (0.3)	18.4 (1.5)
	Cambodia	2013	85	1,812	0.4 (0.1)	10.2 (1.4)
	Myanmar	2007	95	2,227	0.8 (0.3)	9.7 (1.2)
	Uganda	2003	69	1,904	0.8 (0.2)	27.4 (1.7)
	Total			***8,606***	***0.8 (0.2)***	***13.6 (0.9)***
Lower middle	Bangladesh	2014	91	2,753	1.3 (0.5)	14.9 (2.0)
	Belize	2011	88	1,600	13.5 (1.3)	36.3 (2.0)
	Bolivia	2012	88	2,804	4.7 (0.7)	24.3 (1.5)
	Djibouti	2007	83	962	4.6 (0.7)	32.3 (2.0)
	Egypt	2011	85	2,364	7.7 (0.7)	27.5 (2.8)
	El Salvador	2013	88	1,615	10.3 (0.8)	35.2 (2.4)
	Fiji	2010	90	1,495	5.3 (0.5)	27.2 (2.0)
	Ghana	2012	82	1,110	1.9 (0.6)	18.4 (1.6)
	Guatemala	2015	82	3,611	7.7 (1.2)	22.9 (2.8)
	Guyana	2010	76	1,973	4.1 (0.7)	35.7 (2.5)
	Honduras	2012	79	1,486	6.0 (0.6)	30.3 (1.2)
	India	2007	83	7,330	2.2 (0.3)	22.8 (1.1)
	Indonesia	2015	94	8,806	5.3 (0.5)	24.5 (0.9)
	Kiribati	2011	85	1,340	8.0 (1.0)	14.4 (1.0)
	Laos	2015	70	1,644	2.2 (0.6)	19.2 (1.3)
	Macedonia	2007	93	1,550	3.4 (0.5)	49.9 (2.2)
	Mongolia	2013	88	3,707	1.8 (0.2)	39.6 (1.9)
	Morocco	2010	92	2,405	2.8 (0.4)	25.7 (1.3)
	Pakistan	2009	76	4,998	1.0 (0.2)	8.2 (0.8)
	Philippines	2015	79	6,162	2.8 (0.6)	30.7 (1.9)
	Solomon Islands	2011	85	925	2.7 (0.8)	26.5 (2.7)
	Sri Lanka	2008	89	2,504	0.7 (0.2)	33.2 (1.1)
	Sudan	2012	77	1,401	3.6 (1.3)	19.7 (2.1)
	Syria	2010	97	2,929	6.1 (0.7)	25.3 (2.6)
	Tonga	2010	80	1,946	21.9 (1.2)	29.2 (1.4)
	Vietnam	2013	96	1,743	0.6 (0.3)	34.9 (2.1)
	Total			***71,163***	***3.7 (0.2)***	***24.6 (0.6)***
Upper middle	Algeria	2011	98	3,484	3.7 (0.5)	26.8 (1.1)
	Costa Rica	2009	72	2,265	8.9 (0.8)	44.2 (1.6)
	Iraq	2012	88	1,533	7.9 (0.8)	25.6 (1.9)
	Libya	2007	98	1,891	8.3 (0.6)	28.6 (1.6)
	Malaysia	2012	89	16,273	9.7 (0.3)	42.7 (0.9)
	Mauritius	2011	82	2,074	6.2 (0.5)	39.2 (1.7)
	Namibia	2013	89	1,936	1.9 (0.5)	37.2 (1.3)

Peru	2010	85	2,359	2.9 (0.6)	28.7 (1.8)
Suriname	2009	89	1,046	7.2 (0.8)	40.3 (2.3)
Thailand	2015	89	4,132	6.6 (0.6)	50.7 (1.4)
Total			***36,993***	***6.5 (0.2)***	***37.0 (0.6)***

Abbreviation: SE Standard error

[a] Country income level was based on the World Bank classification at the year of the survey in the respective countries.

[b] Response rate was calculated as school response rate multiplied by student response rate.

[c] Based on sample aged 12- 15 years.

[d] Weighted estimates

Figure List:

Figure 1 Prevalence of obesity by time spent sedentary per day

Bars denote 95% confidence intervals.

Figure 2 Association between time spent sedentary per day and obesity (outcome) estimated by multivariable logistic regression

Abbreviation: OR Odds ratio; CI Confidence interval

Reference category is <1 hours/day

Model is adjusted for age, sex, food insecurity (proxy of socioeconomic status), physical activity, low fruit and vegetable consumption, and country.

Figure 3 Country-wise association between sedentary behavior of ≥3h/day and obesity (outcome) estimated by multivariable logistic regression

Abbreviation: OR Odds ratio; CI Confidence interval

Overall estimate was obtained by meta-analysis with fixed effects.

Models are adjusted for age, sex, food insecurity (proxy of socioeconomic status), physical activity, and low fruit and vegetable consumption.