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**Leisure-time sedentary behavior and loneliness among 148,045 adolescents aged 12-15 years from 52 low- and middle-income countries**

Davy Vancampforta,b,\*, Garcia Ashdown-Franksc,d, Lee Smithe, Joseph Firthf,g,h, Tine Van Dammea,b, Lore Christiaansena,i, Brendon Stubbs c,j, Ai Koyanagik,l

1. KU Leuven Department of Rehabilitation Sciences, Leuven, Belgium
2. KU Leuven, University Psychiatric Center KU Leuven, Leuven-Kortenberg, Belgium
3. Physiotherapy Department, South London and Maudsley NHS Foundation Trust, Denmark Hill, London, United Kingdom
4. Department of Exercise Sciences, University of Toronto, Toronto, Ontario, Canada
5. Cambridge Centre for Sport and Exercise Sciences, Anglia Ruskin University, Cambridge, United Kingdom
6. NICM Health Research Institute, Western Sydney University, Westmead, Australia
7. Division of Psychology and Mental Health, Faculty of Biology, Medicine and Health, University of Manchester, United Kingdom
8. Centre for Youth Mental Health, University of Melbourne, Melbourne, Australia
9. KU Leuven Centre of Contextual Psychiatry, Leuven, Belgium
10. Department of Psychological Medicine, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, United Kingdom
11. Research and Development Unit, Parc Sanitari Sant Joan de Déu, CIBERSAM, Sant Boi de Llobregat, Barcelona, Spain
12. ICREA, Pg. Lluis Companys 23, Barcelona, Spain

\*Corresponding author: Tervuursevest 101, 3001 Leuven, Belgium. Tel.: +32 2 758 05 11; Fax: +32 2 759 9879. Email: davy.vancampfort@kuleuven.be

**Abstract**

*Background:* Loneliness is widespread in adolescents and associated with a myriad of adverse physical and mental health outcomes. Exploring variables associated with loneliness is important for the development of targeted interventions. The aim of the current study was to explore associations between leisure-time sedentary behavior (LTSB) and loneliness in adolescents from 52 low- and middle-income countries.

*Methods:* Data from the Global School-based Student Health Survey were analyzed. Data on past 12-month self-perceived loneliness and LTSB were collected. Multivariable logistic regression and meta-analysis were conducted to assess the associations.

*Results:* Among 148,045 adolescents (mean age 13.7± SD 1.0 years; 48.5% female), the prevalence of loneliness increased from 8.7% among those with 1-2 hours/day of LTSB to 17.5% among those spending >8 hours/day sedentary. Compared to those who engage in less than 1 hour of LTSB per day, the OR (95%CI) of loneliness for 1-2 hours/day, 3-4 hours/day, 5-8 hours/day and >8 hours/day were 1.00 (0.91-1.11), 1.29 (1.15-1.45), 1.37 (1.17-1.61), and 1.66 (1.39-1.99), respectively.

*Limitations:* The study is cross-sectional, therefore the directionality of the relationships cannot be deduced.

*Conclusions:*Our data suggest that LTSB is associated with increased odds for feeling lonely in adolescence. Future longitudinal data are required to confirm/refute the findings to inform public health campaigns.

**Keywords:** loneliness; sitting; sedentary; physical activity; mental health; adolescents

**Introduction**

Loneliness is defined as the discrepancy between a person’s desired and actual social relationships (Perlman and Peplau, 1981). It has been associated with a myriad of adverse physical and mental health outcomes in adulthood including premature mortality (odds ratio = 1.26, 95% confidence interval = 1.04 to 1.53) (Holt-Lunstad et al., 2015). Contrary to common stereotypes, loneliness is not restricted to middle-aged or older people, but can occur at any life stage, even in early adolescence (Luhmann and Hawkley, 2016). Indeed, the prevalence of loneliness in adolescents aged 13 to 15 years has been reported to range from 5.2 to 14.7% (Stickley et al., 2016). Although evidence regarding the adverse health outcomes of loneliness in adolescence is limited compared to older adults (Choi and Matz-Costa, 2017; Neergheen et al., 2019), there is preliminary evidence that loneliness is already in this life stage associated with a variety of negative mental and physical health outcomes. In the only study to date, the Social and Health Assessment (SAHA) survey which included 2205 Czech, 1995 Russian, and 2050 US male and female adolescents aged 13 to 15 years old, adolescents who were lonely had a higher odds for reporting anxiety (with odds ratios ranging from 1.63 in Russian male to 5.49 in US male adolescents) and depressive symptoms (with odds ratios ranging from 10.65 in Czech female to 40.13 in US female adolescents) (Stickley et al., 2016). Loneliness was also associated with somatic symptoms such as headaches and pain in at least half of the adolescents (Stickley et al., 2016). The underlying mechanisms for the higher risk for mental and physical health problems in adolescents who feel lonely remain entirely unclear (Cacioppo and Patrick, 2008). In adults, several psychobiological processes including neuroendocrine dysregulation (Cacioppo et al., 2015) and exaggerated blood pressure and inflammatory reactivity to acute stress (Brown et al., 2018) have been suggested. It is also possible that poorer health behaviors might be central to the association between loneliness and mental and physical health problems in adolescents (Stickley et al., 2016). For example, a recent study showed that adolescent loneliness is linked to different forms of substance use (Stickley et al., 2014), while previous research has demonstrated an association between adolescent alcohol and drug use and somatic symptoms and mental health problems (Center on Addiction, 2011).

One health behavior which has rarely been studied in relation to loneliness is sedentary behavior (i.e., any behavior during waking hours with energy expenditure less than or equal to 1.5 metabolic equivalents while in a sitting or reclining posture (Cart, 2012)). There is now evidence that adolescent sedentary behavior is, independent from physical activity levels, associated with physical and mental disease risk (de Oliveira and Guedes, 2016; Farren et al., 2018; Raudsepp et al., 2019; Schuch et al., 2017; Wu et al., 2017). More in detail, more time spent sedentary is in adolescents associated with a higher risk for developing depressive symptoms (Edwards and Loprinzi, 2016), which on its turn are a risk factor for loneliness (Mullarkey et al., 2018). Thus, if loneliness is associated with increasing time spent sedentary, this information may provide clues on the mechanisms that link loneliness with adverse health outcomes.

The current evidence in adolescents comes from a few studies in Western countries and concluded that there is insufficient evidence for an association between time spent in specific sedentary behaviors and loneliness (Hoare et al., 2016). One study on 261 adolescents between 12 and 16 years from suburban California public schools found no significant associations between loneliness and total daily average time spent talking on the phone, watching TV and using the Internet (Gross, 2004), while another Australian study on 336 young people aged between 15 and 21 years from a secondary school and a university population reported no significant associations with time spent online (categorized by time spent communicating, entertainment purposes, or information-related activities) (Donchi and Moore, 2004). Both studies were however conducted before the social media era. Also, the sample size was small and may not have been sufficiently powered to detect a statistical difference. Another gap in the literature is that evidence from low and middle-income countries (LMICs) is currently entirely lacking. Exploring associations between loneliness and sedentary behavior with a focus on LMICs is important given different sociocultural attitudes towards sedentary behavior (e.g., a sign of wealth), different access to devices (e.g., television, computers) and different environmental factors (e.g., safety, climate) in LMICs compared with high-income countries (Arat and Wong, 2017).

Given the current gaps in the literature, the aim of the current study was to assess the association between loneliness and LTSB in adolescents using data from 52 LMICs from six World Health Organization regions (African Region, Region of the Americas, Eastern Mediterranean Region, European Region, South-East Asia Region, and Western Pacific Region).

**Methods**

*The survey*

Publicly available data from the Global school-based Student Health Survey (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 (Brener et al., 1995). 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 used in the current analysis. If there were more than two datasets from the same country, we chose the most recent dataset. A total of 52 countries 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 2016, and consisted of 9 low-income (N=18,576), 27 lower middle-income (N=68,008), 16 upper middle-income (N=61,461) countries based on the World Bank classification at the time of the survey.

***Perceived loneliness*** *(dependent variable)*

Perceived loneliness was assessed with the question “During the past 12 months, how often have you felt lonely?” with answer options ‘never’, ‘rarely’, ‘sometimes’, ‘most of the time’, and ‘always’. This variable was dichotomized as never, rarely, sometimes (coded=0) and most of the time, always (coded=1) as in a previous GSHS publication (Glozah et al., 2018).

***Leisure-time sedentary behavior*** *(LTSB) (independent variable)*

LTSB 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 answer 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) (Guthold et al., 2010). This question was based on the National Health And Nutrition Examination Survey (NHANES) questionnaire from 1999-2000 ([www.cdc.gov/nchs/nhanes.htm](http://www.cdc.gov/nchs/nhanes.htm)), and modified for use in children.

***Covariates***

Covariates included sex, age, food insecurity, anxiety-induced insomnia, number of friends, physical activity, parental support/involvement, and bullying victimization. As in previous studies using the same dataset (Balogun et al., 2014; Carvalho et al., 2018), food insecurity was used as a proxy for socioeconomic status as there were no variables on socioeconomic status in the GSHS. Also, anxiety-induced insomnia was considered a proxy of psychiatric disorders as there were no variables on psychiatric disorders in the dataset (Carvalho et al., 2018). Food insecurity 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’. Anxiety-induced insomnia was defined as replying ‘most of the time’ or ‘always’ to the question “During the past 12 months, how often have you been so worried about something that you could not sleep at night?” (Carvalho et al., 2018). The number of friends was assessed by the question “How many close friends do you have?”. Answer options were categorized as 0, 1-2, and ≥3. To assess levels of physical activity, questions that represented the PACE+ Adolescent Physical Activity Measure (Prochaska et al., 2001) were asked. This measure has been tested for validity and reliability (Prochaska et al., 2001). The question asked about the number of days with physical activity of at least 60 minutes during the past 7 days. Low parental support/involvement was defined as answering ‘rarely’ or ‘never’ to all of the following three questions: (a) ‘during the past 30 days, how often did your parents or guardians check to see if your homework was done?’; (b) ‘during the past 30 days, how often did your parents or guardians understand your problems and worries?’; and (c) ‘during the past 30 days, how often did your parents or guardians really know what you were doing with your free time?’ (Romo et al., 2016). Bullying victimization was defined as being bullied on at least one day during the last 30 days.

***Statistical analysis***

Statistical analyses were performed with Stata 14.1 (Stata Corp LP, College station, Texas). The analysis was restricted to those aged 12-15 years as the exact age outside of this age range was not available. Age-sex adjusted prevalence of loneliness and LTSB by country were calculated using the proportions derived from the overall sample as the standard population. We used multivariable logistic regression analysis to estimate the association between LTSB (independent variable) and loneliness (dependent variable) using the overall, sex-wise, and country-wise samples. The exposure variable was the five-category LTSB variable when the overall and sex-wise samples were used. However, for country-wise analyses, we used the dichotomized LTSB 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 LTSB and loneliness, we calculated the Higgins’ *I*2 which represents the degree of heterogeneity that is not explained by sampling error with a value of <40% often considered as negligible and 40-60% as moderate heterogeneity (Higgins and Thompson, 2002). 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.

 All regression analyses were adjusted for age, sex, food insecurity, anxiety-induced insomnia, number of friends, physical activity, parental support/involvement, bullying victimization, and country with the exception of the sex-wise and country-wise analyses which were not adjusted for sex and country, respectively. Adjustment for country was done by using fixed effects models as in a previous GSHS study (McKinnon et al., 2016). All variables were included in the regression analysis as categorical variables with the exception of age and physical activity (continuous variable). Under 2.5% of the data were missing for the variables included in the study with the exception of bullying victimization (8.2%). 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**

A total of 148,045 adolescents aged 12-15 years [mean (SD) age 13.7 (1.0) years; 48.5% female] constituted the final sample. Overall, the prevalence of loneliness was 10.0%, while the prevalence of <1, 1-2, 3-4, 5-8, and >8 hours of LTSB were 41.4%, 32.9%, 14.8%, 7.4%, and 3.6%, respectively. The age-sex adjusted prevalence of loneliness and LTSB varied widely between countries, with the ranges being 2.3% (Laos) to 28.5% (Afghanistan) for loneliness and 7.6% (Pakistan) to 53.7% (Antigua & Barbuda) for LTSB (Table 1). The prevalence of loneliness were similar in low-income (9.1%), lower middle-income (10.2%), and upper middle-income (10.3%) countries (Chi-squared test; P=0.087), while the prevalence of ≥3 hours/day of LTSB increased linearly with increasing country-income level: 20.5% (low-income countries), 23.1% (lower middle-income countries), and 41.6% (upper middle-income countries) (Chi-squared test; P<0.001). An upward trend in the prevalence of loneliness was observed with increasing hours per day spent in LTSB especially beyond ≥1-2 hours/day (**Figure 1**). For example, in the overall sample, the prevalence of loneliness increased from 8.7% (1-2 hours/day of LTSB) to 17.5% (>8 hours/day). This was also confirmed in the adjusted models where in the overall sample, compared to those who engage in less than 1 hour of LTSB per day, the OR (95%CI) for 1-2 hours/day, 3-4 hours/day, 5-8 hours/day and >8 hours/day were 1.00 (0.91-1.11), 1.29 (1.15-1.45), 1.37 (1.17-1.61), and 1.66 (1.39-1.99), respectively (**Table 2**). The estimates for males and females were similar although 3-4 hours/day of LTSB was significantly associated with loneliness only among females. The country-wise association between LTSB of ≥3 hours/day and loneliness is shown in **Figure 2**. The pooled estimate based on a meta-analysis for all 52 countries was 1.30 (95%CI=1.24-1.37) with a negligible level of between-country heterogeneity (*I2*=23.9%). There was no significant heterogeneity between country-income groups (P=0.229).

**Discussion**

To the best of our knowledge, this is the first multinational study to investigate the relationship between sedentary behavior and perceived loneliness in adolescence, while it is by far the largest study on this topic. We found consistent evidence that adolescents who engaged in sedentary behavior, excluding time at school and when doing homework, for 3 or more hours a day, were more likely to feel lonely across the vast majority of countries included in our study. We also found some evidence suggesting a dose-dependent association between sedentary behavior and loneliness. The prevalence of loneliness increased from 8.9% when being less than one hour/day sedentary to 17.5% when being more than 8 hours/day sedentary. The association between loneliness and LTSB was also confirmed in the analysis adjusting for potential confounders including physical activity 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 1.66 times more likely to feel lonely.

 Although the mechanisms linking sedentary behavior and loneliness are unknown, several hypotheses may be proposed. First, there is evidence to believe that loneliness in adolescents is a central symptom in adolescent depression (Mullarkey et al., 2018). Previous research has suggested a causal pathway from sedentary behavior to adverse mental health outcomes, including negative mood (Edwards and Loprinzi, 2016). Vice versa, feelings of depression may lead to more sedentary behavior (Hoare et al., 2016). Second, social media use might be one of the explanatory factors. It has been associated with increased sitting time while using a computer, and total sitting time during leisure (Alley et al., 2017) and is an important driver of sedentary behavior in adolescents (Sandercock et al., 2016). More time spent on social media has been associated as well with higher levels of interest loss, concentration problems, fatigue, and loneliness (Aalbers et al., 2018). Indeed, social media have become an increasingly popular activity among young people in recent years, which can induce feelings of social rejection due to inherent design aspects of these platforms and/or as a consequence of cyber bullying (Firth et al., 2019). As this study did not include any measures of social media usage, further longitudinal and intervention studies (e.g., limiting time spent on internet and social media) are needed to determine how this may mediate the association between sedentary behavior and loneliness. Besides social media use, the presence of somatic conditions might be a mediator in the relationship between sedentary behavior during leisure time and loneliness. More time spent sedentary is associated with a higher risk for functional somatic symptoms in adolescents (Janssens et al., 2014), while having a chronic condition in adolescents is strongly linked with feelings of loneliness (Maes et al., 2017).

Our findings should however be interpreted in the light of several potential limitations. First of all, the study is cross-sectional, therefore the directionality or causality of the relationships cannot be deduced. For example, the association could be secondary to other factors that are related to social behavior and physical inactivity, such as poor self-rated health, a debilitating chronic illness, and mobility limitations. Longitudinal and intervention studies are required to better disentangle the relationships observed. However, regardless of causality, the mere co-existence of sedentary behavior and loneliness in adolescence is likely to be deleterious to health as they are both independently associated with adverse physical and mental health outcomes (Hoare et al., 2016; Oliveira et al., 2011; Stickley et al., 2016; Stickley et al., 2014). Second, self-reported time spent sedentary excluded time at school and when doing homework and therefore is an underestimate of the real time spent sedentary during the entire day. Future research should utilize objective measures of sedentary behavior. Accelerometers-inclinometers are available that allow for valid and reliable assessment of sedentary behavior. However, the association between sedentary behavior and loneliness may be dependent on the reason for a specific sedentary behavior, something which cannot be captured with an objective assessment tool. For example, while social media use can increase feelings of loneliness if used for social skill compensation, its’ use for making new friends reduces peer-related loneliness over time (Teppers et al., 2014). Therefore, increasing time spent using social media platforms may be associated with more loneliness while at the same time can be used to stay in touch with friends, make plans, get to know people better, and present oneself to others (Shapiro and Margolin, 2014), all of which might have protective benefits. Similarly, it has been suggested that access to internet mayoffer increased access to health information, includingmental health support (Horgan and Sweeney, 2010).Next to this, it is likely that certain leisure-time activities will be linked to loneliness but that other sedentary activities will not be linked to loneliness (e.g. watching TV/playing videos games with friends, meditating, reading).Therefore, in order to better understand the relationship between time spent sedentary during leisure and loneliness, a combination of both objective and subjective assessment of sedentary behavior is warranted. Next, although we adjusted for anxiety-related insomnia as a proxy for mental disorders, it would have been more ideal to adjust for specific mental disorders such as depression and anxiety. In addition, the loneliness variable was based on a single-item question but it has been previously reported that single-item questions produce similar findings to multiple-item scales (Stack, 1998), and that these are generally robust especially when using extreme categories to define loneliness (Victor et al., 2012) as in our study. Future research should also adjust for other variables such as geographical proximity of friends, relationship conflict with friends, frequency of seeing friends, etc. Although we did adjust for parental involvement, future research should also investigate parental influences more in detail. For example, maternal encouragement to be active has been shown to be associated with decreased TV/video time among younger females (Bauer et al., 2011), while parental conflict behavior is associated with feelings of loneliness in children (Feeney, 2006).

Finally, varying degrees of bias may have been introduced by interviewing only schoolchildren who might feel less lonely than those who are not attending school. However, the majority of 12–15 years old adolescents from most of the countries in our study do attend school (UNICEF, 2015).

 In conclusion, the current study provides multi-national evidence from LMICs of a relationship between LTSB and loneliness in adolescents and this was irrespective of physical activity levels. The consistency of these relationships observed, at least beyond 3 hours/day of sedentary behavior, across the included countries adds further weight to the growing evidence for a connection between sedentary behavior and loneliness in adolescents.

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| **Table 1** Survey characteristics and age-sex adjusted prevalence of loneliness and leisure-time sedentary behavior |
| Country income | Country | Year | Na | Response rate (%) | Loneliness (%) | Sedentary behavior (%)b |
| Low | Afghanistan | 2014 | 1,493 | 79 | 28.5 | 22.8 |
|  | Benin | 2016 | 717 | 78 | 10.5 | 25.3 |
|  | Kenya | 2003 | 2,971 | 84 | 17.8 | 37.6 |
|  | Mozambique | 2015 | 668 | 80 | 8.0 | 40.6 |
|  | Myanmar | 2007 | 2,227 | 95 | 3.9 | 10.0 |
|  | Nepal | 2015 | 4,616 | 69 | 5.6 | 9.9 |
|  | Tanzania | 2014 | 2,615 | 87 | 6.7 | 20.4 |
|  | Uganda | 2003 | 1,904 | 69 | 9.3 | 27.1 |
|  | Zambia | 2004 | 1,365 | 70 | 23.6 | 32.6 |
| Lower middle | Bangladesh | 2014 | 2,753 | 91 | 10.3 | 14.1 |
|  | Belize | 2011 | 1,600 | 88 | 12.4 | 36.1 |
|  | Bolivia | 2012 | 2,804 | 88 | 9.9 | 24.2 |
|  | East Timor | 2015 | 1,631 | 79 | 10.8 | 15.2 |
|  | Egypt | 2006 | 4,981 | 87 | 8.0 | 25.5 |
|  | El Salvador | 2013 | 1,615 | 88 | 7.9 | 33.6 |
|  | Ghana | 2012 | 1,110 | 82 | 12.7 | 18.3 |
|  | Guyana | 2010 | 1,973 | 76 | 16.6 | 35.9 |
|  | Honduras | 2012 | 1,486 | 79 | 10.1 | 30.4 |
|  | Indonesia | 2015 | 8,806 | 94 | 6.3 | 25.7 |
|  | Jordan | 2007 | 1,648 | 100 | 15.0 | 38.1 |
|  | Kiribati | 2011 | 1,340 | 85 | 4.9 | 14.9 |
|  | Laos | 2015 | 1,644 | 70 | 2.3 | 17.4 |
|  | Macedonia | 2007 | 1,550 | 93 | 5.8 | 50.3 |
|  | Maldives | 2009 | 1,981 | 80 | 18.4 | 44.4 |
|  | Mauritania | 2010 | 1,285 | 70 | 16.4 | 39.2 |
|  | Mongolia | 2013 | 3,707 | 88 | 11.4 | 39.8 |
|  | Morocco | 2010 | 2,405 | 92 | 17.0 | 25.9 |
|  | Pakistan | 2009 | 4,998 | 76 | 11.9 | 7.6 |
|  | Philippines | 2015 | 6,162 | 79 | 15.1 | 30.5 |
|  | Samoa | 2011 | 2,200 | 79 | 23.1 | 37.5 |
|  | Solomon Islands | 2011 | 925 | 85 | 12.0 | 27.8 |
|  | Sri Lanka | 2008 | 2,504 | 89 | 7.3 | 33.4 |
|  | Tonga | 2010 | 1,946 | 80 | 15.6 | 28.3 |
|  | Tunisia | 2008 | 2,549 | 83 | 17.0 | 24.1 |
|  | Vanuatu | 2011 | 852 | 72 | 7.4 | 20.0 |
|  | Yemen | 2014 | 1,553 | 75 | 14.2 | 19.4 |
| Upper middle | Antigua & Barbuda | 2009 | 1,235 | 67 | 11.8 | 53.7 |
|  | Argentina | 2012 | 21,528 | 71 | 8.5 | 49.1 |
|  | Botswana | 2005 | 1,397 | 95 | 14.4 | 35.7 |
|  | Costa Rica | 2009 | 2,265 | 72 | 5.5 | 43.1 |
|  | Fiji | 2016 | 1,537 | 79 | 12.1 | 24.4 |
|  | Grenada | 2008 | 1,299 | 78 | 13.4 | 41.4 |
|  | Iraq | 2012 | 1,533 | 88 | 15.9 | 25.6 |
|  | Lebanon | 2011 | 1,982 | 87 | 11.8 | 47.0 |
|  | Malaysia | 2012 | 16,273 | 89 | 6.8 | 42.6 |
|  | Namibia | 2013 | 1,936 | 89 | 12.5 | 36.9 |
|  | Peru | 2010 | 2,359 | 85 | 9.9 | 27.4 |
|  | St. Lucia | 2007 | 1,072 | 82 | 13.6 | 53.5 |
|  | St. Vincent & the Grenadines | 2007 | 1,188 | 84 | 15.4 | 39.7 |
|  | Suriname | 2009 | 1,046 | 89 | 13.7 | 39.1 |
|  | Thailand | 2015 | 4,132 | 89 | 9.8 | 51.0 |
|   | Tuvalu | 2013 | 679 | 90 | 8.3 | 15.4  |

a N is based on those aged 12-15 years.

b Leisure-time sedentary behavior of ≥3 hours/day.

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| **Table 2** Association between leisure-time sedentary behavior and loneliness estimated by multivariable logistic regression |
|   | Overall |   | Male |   | Female |   |
| Hours spent sedentary | OR | 95%CI | OR | 95%CI | OR | 95%CI |
| <1 hour/day | 1.00 |  | 1.00 |  | 1.00 |  |
| 1-2 hours/day | 1.00 | [0.91,1.11] | 0.92 | [0.78,1.09] | 1.09 | [0.97,1.22] |
| 3-4 hours/day | 1.29\*\*\* | [1.15,1.45] | 1.08 | [0.90,1.30] | 1.46\*\*\* | [1.27,1.69] |
| 5-8 hours/day | 1.37\*\*\* | [1.17,1.61] | 1.35\* | [1.03,1.77] | 1.39\*\*\* | [1.18,1.63] |
| >8 hours/day | 1.66\*\*\* | [1.39,1.99] | 1.63\*\*\* | [1.23,2.14] | 1.66\*\*\* | [1.34,2.07] |

Abbreviation: OR Odds ratio; CI Confidence interval

Models are adjusted for age, food insecurity, anxiety-induced insomnia, number of friends, physical activity, parental support/involvement, bullying victimization, and country. The model based on the overall sample is additionally adjusted for sex.

\* p<0.01, \*\* p<0.001

**Figure 1** Prevalence of loneliness by hours of leisure-time sedentary behavior per day

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**Figure 2** Country-wise association between leisure-time sedentary behavior of ≥3 hours/day (exposure) and loneliness (outcome) estimated by multivariable logistic regression

Abbreviation: OR Odds ratio; CI Confidence interval.

Models are adjusted for age, sex, food insecurity, anxiety-induced insomnia, number of close friends, physical activity, parental support / involvement and bullying victimization.

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