How Sedentary are University Students? A Systematic Review and Meta-analysis

Oscar Castro[a]; Jason Bennie[a]; Ineke Vergeer[a]; Grégoire Bosselut[b]; Stuart J.H. Biddle[a]

[a]Physically Active Lifestyles Research Group (USQ-PALs), Institute for Resilient Regions, University of Southern Queensland, Springfield Central, Queensland, Australia.

[b]Laboratory Epsylon "Dynamics of Human Abilities and Health Behavior" (EA 4556), University of Montpellier, Montpellier, Hérault, France.

Oscar Castro: Oscar.CastroSerrano@usq.edu.au

Jason Bennie: Jason.Bennie@usq.edu.au

Ineke Vergeer: Ineke.Vergeer@usq.edu.au

Grégoire Bosselut: Gregoire.Bosselut@umontpellier.fr

Stuart J.H. Biddle: Stuart.Biddle@usq.edu.au

Corresponding Author: Oscar Castro; Postal address: University of Southern Queensland, Springfield campus, PO BOX 4393, Raceview LPO, Raceview, QLD 4305, Australia.

The number of pages: 32; The number of words of the abstract: 249; The number of references in the main text: 47; The number of figures: 1; The number of tables: 3

Abstract

Accumulating high volumes of sedentary behaviour is a risk factor for multiple negative health-related outcomes. The objective of this review was to synthesise the evidence on the levels of sedentary behaviour in university students. Screened records from 13 databases were included if: (i) published after 2007; and (ii) reported on university students' amount of total or domain-specific sedentary behaviour. Sub-group and meta-regression analyses were conducted to investigate potential sources of heterogeneity (moderators). A total of 125 studies met the inclusion criteria. Most studies were cross-sectional (84%) and reported screen time (61%) or total sedentary time (39%). Self-reported data indicated that university students spend 7.29 hours per day being sedentary. The levels of total sedentary behaviour were significantly higher when measured with accelerometers (M = 9.82 hours per day). Computer use presented significantly higher prevalence over other modalities of screen time. Among the explored factors (i.e., countries' income, age, gender, and study's publication date), only publication date significantly moderated sedentary behaviour. Results suggest that a considerable proportion of university students (i) engage in higher levels of sedentary time compared to the general young adult population, and (ii) accumulate levels of sedentary time that have been associated with an increased risk for detrimental health outcomes. In addition, meta-regression analyses suggest that sedentary time has increased over the last 10-year period among university students. These findings may inform future initiatives and policies targeting university students' sedentary behaviour. Further research is needed to identify the factors moderating sedentary behaviour in the university setting.

Keywords: sitting; sedentary time; college students; correlates.

How Sedentary are University Students? A Systematic Review and Meta-analysis

Introduction

Sedentary behaviours are waking activities characterized by low energy expenditure and undertaken in a sitting or reclining posture, e.g., reading, watching television, or driving (Tremblay et al. 2017). Recently, engaging in high volumes of sedentary behaviour has been recognised as a risk factor for premature death and several chronic diseases, e.g., type 2 diabetes, metabolic syndrome, and cardiovascular disease (Patterson et al. 2018; Biswas et al. 2015; Wilmot et al. 2012). Evidence also suggests that high levels of sedentary behaviour might have an impact on mental wellbeing, including an increased risk of anxiety and depression (Teychenne et al. 2015; Zhai et al. 2015). Of note, the health risks of sedentary behaviour have been shown to be somewhat independent of meeting current physical activity guidelines (Thorp et al. 2011; Dogra and Stathokostas 2012). While physical activity can play a protective role as a counter to the negative effects of time spent sedentary, levels of physical activity that are considerably higher than currently recommended guidelines may be needed to eliminate the mortality risk associated with sedentary behaviour (Ekelund et al. 2016).

Accelerometer-based estimates show that adults in high-income countries spend a significant proportion of time being sedentary, ~55% to 65% of their waking hours (Hansen et al. 2012; Matthews et al. 2008). Moreover, there is evidence suggesting that time spent in sedentary behaviour is increasing (Du et al., 2019). Studies highlight substantial variation in sedentary time according to socio-demographic factors, such as age, gender, or economic status (Lakerveld et al. 2017). ‘Current occupation’ has been identified as one of the key moderators (Loyen et al. 2016). For example, research consistently shows that white-collar workers report higher levels of sedentary behaviour when compared to the general population

(Owen et al. 2011). This might explain why the majority of sedentary behaviour and public health research among working-aged adults concentrates on desk-based office workers (Gardner et al. 2016). Much like office workers, university students are also a population sub-group at risk of accumulating high levels of sedentary behaviour; activities such as attending lectures or studying likely involve long periods of sitting (Cotton and Prapavessis 2016). A cross-sectional study conducted in Brazil concluded university students spend an average of 8.3 hours of self-reported sedentary time per day (Mussi et al. 2017), and the average is commonly two to three hours higher when using accelerometers (Clark et al. 2016; Conroy et al. 2013). Evidence thus exists suggesting that university students are highly sedentary (Rouse and Biddle 2010; Farinola and Bazán 2011), and that their sedentary behaviour levels are comparable or likely to exceed those of desk-based office workers (Moulin and Irwin 2017). However, to our knowledge, the literature on sedentary behaviour levels in university students is yet to be reviewed systematically. University students are an important proportion of the young adult population, over 35% in most developed countries (Dragoescu 2013; Universities UK 2012). Gaining a better understanding of university students' volume and type of sedentary behaviours could inform future intervention and policy development for this potentially 'at-risk' population sub-group. Moreover, since many adult health-related behaviours are established during late adolescence and young adulthood, the university years are an important period for the development of future life patterns (DHHS 2000).

The objective of the present study was to synthesise the available evidence regarding the amount of sedentary behaviour accumulated by university students. In particular, the purpose of this review was to: (i) provide an overview of the existing studies that assessed sedentary behaviour in the university setting; (ii) describe the reported levels of total and domain-specific sedentary behaviour; and (iii) explore potential variation in sedentary behaviour levels according to country's income, age, gender, and study's publication date.

Methods

The research protocol of this study was registered with the PROSPERO international prospective register of systematic reviews in October 2017 (registration number: CRD42017074198). The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement and the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines were followed for the conduct and reporting of this review (Moher et al. 2009; Stroup et al. 2000). A completed PRISMA checklist is available as online supplementary material (File 1).

Search Strategy

A computerized search for literature was performed within the following databases: Web of Science (including Web of Science Core Collection and MEDLINE), SciELO, Scopus, and EBSCOhost MegaFile Ultimate (including CINAHL with Full Text, Academic Search Ultimate, PsycINFO, PsycARTICLES, Education Research Complete, Psychology and Behavioral Sciences Collection, ERIC, and SPORTDiscus with Full Text). Automatic search alerts were set up and maintained until the final analyses (November 2018) to identify new published papers since the original database search. The search strategy was developed with the assistance of a research librarian and included key words in three categories: 'student', 'university' (e.g. higher education, undergraduate), and 'sedentary behaviour' (e.g. sitting, screen time). The full search strategy for EBSCOhost MegaFile Ultimate is available as online supplementary material (File 2). In addition to the electronic search, reference lists of included studies were hand-searched to identify studies.

Inclusion Criteria

Studies that met the following criteria were included in the review: (1) published after 01/01/2007 in a peer-reviewed journal in English, Spanish, or French; (2) included university

students (undergraduate or postgraduate students); and (3) reported on the students' levels of total and/or domain-specific sedentary behaviour. Study designs eligible for inclusion were observational (e.g., cross-sectional and prospective) and interventional (e.g., randomised controlled and quasi-experimental). For intervention studies, only baseline or control data were included. The starting point of the search (i.e., 2007) was chosen in order to capture the relatively current levels of sedentary behaviour. For the type of sedentary behaviour, one or more of the following were included: total accelerometer-based sedentary time (with ≤ 100 activity counts assumed to be sedentary), total self-reported sedentary time (with total sitting time used as a proxy measure of total sedentary time in most self-report methods), screen time (e.g., TV viewing, computer use), occupational sedentary behaviour (e.g., lecture attendance, private study time), or passive transportation. Sedentary behaviour was reported either as a summary point estimate (e.g., mean minutes/hours per day) or as a proportion (e.g., percentage of the sample sitting more than 6 hours per day).

Selection Process

Two reviewers (OC and GB) independently screened the title/abstract of articles identified through database or manual searches to assess whether they met the inclusion criteria. Full-text papers of retained articles were then retrieved and examined by the same two reviewers independently, with any discrepancies resolved with a consensus discussion (89% agreement prior to discussion). Disagreements that could not be resolved by consensus were discussed with a third reviewer (SJHB).

Data Extraction

The same two reviewers (OC and GB) independently extracted data on publication details, study design, sample characteristics, measurement of sedentary behaviour, type of sedentary behaviour, level of measurement (e.g., average minutes per day, threshold), and

reported amount of sedentary behaviour. The reviewers utilised a standardised pre-piloted data extraction form and resolved any discrepancies with discussion and consensus (84% agreement prior to discussion). Where consensus could not be reached, a third reviewer (SJHB) was consulted.

Data Analysis

Studies reporting sedentary behaviour as mean (standard deviation) and/or proportion (e.g., percentage of the sample sitting more than 6 hours per day) were inputted in the software Comprehensive Meta-analysis version 3 (CMA; Biostat Inc., Englewood, United States) for quantitative synthesis. When sedentary behaviour was reported as median (interquartile range) or data were missing (e.g., standard deviation), corresponding authors were contacted by email for additional information. After seven business days, a second reminder was sent if there was no response to the initial email. Of the 20 authors contacted, 12 authors provided the requested data. Two authors could not comply with the request due to no current access to the data. The remaining six authors did not reply to either of the two emails that were sent.

Confidence intervals (95%) were calculated for every sedentary behaviour point estimate and proportion. The variability in the point estimates and proportions between the included studies was measured with the Q and L^2 statistics. A significant Q-test and a high L^2 value (above 75%) are considered indicators of substantial heterogeneity (Higgins and Green 2011). Sub-group (categorical) and meta-regression analyses were conducted to investigate the contribution of specific variables to heterogeneity. Sub-group analyses were employed for a particular sedentary behaviour domain when more than four articles were available for each subgroup variable (Fu et al. 2011). Based on this criterion, three categorical variables were included in the sub-group analyses: countries' income status (e.g., middle-income vs high-

income), screen time modality (e.g., TV viewing vs computer use), and assessment method (self-reported vs accelerometer-based measures). Meta-regressions were employed when ten or more studies were available for a particular sedentary behaviour domain (Higgins and Green 2011). This criterion resulted in the inclusion of three continuous variables in the meta-regression: mean sample age, study's publication date, and percentage of females in the sample. All analyses were conducted under a random-effects model, owing to the methodological assumption that included studies reflect different populations.

A common scale (hours per day) was chosen in order to facilitate comparison across studies, transforming the raw data where necessary (see online materials for study-specific details). When studies with repeated measures were included into the meta-analysis (k = 8), only the first point estimate or proportion (T1) was computed in CMA in order not to over-represent prospective cohort studies. Similarly, when studies reported data separately for weekdays and weekend (k = 14), only the weekdays point estimate or proportion was meta-analysed (tables with data broken down by time frame are available as online supplementary material – Files 3 and 4). Data reported as categories (k = 27 studies) were transformed into proportions for different cut-offs criteria (e.g., screen time – TV: 36.9% of participants <1 hr/d / 38% 1-2 hr/d / 25.1% >2 hr/d was transformed into 63.1% of participants >1 hr/d / 25.1% >2 hr/d). When sedentary behaviour was reported separately by gender or treatment group (i.e., multiple subgroups within a study; k = 14 studies), the subgroups were combined for each study following previous guidelines (Borenstein et al. 2009; formula available as online supplementary material – File 5). As such, the summary data for each subgroup (mean, standard deviation, and sample size) were used to recreate the sedentary behaviour point estimate for the study as a whole, allowing a wider comparison across studies (i.e., study as the unit of analysis).

Risk of Bias

The risk of bias was assessed using a version of the Cochrane Collaboration's Tool for Assessing Risk of Bias (Higgins et al. 2011) adapted for observational studies (Poitras et al. 2016; Prince et al. 2017). Studies were assessed for potential biases, including selection bias (random sampling method), performance bias (sedentary behaviour measurement), attrition bias (completeness of outcome data), and selective reporting bias (selective outcome reporting). Each potential source of bias was marked as high, low, or unclear risk of bias according to pre-specified criteria. Risk of bias assessments were carried out by two reviewers independently (OC and GB). Discrepancies were identified and resolved through discussion (83% agreement prior discussion), with a third reviewer mediating where necessary (SJHB). For each study, a composite risk of bias score was calculated by summing the number of criteria marked 'low risk of bias' (50% criterion). Sub-groups analyses (high risk of bias studies vs low risk of bias studies) and meta-regressions (number of criteria marked 'low risk of bias') were conducted to explore whether risk of bias results explained variation in the sedentary behaviour point estimates (sensitivity analysis). The risk of bias instrument is available as online supplementary material (File 6). In addition, a further sensitivity analysis was conducted with the studies' sample size as a meta-regression (moderator) variable, in order to explore potential variation of results according to the number of participants included.

Results

Narrative Synthesis (k = 125)

Description of Studies

A total of 125 studies met the inclusion criteria (see Figure 1 for PRISMA flowchart). Studies were published in English (88%) or Spanish (12%) and included data from 110,214 participants, with a median sample size of 306 participants (*IQR* = 149-751). Most studies

were cross-sectional (84%), with smaller proportions being prospective cohort studies (10%) and randomized control trials (6%). Studies were conducted in Europe (32%), Asia (23%), North America (21%), South America (11%), Africa (9%), and Australia (2%). Over half of the participants were described as undergraduate students (61%). However, data on the students' enrolment status was missing in one third of the studies (33%). A comprehensive overview of all included studies per sedentary behaviour domain is available as online supplementary material (Files 7-11), along with the full list of citations (File 12).

Measurement of Sedentary Behaviours

Most studies (93%) based their measurements on self-reported sedentary behaviour (e.g., questionnaires or inventories). The primary measure of sedentary behaviour was screen time (61%), followed by total sedentary behaviour (39%), occupational sedentary behaviour (10%), and passive transportation (2%). Sedentary behaviour was reported both as a point estimate (73%) and as a proportion (33%). Only three studies reported data on breaks from sedentary behaviour (e.g., frequency and duration of movement breaks).

Risk of Bias Assessment

The majority of studies were classified as low risk of bias studies (68%), according to the composite risk of bias score. In relation to the risk of bias per bias criterion, over half of the studies (57%) measured sedentary behaviour employing a non-validated tool and were thus coded as having a high risk of performance bias. Similarly, a majority of studies (61%) had a high risk of selection bias due to the use of convenience (non-random) samples. Only a few studies (16%) presented high attrition bias. Finally, studies were predominantly free of selective reporting bias (81%). Detailed risk of bias results are available as online supplementary material (File 13).

Quantitative Synthesis (k = 119)

Total Sedentary Behaviour

Self-reported Sedentary Time

For self-reported sedentary time, 32 studies reported point estimates (Table 1). In addition, six studies reported proportions (Table 2). Sufficient studies reported on point estimates of sedentary time to allow for the conduct of heterogeneity analyses specifically for this sedentary behaviour domain (i.e., ≥10 studies for meta-regression and ≥4 studies for each subgroup variable). Heterogeneity was significant and high (Q = 6566.23, df = 31, p = 0.00; I^2 = 99.52%). The difference in self-reported sedentary time between upper middle-income and high-income countries was not statistically significant (Upper middle-income: 7.84 hr/d, 95% CI: 6.92 – 8.76, k = 19; high-income: 6.87 hr/d, 95% CI: 6.24 – 7.49, k = 11; Q = 2.93, p = 0.08). The difference in self-reported sedentary time between high risk of bias and low risk of bias studies was also non-significant (high risk of bias: 7.76 hr/d, 95% CI: 7.06 – 8.47, k = 5; low risk of bias: 7.21 hr/d, 95% CI: 6.57 – 7.84, k = 27; Q = 1.33, p = 0.24). Study's publication date significantly moderated self-reported sedentary time, with recent studies reporting higher point estimates (Table 3).

Accelerometer-based Sedentary Time

For accelerometer-based sedentary time, eight studies reported point estimates (Table 1). This number was sufficient to compare self-reported and accelerometer-based sedentary time. The summary point estimate for accelerometer-based sedentary time (9.82 hr/d, 95% CI: 8.63 – 11.01, k = 6) was significantly higher than the one for self-reported sedentary time (7.29 hr/d, 95% CI: 6.73 – 7.85, k = 32; Q = 14.22, p = 0.00).

Domain-specific Sedentary Behaviour

Screen Time

For screen time (including TV, computer, mobile phone, video games, or a combination of these), 37 studies reported point estimates (Table 1). In addition, 41 studies reported proportions (Table 2). Sufficient studies reported on TV viewing, computer use, and the proportion of university students exceeding two hours of daily TV viewing to allow for the conduct of heterogeneity analyses specifically for these domains.

For the TV viewing point estimate, heterogeneity was significant and high (Q = 9345.46, df = 20, p = 0.00; L^2 = 99.78%). The difference in TV viewing between high risk of bias and low risk of bias studies was non-significant (high risk of bias: 1.62 hr/d, 95% CI: 1.38 – 1.87, k = 9; low risk of bias: 1.38 hr/d, 95% CI: 0.94 – 1.82, k = 12; Q = 0.91, p = 0.33). None of the examined variables significantly moderated the levels of TV viewing (Table 3).

For the proportion of university students exceeding two hours of daily TV viewing, heterogeneity was significant and high (Q = 2750.24, df = 14, p = 0.00; L^2 = 99.49%). The difference in the proportion of students exceeding the two hours cut-off between high risk of bias and low risk of bias studies was non-significant (high risk of bias: 42% exceeding the cut-off, 95% CI: 27 – 58, k = 8; low risk of bias: 27% exceeding the cut-off, 95% CI: 16 – 40, k = 7; Q = 2.22, p = 0.13). None of the examined variables significantly moderated the proportion of university students exceeding two hours of daily TV viewing (Table 3).

For the computer use point estimate, heterogeneity was significant and high (Q = 3727.7, df = 15, p = 0.00; L^2 = 99.59%). There was no significant difference in computer use between university students from lower middle-income and high-income countries (lower middle-income countries: 2.21 hr/d, 95% CI: 0.98 – 3.45, k = 4; high-income countries: 3.05 hr/d, 95% CI: 2.25 – 3.85, k = 10; Q = 1.24, p = 0.26). The difference in computer use between high risk of bias and low risk of bias studies was non-significant (high risk of bias:

3.26 hr/d, 95% CI: 2.71 – 3.82, $k = 6$; low risk of bias: 2.7 hr/d, 95% CI: 1.97 – 3.42, $k = 10$; $Q = 1.46$, $p = 0.22$). None of the examined variables significantly moderated the levels of computer use (Table 3).

A sufficient number of studies were available to compare the time spent in different screen time modalities. University students reported significantly more time using the computer (2.91 hr/d, 95% CI: 2.32 – 3.5, $k = 16$) than watching TV (1.49 hr/d, 95% CI: 1.22 – 1.76, $k = 21$; $Q = 18.16$, $p = 0.00$) or playing video games (0.37 hr/d, 95% CI: 0.11 – 0.62, $k = 7$; $Q = 59.47$, $p = 0.00$).

Occupational Sedentary Behaviour

For occupational sedentary behaviour (including time spent studying, in lectures, or a combination of these), nine studies reported point estimates (Table 1). In addition, four studies reported proportions (Table 2). There were not sufficient studies to allow for the conduct of heterogeneity analyses specifically for this sedentary behaviour domain.

Passive Transportation

A total of two studies reported passive transportation using point estimates (Table 1). There were not sufficient studies to allow for the conduct of heterogeneity analyses specifically for this sedentary behaviour domain.

Discussion

To our knowledge, the present systematic review and meta-analysis is the first to examine the amount of total and domain-specific sedentary behaviour accumulated by university students. Regarding total sedentary behaviour, self-reported estimates across 32 studies indicate that university students spend on average 7.29 hours per day sitting. The Eurobarometer 64.3 investigated the levels of self-reported sedentary time across multiple

countries and reported that adults aged 18-25 spend on average 5.86 hours per day sitting (95% CI: 5.76 – 5.96, *n* = 3,114; European commission 2012). Therefore, our data might be an indication that most university students engage in higher levels of self-reported sedentary time compared to the general young adult population (in high income countries). This also seems to be the case when accelerometer-based measures of sedentary behaviour are employed. Findings from the US National Health and Nutrition Examination Survey (NHANES) indicate that adults aged 20-29 spend on average 7.48 hours per day being sedentary (95% CI: 7.26 – 7.69, *n* = 636; Matthews et al. 2008). Our data across six studies suggest that many university students engage in larger volumes of sedentary behaviour per day (*M* = 9.82 hr/d, 95% CI: 8.63 – 11.01). While further research is needed to examine the extent and causes of this apparent discrepancy, the high levels of sedentary behaviour in university students might be explained by the activities that they usually perform, requiring long periods of sitting (e.g., studying, writing assignments, attending lectures).

Increasing our knowledge of the patterns and distributions of sedentary behaviour in university students is relevant given that the quantity of time spent sedentary has been recognised as a risk factor for several negative health-related outcomes (Biswas et al. 2015; Wilmot et al. 2012; Zhai et al. 2015). Previous meta-analyses have investigated the dose–response relationship between self-reported sitting time and mortality risk, after controlling for physical activity. Patterson et al. (2018) found positive and non-linear associations between self-reported sitting and cardiometabolic / mortality outcomes across 34 studies (*n* = 1,331,468). A threshold of between 6–8 hours per day of total sitting was identified, above which the mortality risk is increased. Chau et al. (2013) reported similar results: the hazard ratios for all-cause and cardiovascular mortality start to increase significantly from 7–8 hours of self-reported sitting per day onwards (*n* = 595,086). In relation to accelerometer-based sedentary behaviour, a recent meta-analysis has also found evidence of a non-linear

association between time spent sedentary and risk of death across eight studies (n = 36,383). Authors reported a statistically significant higher mortality risk for daily sedentary times of 9.5 or more hours (Ekelund et al. 2019). Given that our summary point estimates for total self-reported and accelerometer-based sedentary time are within or slightly above the mentioned thresholds, we interpret that a considerable percentage of students are likely to be at an increased risk for the negative health consequences of sitting. The summary proportions for self-reported sedentary time also reinforce this idea. Around one third of the university students reported spending more than 8 hours sitting per day, in two studies totalling 6,923 participants. Taken together, these findings might be relevant to inform the development and implementation of public health programs targeting sitting time reductions in university students, along with physical activity promotion. Sedentary behaviour reduction and other behaviour change interventions with adolescents and young adults offer the opportunity to promote a lifelong healthy lifestyle (DHHS 2000). This is important as university students are more likely to work in white-collar occupations upon graduation and will thus be potentially exposed to high levels of sitting during workdays. In addition, meta-regression analyses with self-reported total sedentary behaviour suggest that time spent sedentary has increased over the last 10-year period. This finding is consistent with previous studies; Du et al. (2019) noted that self-reported sedentary time among US adults has increased in the last decade across all analysed subgroups (including age, gender, educational level, race/ethnicity, and BMI categories). While the reasons for this positive trend remain unclear and warrant further investigation, it is plausible that recent environmental and social changes prompt individuals to sit down for longer periods (e.g., wider availability of screen-based devices and passive forms of transportation, increased number of sedentary, office-based occupations).

Over half of the included studies reported on university students' screen time. Several studies have reported significant associations between different forms of screen time (mainly

TV) and negative health-related outcomes in young adults. This includes physical effects, e.g., poor sleep quality (Wu et al. 2015), increased risk of headaches (Montagni et al. 2016), chronic neck pain (Camacho and Nakazato 2018), and psychological effects, e.g., increased risk of depression (Madhav et al. 2017) and decreased well-being (Kross et al. 2013). Alternatively, recent calls have been made claiming that the use of screens may also have positive effects (Bell et al. 2015; Gao et al. 2015), and that certain modalities of screen time may be more detrimental than others (Altenburg et al. 2013). Rather than the total amount of screen time, the purpose of screen use might be more important (e.g., recreational vs educational screen time). Unfortunately, purpose of screen use was rarely reported among the included studies, and therefore warrants further attention. In our review, the dominant screen time modality used by university students was the computer. These data may suggest that future epidemiology studies on screen time in university students, or intervention studies targeting screen time reduction, should pay closer attention to computer use.

A substantial variation in the sedentary behaviour point estimates and proportions was found across the included studies. Given that studies used similar research designs, measurement tools, and modes of administration, we consider that heterogeneity might reflect differences across the included participants (and not methodological differences across the studies). We used sub-group and meta-regression analyses in order to investigate the contribution of specific factors to heterogeneity (i.e., countries' income, age, study's publication date, and gender). However, while these factors have contributed to variation in total or domain-specific sedentary behaviour in previous studies, only publication date was a significant moderator in our review. It might be that the factors explaining variation in university students are different from those in the general population. University-specific factors such as major subject of study, enrolment status, or year of enrolment, are potentially relevant to explain variation in sedentary behaviour levels. For example, we can expect

graduate students to have a higher workload than undergraduate students, thus accumulating more sitting hours. Similarly, full-time students might engage in higher levels of sitting than part-time students. That is, the found variability across the included studies might reflect different sedentary behaviour levels within the university student population. Unfortunately, these university-specific variables could not be analysed in our review due to lack of sufficient studies and poor study reporting. This constitutes a limitation for our meta-analysis, as it could have been more appropriate to calculate different summary point estimates and proportions for different group of university students. Given the high heterogeneity, our summary data should be understood as an estimation of how sedentary are university students. Further research is needed exploring the factors influencing sedentary behaviour in the university setting.

Recommendations for Future Research

While the overall risk of bias was low for the majority of studies included in the systematic review, there were still two risk of bias criteria that deserve attention in upcoming studies: selection bias (marked as high risk of bias in 61% of the studies) and performance bias (marked as high risk of bias in 57% of the studies). To reduce these risks, future studies should use probability samples and validated measurement tools. Second, only three studies reported data on breaks from sedentary behaviour (e.g., frequency and duration of movement breaks). Along with reducing overall sitting time, breaking up sitting time frequently is recommended by several national public health guidelines (Australian Department of Health 2014; UK Department of Health 2011). Therefore, frequency and duration of movement breaks need to be assessed and reported. Third, we found that the summary point estimate for accelerometer-based sedentary time was significantly higher than the one for self-reported sedentary time. This is consistent with previous literature suggesting that self-reports underestimate sedentary behaviour when compared to accelerometer-based methods (Chastin

et al. 2014). However, accelerometers do not provide contextual information and this information may be crucial to better understand sedentary behaviour patterns and inform future interventions. We recommend a combination of both accelerometer-based and self-reported measures in future epidemiology studies. Last, sample description should be improved; relevant information such as university students' enrolment status or major subject of study were missing in most studies. This is important information for future reviewing efforts, as well as to potentially identify sub-groups of students at risk of being highly sedentary and inform intervention development.

Study Limitations and Strengths

Searches were restricted to published studies due to time constraints, which may have resulted in missing relevant literature. Similarly, we only searched for key terms in abstract and title and thus it is possible that potentially eligible articles were not identified. For example, the majority of studies assessed self-reported sitting with the International Physical Activity Questionnaire (IPAQ), which is a questionnaire focused on physical activity. Other study authors using the IPAQ may have prioritised the physical activity findings, not including sedentary behaviour-related terms in the article's title and abstract. However, a particular strength of our search strategy is that we reviewed articles in different languages (English, Spanish, and French) from a large number of electronic databases and reference lists of included articles. In addition, the PRISMA guidelines regarding the conduct and reporting of systematic reviews were carefully followed. Two researchers independently carried out the different stages of the review process (screening, data extraction, risk of bias assessment), reducing the risk of errors and maximizing reliability.

Conclusions

Our findings suggest that most university students engage in high levels of sedentary behaviour, compared to different estimates from the general young adult population. In addition, a substantial proportion of university students seem to accumulate daily volumes of sedentary time that previous meta-analyses have associated with an increased risk for negative health outcomes. Moreover, meta-regression analyses suggest that time spent sedentary has increased over the last decade among university students. These findings may inform future health programs and policies targeting sitting time reductions in university students. In terms of screen time, university students reported spending significantly more time using the computer than watching TV or playing video games. Last, while heterogeneity in the levels of sedentary behaviour was high, only one of the explored factors was a significant moderator (i.e., study's publication date). Further research is needed exploring the factors influencing sedentary behaviour in the university setting.

Acknowledgments

We thank research librarian Dr. Tricia Kelly for her important contributions to the development of the database search strategy.

Author Contribution

OC, JB, IV, and SJHB contributed to the conception and design of the study, as well as to the development of the search strategy. OC and GB conducted the selection and data extraction processes, with input from SJHB. OC performed the data analysis and JB, IV, and SJHB assisted with the interpretation of findings. OC developed the first draft of the paper. All authors contributed to the drafting and revision of the final article. All authors approved the final submitted version of the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data-Sharing Statement

All data relevant to the study are included in the article or uploaded as supplementary online information.

Compliance with Ethical Standards

Conflict of Interest

OC, JB, IV, and GB report no conflict of interest. SJHB is an international advisory panel member for the 'Get Britain Standing' campaign.

Ethical Approval and Informed Consent

Not applicable due to the nature of the manuscript (i.e., systematic review and meta-analysis).

References

Altenburg, T. M., de Kroon, M. L., Renders, C. M., HiraSing, R., & Chinapaw, M. J. (2013). TV time but not computer time is associated with cardiometabolic risk in Dutch young adults. *PloS one*, *8*, e57749.

Australian Department of Health (2014). *Australia's Physical Activity and Sedentary Behaviour Guidelines for Adults (18–64 years)*. Canberra, Australia: Department of Health.

Bell, V., Bishop, D. V., & Przybylski, A. K. (2015). The debate over digital technology and young people. *BMJ, 351*, h3064.

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Annals of Internal Medicine*, *162*, 123-132.

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2009) *Chapter 23: Independent Subgroups Within a Study*. In: M. Borenstein (Ed), *Introduction to Meta-analysis* (pp. 217–23). Chichester, England: John Wiley & Sons.

Camacho, G., & Nakazato, T. (2018). Looking at the smartphone screen for a prolonged time is associated with chronic neck pain, specially in young adults. *Annals of Physical and Rehabilitation Medicine*, *61*, e113.

Chastin, S. F. M., Culhane, B., & Dall, P. M. (2014). Comparison of self-reported measure of sitting time (IPAQ) with objective measurement (activPAL). *Physiological measurement*, *35*, 2319.

Chau, J. Y., Grunseit, A. C., Chey, T., Stamatakis, E., Brown, W. J., Matthews, C. E., ... & van der Ploeg, H. P. (2013). Daily sitting time and all-cause mortality: a meta-analysis. *PloS one*, *8*, e80000.

Clark, B. K., Pavey, T. G., Lim, R. F., Gomersall, S. R., & Brown, W. J. (2016). Past-day recall of sedentary time: validity of a self-reported measure of sedentary time in a university population. *Journal of Science and Medicine in Sport*, *19*, 237-241.

Conroy, D. E., Maher, J. P., Elavsky, S., Hyde, A. L., & Doerksen, S. E. (2013). Sedentary behavior as a daily process regulated by habits and intentions. *Health Psychology*, *32*, 1149.

Dogra, S., & Stathokostas, L. (2012). Sedentary behavior and physical activity are independent predictors of successful aging in middle-aged and older adults. *Journal of Aging Research*, 2012:190654.

Dragoescu, R. M. (2013). An overview of higher education at the European level. *Computational Methods in Social Sciences*, *1*, 21-29.

Du, Y., Liu, B., Sun, Y., Snetselaar, L. G., Wallace, R. B., & Bao, W. (2019). Trends in adherence to the physical activity guidelines for americans for aerobic activity and time spent on sedentary behavior among US adults, 2007 to 2016. *JAMA, 2*, e197597-e197597.

Ekelund, U., Steene-Johannessen, J., Brown, W. J., Fagerland, M. W., Owen, N., Powell, K. E., ... & Lancet Sedentary Behaviour Working Group. (2016). Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *The Lancet*, *388*, 1302-1310.

Ekelund, U., Tarp, J., Steene-Johannessen, J., Hansen, B. H., Jefferis, B., Fagerland, M. W., … & Lee, M. (2019). Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ, 366*, l4570.

European Commission (2012): Eurobarometer 64.3. TNS OPINION & SOCIAL, Brussels [Producer]. GESIS Data Archive, Cologne. ZA4415 Data file Version 1.0.1, doi:10.4232/1.10971

Farinola, M. G., & Bazán, N. E. (2011). Sedentary behavior and physical activity in university students: a pilot study. *Argentine Journal of Cardiology*, *79*, 351-354.

Fu, R., Gartlehner, G., Grant, M., Shamliyan, T., Sedrakyan, A., Wilt, T. J., ... & Santaguida, P. (2011). Conducting quantitative synthesis when comparing medical interventions: AHRQ and the Effective Health Care Program. *Journal of Clinical Epidemiology*, *64*, 1187-1197.

Gao, Z., Chen, S., Pasco, D., & Pope, Z. (2015). A meta-analysis of active video games on health outcomes among children and adolescents. *Obesity Reviews*, *16*, 783-794.

Gardner, B., Smith, L., Lorencatto, F., Hamer, M., & Biddle, S. J. (2016). How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychology Review*, *10*, 89-112.

Hansen, B. H., Kolle, E., Dyrstad, S. M., Holme, I., & Anderssen, S. A. (2012). Accelerometer-determined physical activity in adults and older people. *Medicine and Science in Sports and Exercise*, *44*, 266-272.

Higgins, J. P., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]*. The Cochrane Collaboration. Available from http://handbook.cochrane.org.

Higgins, J. P., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., ... & Sterne, J. A. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*, 343, d5928.

Kross, E., Verduyn, P., Demiralp, E., Park, J., Lee, D. S., Lin, N., ... & Ybarra, O. (2013). Facebook use predicts declines in subjective well-being in young adults. *PloS one*, *8*, e69841.

Lakerveld, J., Loyen, A., Schotman, N., Peeters, C. F., Cardon, G., van der Ploeg, H. P., ... & Brug, J. (2017). Sitting too much: a hierarchy of socio-demographic correlates. *Preventive Medicine*, *101*, 77-83.

Loyen, A., van der Ploeg, H. P., Bauman, A., Brug, J., & Lakerveld, J. (2016). European sitting championship: prevalence and correlates of self-reported sitting time in the 28 European Union member states. *PloS one*, *11*, e0149320.

Madhav, K. C., Sherchand, S. P., & Sherchan, S. (2017). Association between screen time and depression among US adults. *Preventive Medicine Reports*, *8*, 67-71.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., & Troiano, R. P. (2008). Amount of time spent in sedentary behaviors in the United States, 2003–2004. *American Journal of Epidemiology*, *167*, 875-881.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, *151*, 264-269.

Montagni, I., Guichard, E., Carpenet, C., Tzourio, C., & Kurth, T. (2016). Screen time exposure and reporting of headaches in young adults: A cross-sectional study. *Cephalalgia*, *36*, 1020-1027.

Moulin, M. S., & Irwin, J. D. (2017). An Assessment of Sedentary Time Among Undergraduate Students at a Canadian University. *International Journal of Exercise Science*, *10*, 1116-1129.

Mussi, F. C., Pitanga, F. J. G., & Pires, C. G. D. S. (2017). Cumulative sitting time as discriminator of overweight, obesity, abdominal obesity and lipid disorders in nursing university. *Revista Brasileira de Cineantropometria & Desempenho Humano*, *19*, 40-49.

Owen, N., Sugiyama, T., Eakin, E. E., Gardiner, P. A., Tremblay, M. S., & Sallis, J. F. (2011). Adults' sedentary behavior: determinants and interventions. *American Journal of Preventive Medicine*, *41*, 189-196.

Patterson, R., McNamara, E., Tainio, M., de Sá, T. H., Smith, A. D., Sharp, S. J., ... & Wijndaele, K. (2018). Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: a systematic review and dose response meta-analysis. *European Journal of Epidemiology*, 33, 811-29. doi: 10.1007/s10654-018-0380-1.

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J. P., Janssen, I., ... & Sampson, M. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Applied Physiology, Nutrition, and Metabolism*, *41*, 197-239.

Prince, S. A., Reed, J. L., McFetridge, C., Tremblay, M. S., & Reid, R. D. (2017). Correlates of sedentary behaviour in adults: a systematic review. *Obesity reviews*, *18*, 915-935.

Rouse, P. C., & Biddle, S. J. (2010). An ecological momentary assessment of the physical activity and sedentary behaviour patterns of university students. *Health Education Journal*, *69*, 116-125.

Stroup, D. F., Berlin, J. A., Morton, S. C., Olkin, I., Williamson, G. D., Rennie, D., ... & Thacker, S. B. (2000). Meta-analysis of observational studies in epidemiology: A proposal for reporting. *JAMA*, *283*, 2008-2012.

Teychenne, M., Costigan, S. A., & Parker, K. (2015). The association between sedentary behaviour and risk of anxiety: a systematic review. *BMC Public Health*, *15*, 513.

Thorp, A. A., Owen, N., Neuhaus, M., & Dunstan, D. W. (2011). Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. *American Journal of Preventive Medicine*, *41*, 207-215.

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., ... & Chinapaw, M. J. (2017). Sedentary behavior research network (SBRN)–terminology consensus project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity*, *14*, 75.

UK Department of Health (2011). *Start Active, Stay Active: a Report on Physical Activity for Health from the Four Home Countries' Chief Medical Officers*. London, England: Crown Copyright.

Universities UK (2017). *Patterns and trends in UK higher education 2016*. London, England: Higher Education Statistics Agency.

US Department of Health and Human Services (2000). *Healthy People 2010: Understanding and Improving Health*. Washington, DC: US Government Printing 2011.

Wilmot, E. G., Edwardson, C. L., Achana, F. A., Davies, M. J., Gorely, T., Gray, L. J., ... & Biddle, S. J. (2012). Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia*, *55*, 2895-905.

Wu, X., Tao, S., Zhang, Y., Zhang, S., & Tao, F. (2015). Low physical activity and high screen time can increase the risks of mental health problems and poor sleep quality among Chinese college students. *PloS one*, *10*, e0119607.

Zhai, L., Zhang, Y., & Zhang, D. (2015). Sedentary behaviour and the risk of depression: a meta-analysis. *British Journal of Sports Medicine*, *49*, 705-709.

Figure legends

Figure 1. Flow chart for the articles included in the systematic review and meta-analysis.