Received: 4 November 2020 | Revised: 10 April 2021 | Accepted: 10 April 2021
DOI: 10.1111/obr.13263

PEDIATRIC OBESITY/BEHAVIOUR

OBESITY Reviews WILEY

Age-related change in sedentary behavior during childhood and adolescence: A systematic review and meta-analysis

Elli Kontostoli[1] | Andy P. Jones[2] | Natalie Pearson[3] | Louise Foley[4] | Stuart J. H. Biddle[5] | Andrew J. Atkin[1]

[1]School of Health Sciences, Faculty of Medicine and Health Sciences, University of East Anglia, Norwich, UK

[2]Norwich Medical School, Faculty of Medicine and Health Sciences, University of East Anglia, Norwich, UK

[3]School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, UK

[4]Centre for Diet and Activity Research at the MRC Epidemiology Unit, University of Cambridge, Cambridge, UK

[5]Centre for Health Research, University of Southern Queensland, Toowoomba, Queensland, Australia

Correspondence
Elli Kontostoli, School of Health Sciences, Faculty of Medicine and Health Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, UK.
Email: e.kontostoli@uea.ac.uk

Funding information
University of East Anglia, Faculty of Medicine and Health Sciences; Academy of Medical Sciences/the British Heart Foundation/the Government Department of Business, Energy and Industrial Strategy/the Wellcome Trust Springboard Award, Grant/Award Number: SBF003\1015

Summary

Sedentary behaviors are highly prevalent in youth and may be associated with markers of physical and mental health. This systematic review and meta-analysis aimed to quantify the age-related change in sedentary behavior during childhood and adolescence. Ten electronic databases were searched. Inclusion criteria specified longitudinal observational studies or control group from an intervention; participants aged ≥5 and ≤18 years; a quantitative estimate of the duration of SB; and English language, peer-reviewed publication. Meta-analyses summarized weighted mean differences (WMD) in device-assessed sedentary time and questionnaire-assessed screen-behaviors over 1-, 2-, 3-, or more than 4-year follow-up. Effect modification was explored using meta-regression. Eighty-five studies met inclusion criteria. Device-assessed sedentary time increased by (WMD 95% confidence interval [CI]) 27.9 (23.2, 32.7), 61.0 (50.7, 71.4), 63.7 (53.3, 74.0), and 140.7 (105.1, 176.4) min/day over 1-, 2-, 3-, and more than 4-year follow-up. We observed no effect modification by gender, baseline age, study location, attrition, or quality. Questionnaire-assessed time spent playing video games, computer use, and a composite measure of sedentary behavior increased over follow-up duration. Evidence is consistent in showing an age-related increase in various forms of sedentary behavior; evidence pertaining to variability across socio-demographic subgroups and contemporary sedentary behaviors are avenues for future research.

KEYWORDS
adolescents, change, children, sedentary behavior, systematic review

1 | INTRODUCTION

There is evidence that sedentary behavior during childhood may be associated with several adverse health outcomes, independently of physical activity.[1] Device-measured total sedentary time and self-reported screen-based sedentary behavior may be associated with a higher risk of obesity and low cardiorespiratory fitness.[2,3] Total sedentary time may also be associated with poor academic achievement and social interactions,[2] depression, and low self-esteem.[4–6] This evidence is reflected in public health guidelines suggesting that sedentary behavior be limited, though there remain important inconsistencies and limitations of the existing research,[7–11] and further high-quality longitudinal and experimental research is required to better understand the links between sedentary behavior and health in this population.

Several studies have shown that sedentary behavior is highly prevalent in young people. Global surveillance data showed that approximately half of children and adolescents spend more than 2 h a day in screen-based activities.[12] A systematic review found that device-measured sedentary time accounted for almost half of the after-school time in children and over half of the after-school time in adolescents.[13] Another review found that device measured sedentary time accounted for 6.4 h a day in children and 7.3 h a day in adolescents.[14] Informed by this evidence, public health recommendations advise that children and adolescents should minimize the amount of time they spend sedentary[11] or limit the duration of specific sedentary behaviors, such as recreational screen time.[15]

In public health surveillance and epidemiological studies, sedentary behaviors are typically measured using body-worn devices (e.g., accelerometry) or self- or proxy-reported questionnaires. Despite some overlap in content, the correlation between device- and questionnaire-assessed sedentary behavior is typically low, and they appear to be differentially associated with health markers.[16,17] It is of interest, therefore, to examine both methods of measurement when exploring changes in sedentary behavior over time. A recent systematic review of longitudinal studies reported an increase of 10–20 min/day/year in device-measured sedentary time and screen-based sedentary behavior during the transition from primary to secondary education.[18] This is consistent with cross-sectional data from the International Children's Accelerometry Database (ICAD), which showed that device-measured sedentary time increased progressively from the age of 5 years.[19] Previous research has shown that sedentary behavior may be higher in non-White children, those with a higher body mass index (BMI),[14,18] and those from families of lower socio-economic position,[20,21] suggesting that age-related change in sedentary behavior may also vary in these subgroups. Understanding of social and demographic variation in sedentary behavior change will help with the targeting of behavior change interventions.

It is understood that health behaviors in childhood and adolescence may persist into adulthood,[22] highlighting the need to establish the timing of changes in sedentary behavior during this period, as well as the population groups that may be most at risk. To our knowledge, there is no published systematic review that quantifies the age-related change in sedentary behavior during childhood and adolescence. Therefore, the aim of this review was to synthesize existing evidence on age-related changes in sedentary behavior during childhood and adolescence. A secondary aim was to examine whether the magnitude of change varied across social or demographic population groups.

2 | METHODS

The review protocol was registered with the International Prospective Register of Systematic Reviews ([PROSPERO] CRD42018106948). The review is reported in accordance with The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PRISMA checklist is available in Table S1) and Meta-analysis Of Observational Studies in Epidemiology (MOOSE).[23,24]

2.1 | Search strategy

Ten electronic databases were searched (PsycINFO, CINAHL, Web of Science, MEDLINE, Embase, Scopus, LILACS, Cochrane Library, Allied and Complementary Medicine Database [AMED], and Applied Social Sciences Index and Abstracts [ASSIA]) in September 2018 with no chronological limits set. Searches were re-run in June 2020. Manual searches of the reference lists of published systematic reviews and related articles were also completed to identify potentially relevant articles. The searches were focused on three groups of keywords: sedentary behavior, study design, and study population. Key terms were used in combination with relevant MeSH headings. The search strategy was developed in conjunction with an academic librarian. An example search strategy is provided in Table S2. The search was conducted by EK.

2.2 | Inclusion and exclusion criteria

Studies were included if they (1) used an observational study design or a provided data for the control arm in an experimental study; (2) provided a quantitative estimate of duration of at least one sedentary behavior with data collected at ≥2 time points (minimum of 1-year between baseline and follow-up); (3) included children and/or adolescents aged ≥5 and ≤18 years at baseline and follow-up; and (4) were published in an English language peer-reviewed journal. Commentaries, conference papers, qualitative studies, pilot studies, and trials without a no-treatment control group were excluded, as were studies in clinical populations.

When the same study was reported in multiple papers, the following prioritization was applied to select papers for inclusion: (1) the article with the most follow-up assessment points; (2) the article with a variety of activities (i.e., most sedentary behaviors) for self-reported data; (3) the paper with the biggest sample size; and (4) stratification for boys/girls, week/weekend days.

2.3 | Identification of relevant studies

Covidence review management software (www.covidence.org) was used for the screening and selection of records retrieved from electronic and manual searches, including the removal of duplicates. Articles were selected by screening the titles and the abstracts, and if abstracts were not available or did not provide enough data, the entire article was retrieved and screened to determine whether it met the inclusion criteria. Articles that were not available through open access publication were obtained through a university library subscription, email request to the author or inter-library loan as appropriate. Screening of titles, abstracts, and full-texts was undertaken by the lead author (EK). A second reviewer (AJA) independently screened 10% of titles and abstracts with disagreements resolved by discussion. Ninety-two percent agreement was achieved at this stage. Ten percent of full texts were also screened by a second reviewer (NP). There was an agreement of 96% at this stage. Disagreements were solved by discussion and when uncertainties were raised, adjudication was made by AJA.

2.4 | Data extraction

Data were extracted on forms developed specifically for this review. Extracted data included (1) author name, year of publication, country, and study name (if applicable); (2) study design; (3) aim(s) of the study; (4) follow-up duration; (5) sample size; (6) baseline age, gender, ethnicity, socioeconomic position, weight status, BMI, and BMI *z*-score; (7) age at follow-up; (8) methods utilized for device-based (counts, epochs, time, and days needed for inclusion) and self- or proxy-reported assessments; (9) duration of sedentary behavior for each assessment or change between assessments; and (10) attrition rates. Data were extracted for the smallest reported independent subsample (*k*). Data extraction was conducted by EK, and extracted data for 10% of papers were checked for accuracy by AJA.

2.5 | Methodological quality assessment

Included studies were appraised for methodological and reporting quality using a scale adapted from previous reviews of observational longitudinal research.[25–27] The following domains were assessed: study population and participation rate (two items); study attrition (three items); data collection (three items); and data analysis (one item). An additional item, pertaining to report of cut-point used in data processing, was included in appraisal of studies that assessed sedentary time by accelerometer (Table S3). Published methods papers were reviewed alongside included studies where necessary. The lead author (EK) undertook quality appraisal. A second reviewer (LF) conducted duplicate quality appraisal in a 10% subsample of papers and disagreements were resolved by discussion. Each item for the included studies was assessed with a 1 or 0 score. The overall quality of a study was determined by the sum of positively scored items and by converting to a percentage. Studies were rated high quality if score was ≥71%, moderate quality if score was ≥41% and ≤70%, and low quality if score was ≤40%.

2.6 | Data synthesis

The unit of analysis was independent subsample (*k*), defined as the smallest subsample for which relevant data were reported. Data on device-measured sedentary time and self- or proxy-reported screen behaviors were synthesized by meta-analysis. We opted to meta-analyze screen-based behaviors due to prominence of those in children and adolescents and inclusion in public health guidelines. In order to prepare data for meta-analysis, conversion for reports of device-based and self- or proxy-reported data were undertaken as follows. The metric chosen was the original unit reported in most of the studies (i.e., minutes per day during the week [Monday to Sunday]). When studies reported sedentary time separately for Saturday and Sunday, the mean and standard deviation (SD) of those values were calculated to provide mean sedentary time for the weekend. Conversions were also made for studies reporting minutes per day separately on a weekday and minutes per day on a weekend; in those cases, the mean value was calculated to provide mean weekly sedentary time $((5 \times \text{weekday}) + (2 \times \text{weekend})/7)$. For studies reporting hours per day or hours per week, data were converted to minutes per day. For studies reporting data in medians, interquartile range (IQR), and standard error, data were converted to mean and SD following published methods.[28] For self or proxy methods, studies were grouped according to whether they reported on a single sedentary behavior (e.g., TV viewing only) or a composite of multiple behaviors in various combinations (e.g., TV viewing, computer use, and video games).

We opted not to meta analyze data on non-screen-based behaviors due to limited number of studies providing this data, the heterogeneity in questionnaire content and the limited evidence of associations with health and well-being. None of the studies tested statistically for change over time. Findings are summarized in the table but omitted from the synthesis.

2.7 | Statistical analysis

Data on change in sedentary behavior were combined using random effect meta-analysis, conducted in STATA 16.0 (Stata Corporation, Texas, USA). Data included in the meta-analysis were converted to a common metric, non-standardized weighted mean differences (WMD). Studies were meta-analyzed according to the duration of follow-up (e.g., 1, 2, 3, and 4+ years) except for video games and computer use for which meta-analysis was conducted for 1, 2, and 3 + years of follow-up due to the limited number of studies that assessed change over 4 or more years (video games $N = 2$ and computer use $N = 3$). Heterogeneity was quantified using the I^2 statistic.[29] Meta-regression was used to explore the impact of possible effect modifiers (gender, age span, study's location, and quality). Candidate moderators were selected based on the data extracted and potential to inform behavior change interventions. Age range referred to either childhood (age from 5 to 10 years old) or adolescence (age 11 to 18 years old) at baseline. Study location was summarized as Europe, North America, South America, Australia and New Zealand, Africa, or Asia. Annual change in sedentary behavior (minutes/day/year) was estimated by subtracting baseline sedentary behavior from follow-up and dividing by duration of follow up (years).[29] SD of annual change was calculated according to methods described by Higgins et al., assuming a correlation of 0.5, consistent with previous research.[30] Eggers test for publication bias was conducted for all meta-analyses.[31]

3 | RESULTS

The literature search returned 17,296 references (Figure 1). After removal of duplicates, 14,341 titles and abstracts were screened, from which 834 full-text papers were assessed for eligibility. Of those, 722 were excluded due to not meeting the inclusion criteria. Subsequently, a further 27 papers were excluded as they included duplicate data available in other papers. Eighty-five papers were included in the review, of which 10 were identified in the updated search in June 2020.

Most studies were conducted in Europe ($N = 36$) or in North America ($N = 23$), had a sample size of >1000 participants ($N = 33$), and had a follow-up duration of ≤3 years ($N = 51$). The majority ($N = 63$; k independent samples = 129) used self-reported instruments to measure TV-viewing, video games, computer use, doing homework, or traveling by car/bus, either separately or in combination. Thirty studies ($k = 52$) used device-based methods to assess total sedentary time. Eight papers reported data for both device-based and self-assessment or proxy assessment. Methodological characteristics of included studies are summarized in Table 1, stratified by method of measurement. A study-level summary of included studies is presented in Tables S4a and S4b.

Methodological quality scores for each study are provided in Table S5. An 84% agreement was achieved on bias scoring between reviewers, and discrepancies were resolved via discussion. Of the 85 included studies, 63% were rated high quality, 32% were rated moderate quality, and 5% were rated low quality.

3.1 | Device-measured sedentary time

Meta-analysis indicated that sedentary time increased by (WMD [95% CI]) 27.9 (23.2, 32.7), 61 (50.7, 71.4), 63.7 (53.3, 74), and 140.7

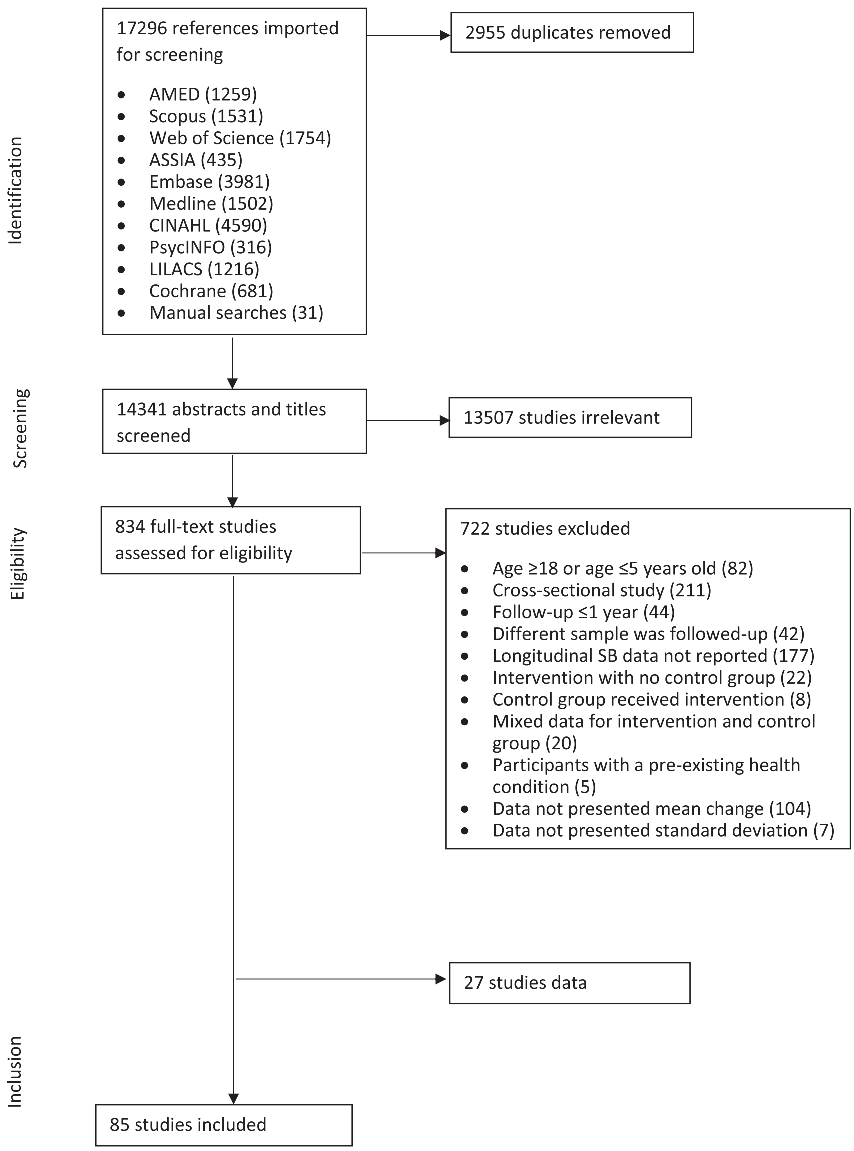

FIGURE 1 Literature search and article screening process

TABLE 1 Descriptive characteristics of the included studies, stratified by method of sedentary behavior measurement

	Device measured	Self-reported or proxy reported
	N = 30	N = 55
Sample size		
<100	2 (6.6)	5 (9)
100–499	14 (46.6)	10 (18.1)
500–999	7 (23.3)	14 (25.4)
>1000	7 (23.3)	26 (47.2)
Duration of follow-up		
1 year	5 (16.6)	12 (21.8)
2 years	12 (40)	18 (30.9)
3 years	4 (13.3)	10 (16.3)
4+ years	9 (30)	15 (27.2)
Region		
Europe	18 (60)	18 (32.7)
Australia and NZ	5 (16.6)	12 (21.8)
N. America	5 (16.6)	18 (32.7)
S. America	n/s	3 (5.4)
Asia	2 (6.6)	3 (5.4)
Africa	n/s	1 (1.8)
Age at baseline		
Children only	14 (46.6)	26 (47.2)
Adolescents only	12 (40)	28 (50.9)
Children and adolescents	4 (13.3)	1 (1.8)

Data are presented *N* (%).
Abbreviations, NZ: New Zealand, n/s: no studies.

(105.1, 176.4) min/day over 1, 2, 3, and 4+ years of follow-up, respectively. In all cases, heterogeneity was high (≥96%) and statistically significant (Figure 2). Meta-regression indicated no statistically significant effect modification by gender, baseline age or study's location, attrition rate, or quality ($p > 0.05$). Using Egger's test, there was no evidence for publication bias in 1, 3, and 4+ years of follow-up, but there was some evidence for publication bias for 2-year duration of follow-up ($p = 0.04$).

Meta-analysis indicated an annual change in sedentary time (minutes per day) of (ES [95% CI]) 7.8 (6.4, 9.1) (Figure S1). The I^2 value was 80.9%, indicating high heterogeneity.

3.2 | Self- or proxy-reported sedentary behavior

Studies reporting data collected by questionnaire presented data for single behaviors (such as TV viewing, video games, computer use, homework, and travel by car or bus) and/or behaviors aggregated in various combinations to create composite measures. Findings are summarized narratively only for studies that reported change in academic related activities and travel by car/bus (Table S6).

3.2.1 | Single sedentary behaviors

Meta-analysis indicated that changes in duration of TV viewing were nonsignificant at 1 year (WMD [95% CI]) (−0.6 [−5.0, 3.7]), 2 years (7 [−0.1, 14.2]), and 3 years (0 [−4.8, 4.8]) of follow-up. Based on 16 independent samples, an increase in TV viewing was reported in those studies that reported change over 4+ years of follow-up (26.1 [0.9, 51.3]). In all cases, heterogeneity was high (≥93.7%) and statistically significant (Figure 3). Time spent playing video games increased by (WMD [95% CI]) 12.4 (4.8, 19.9), 5.7 (0.3, 11), and 15.3 (4.8, 25.8) min/day over 1, 2, and 3+ years of follow-up, respectively. In all cases, heterogeneity was high (≥92.2%) and statistically significant (Figure 4). Computer use increased by (WMD [95% CI]) 18.4 (5.3, 31.5), 28.7 (16.8, 40.5), and 35.5 (19.4, 51.6) min/day over 1, 2, and 3 + years of follow-up, respectively. Heterogeneity was high (≥68%) and statistically significant (Figure 5). Using Egger's test, there was no evidence for publication bias for single sedentary behaviors over 1, 2, 3, or 4+ years of follow-up. Meta-regression indicated no statistically significant effect modification by gender, baseline age, or study attrition rate or quality ($p > 0.05$). Compared to Europe, studies conducted in South America reported larger increases in video game use over 1 year of follow-up ($p = 0.002$) and those conducted in Asia reported larger increases in computer use over 2 years of follow-up ($p = 0.03$).

Estimated annual changes (minutes per day) in TV viewing, video game, and computer use were (ES [95% CI]) 0.6 (−0.1, 1.4), 0.6 (0.2, 1.1), and 2 (1, 3), respectively (Figures S2–S4).

3.2.2 | Composite measures

Meta-analysis indicated that combined TV viewing, video game play, and computer use increased by (WMD [95% CI]) 20.8 (9.9, 31.8), 19.9 (14.1, 25.6), 40 (16.3, 63.7), and 42.6 (21.1, 64.1) min/day over 1, 2, 3, and 4+ years of follow-up, respectively. In all cases, heterogeneity was high (≥97.3%) and statistically significant (Figure 6). Using Egger's test, there was no evidence for publication bias over 1, 2, 3, and 4 + years of follow-up. Meta-regression indicated no statistically significant effect modification by gender, baseline age or study's location, attrition rate, or quality ($p > 0.05$).

Estimated annual change (minutes per day) in TV viewing, video game play, and computer use was (ES [95% CI]) 0.3 (0.2, 0.5) (Figure S5).

4 | DISCUSSION

To our knowledge, this is the first systematic literature review to summarize and meta-analyze longitudinal data on changes in sedentary

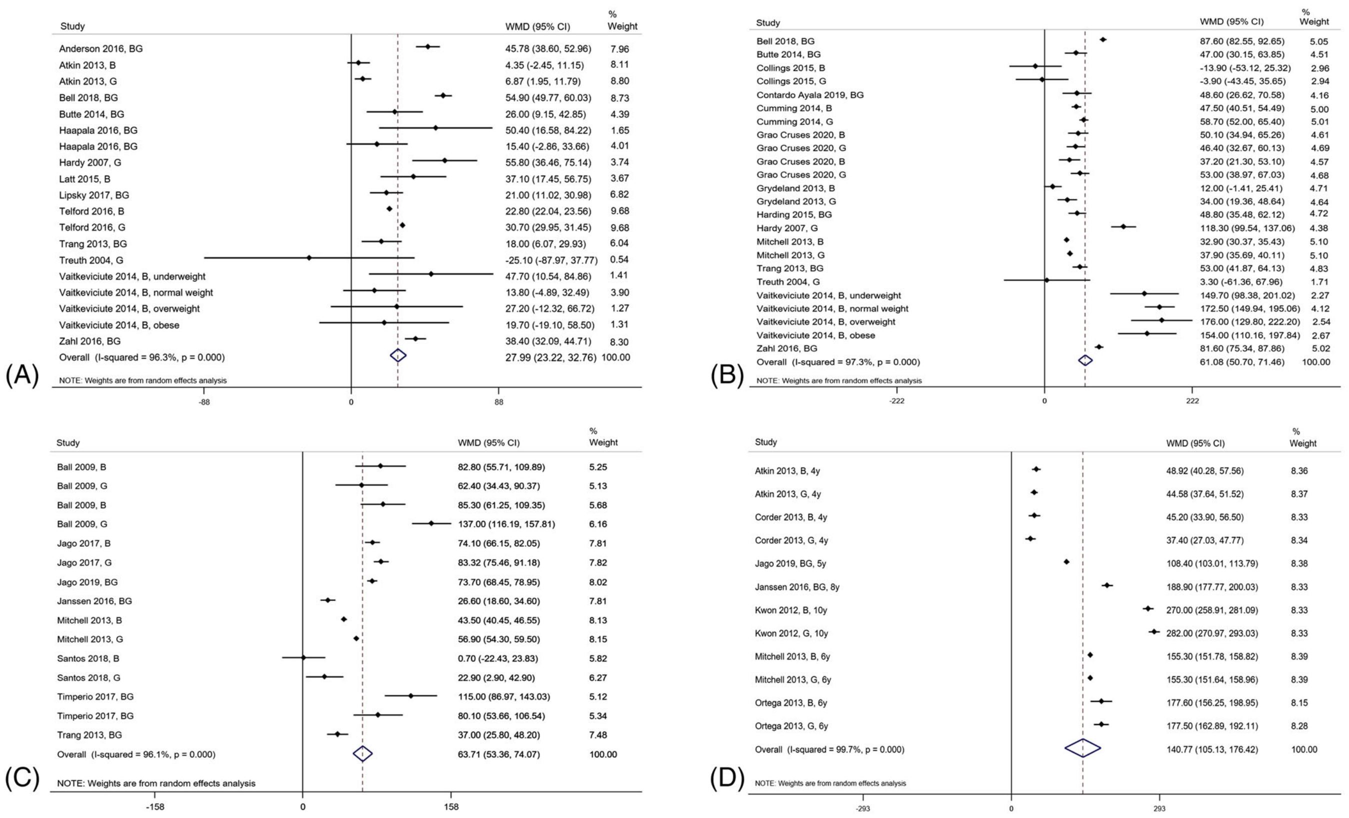

FIGURE 2 Change in device-measured sedentary time over (A) 1-, (B) 2-, (C) 3-, and (D) 4- to 10-year duration. Abbreviations, B: boys, G: girls, BG: boys and girls, y: year

behavior during childhood and adolescence. For device-based measures of sedentary behavior, meta-analysis indicated that sedentary time increases over time, with larger increases seen over longer durations of follow-up. The meta-regression indicated no statistically significant differences in sedentary time change according to age, gender, study location, quality, or attrition. For self- or proxy-reported sedentary behavior, our synthesis indicated increases in time spent in video game play, computer use, and a composite marker of screen-based behavior, but TV viewing appeared relatively stable and increased only over the longest durations of follow-up.

The meta-analysis indicated that device-measured daily sedentary time increased as children and adolescents age, by approximately 28 min over 1 year, 61 min over 2 years, 64 over 3 years, and 141 min over 4 years of follow-up. Findings are consistent with cross-sectional data from the ICAD study, which showed that sedentary time increased in an approximately linear manner from the age of 5 years onward, though the magnitude of change was not quantified in minutes.[19] Similarly, a recent study using pan-European harmonized accelerometer data showed a linear increase in sedentary time with age; at age 4/5 years, children accumulated approximately 250 min/day of sedentary time increasing to around 450 min/day at age 14/15.[32] Changes in sedentary behavior mirror the well-documented reduction in physical activity during childhood.[19,30,33,34] Given evidence that sedentary behavior tracks moderately from childhood to adulthood,[35,36] age-related increases in overall sedentary time, as captured by device-based measurement, likely reflect changes in behavior in a number of domains and settings over time. The need for behavior change interventions to limit such changes will require clearer evidence on the specific nature of these changes, accompanied by stronger epidemiological evidence on how specific behaviors are linked with health and well-being.

A key finding of this review was that change in sedentary behavior did not differ according to age at first assessment. Our meta-regression showed that changes in this behavior were similar in children (≥5 and <10 years old) and adolescents (≥10 and <18 years old) for either device-measured or self- or proxy-reported sedentary behavior, supporting the view that, where appropriate, interventions to limit the age-related increase in sedentary behavior may need to be implemented throughout the childhood period. There is substantial evidence that adolescents engage in higher levels of sedentary behavior than children,[14,18] but this is the first study to our knowledge that has examined whether changes in sedentary time within these periods differ. Findings are consistent with recent evidence that the age-related decline in physical activity may start during childhood, rather than being limited to the adolescent period.[37] Further information on how the accumulation of device-assessed sedentary time changes with age, including bout length and

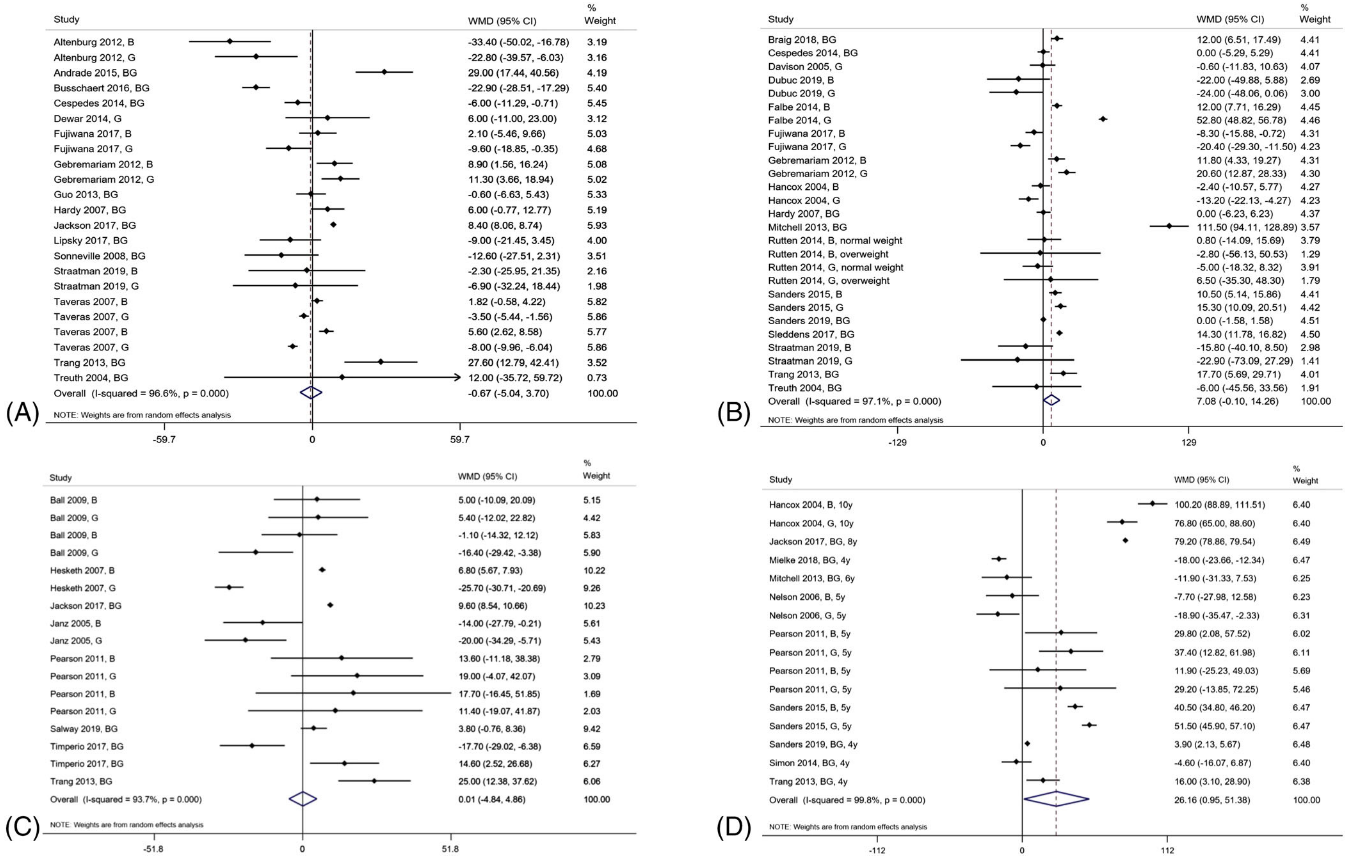

FIGURE 3 Change in self- or proxy-reported TV viewing over (A) 1-, (B) 2-, (C) 3-, and (D) 4- to 10-year duration. Abbreviations, B: boys, G: girls, BG: boys and girls, y: year

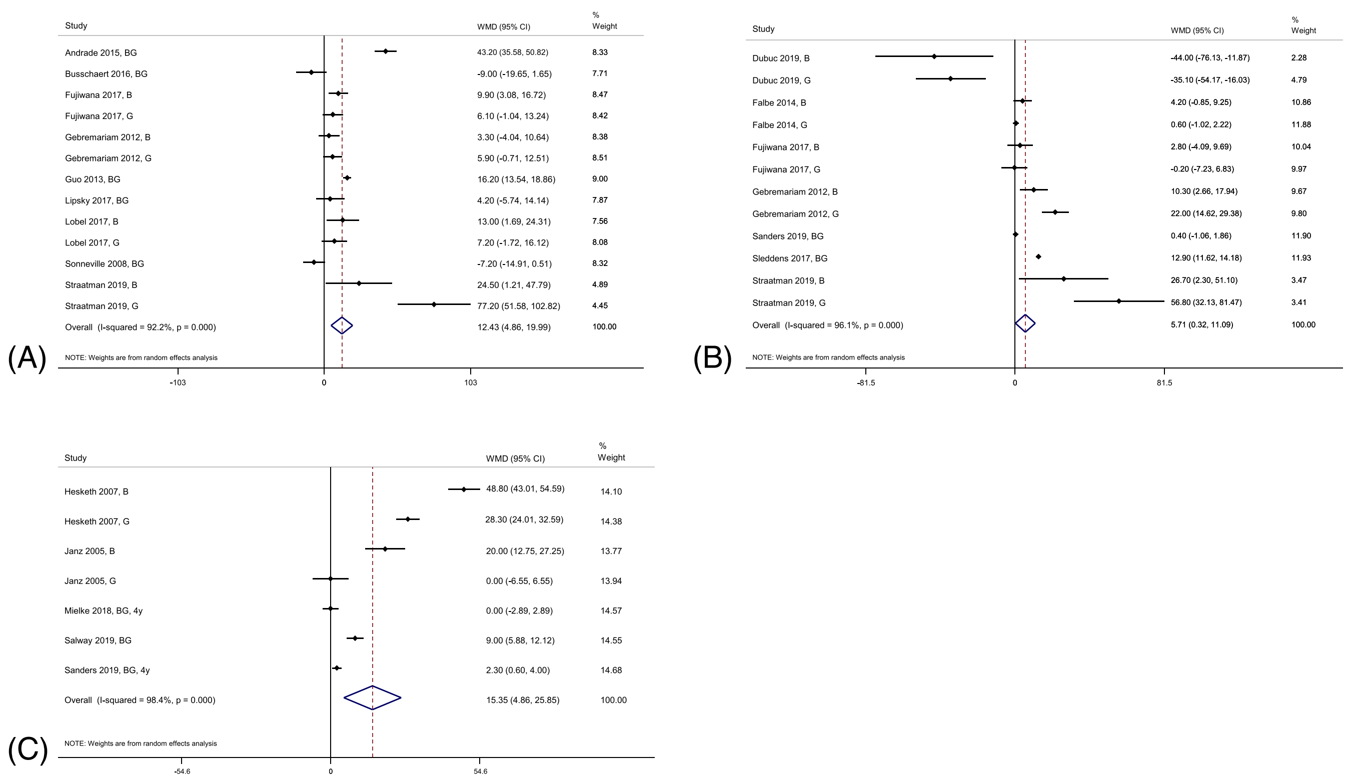

FIGURE 4 Change in self- or proxy-reported video games over (A) 1-, (B) 2-, and (C) 3- to 4-year duration. Abbreviations, B: boys, G: girls, BG: boys and girls, y: year

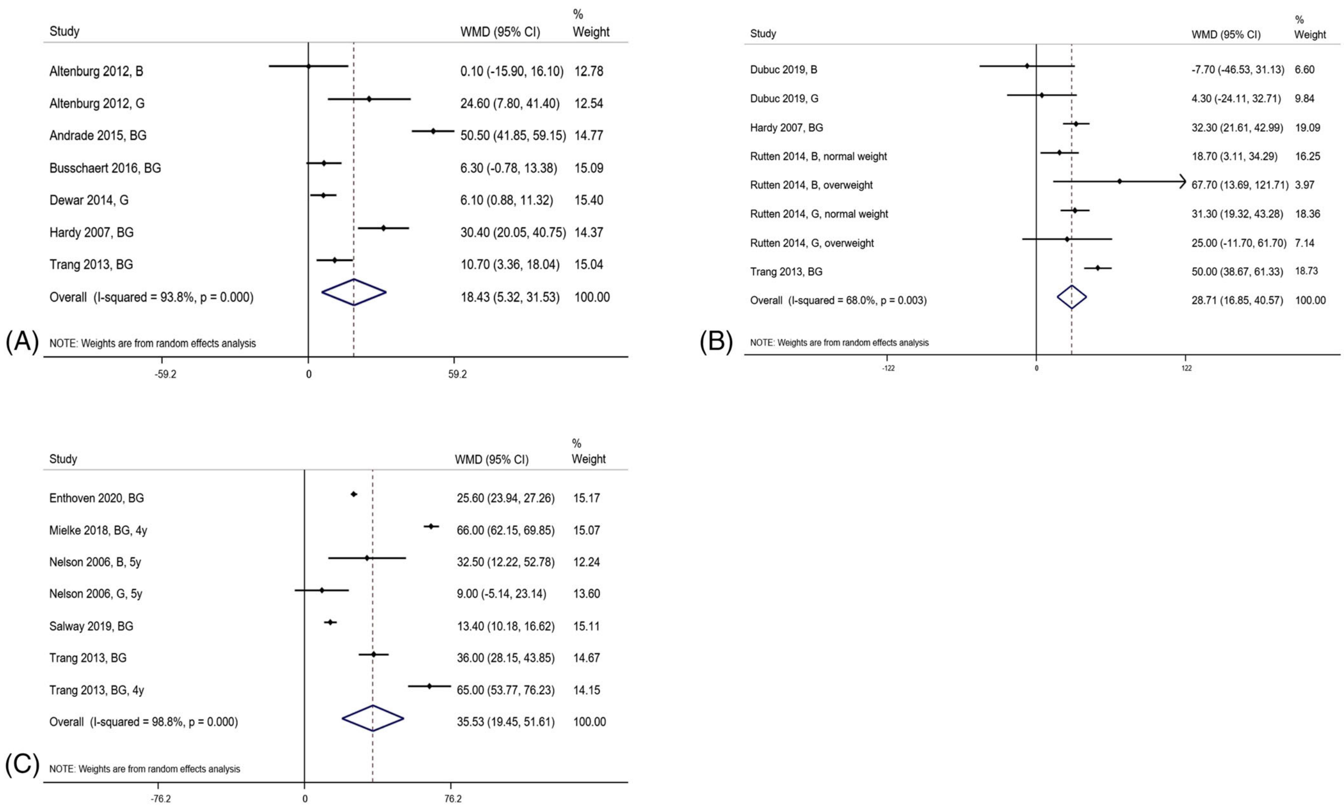

FIGURE 5 Change in self- or proxy-reported computer use over (A) 1-, (B) 2-, and (C) 3- to 5-year duration. Abbreviations, B: boys, G: girls, BG: boys and girls, y: year

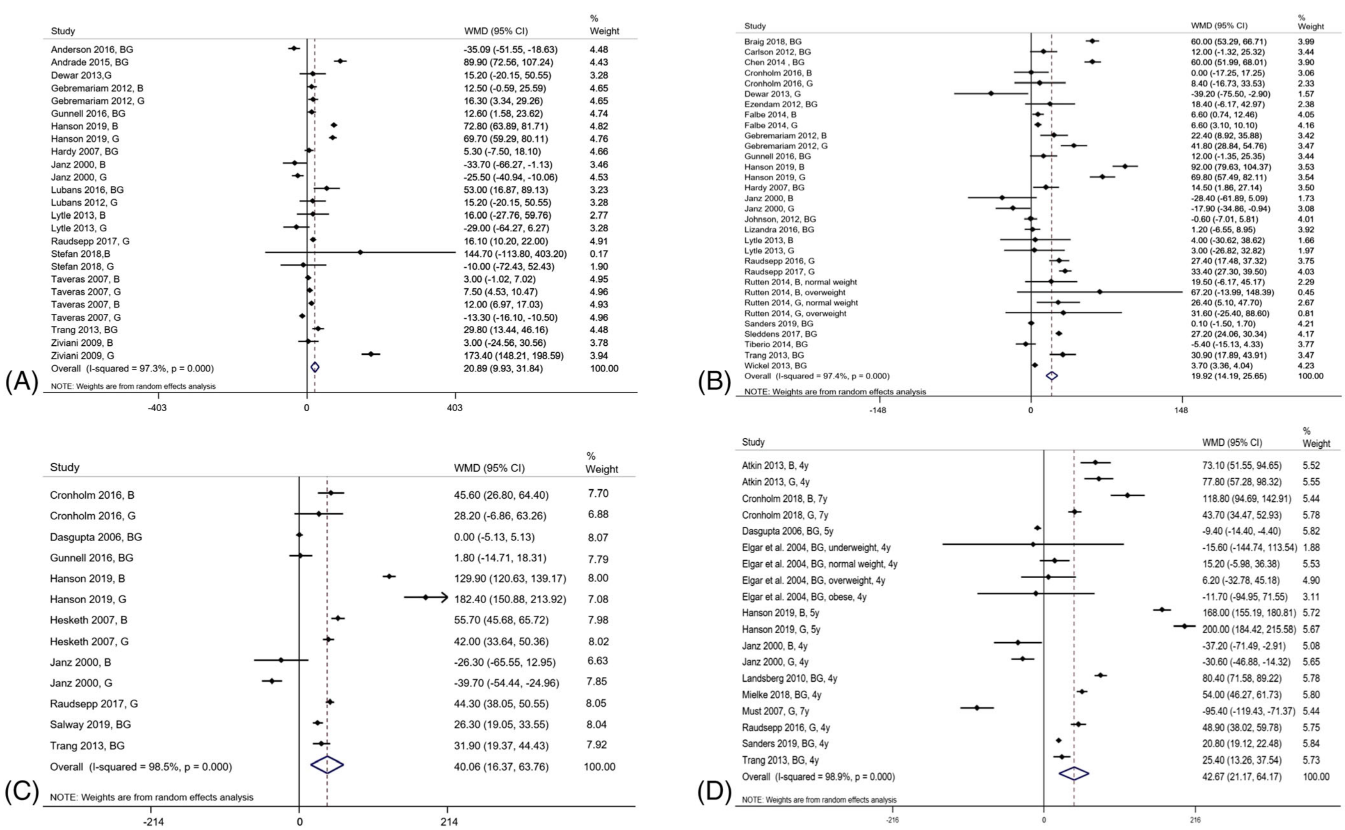

FIGURE 6 Change in self- or proxy-reported composite screen-based behaviors over (A) 1-, (B) 2-, (C) 3-, and (D) 4- to 7-year duration. Abbreviations, B: boys, G: girls, BG: boys and girls, y: year

frequency of breaks, would be beneficial, as such factors may have important implications for health. Moreover, further evidence describing the social and environmental factors that influence sedentary behavior and how these evolve over time is also required to inform intervention design.

We found no evidence that change in device-measured sedentary time and self- or proxy-reported sedentary behavior differed between boys and girls over time. This is in line with the results from a recent study using pan-European accelerometer data, which suggested that, while girls accumulated more sedentary time than boys, the pattern of change with increasing age was similar.[32] A recent systematic review that focused on sedentary behavior change across the primary to secondary school transition also found no evidence for a gender difference, but this was not tested statistically.[18] Additionally, a systematic review of tracking of sedentary behavior from childhood to adolescence found little evidence of a gender difference.[38] Results from an analysis in ICAD showed that boys were less sedentary and more active than girls at all ages, though the change in sedentary time appeared similar for both boys and girls over time.[19] Despite the apparent consistency of existing evidence, changes in sedentary time between both genders over time have attracted little attention. Of the 85 studies that were included in the review, only 39 (42%) reported data separately for boys and girls. Although trajectories of overall sedentary time may be similar, it remains unclear whether changes in time spent in specific sedentary behaviors differ between boys and girls; further information on this topic would be informative for intervention design.

The meta-analyses indicated that time spent in video game play, computer use, and a composite measure of screen-based behavior increased over all durations of follow-up examined; however, time spent in TV viewing did not change for up to 3 years but it increased for more than 4-year duration of follow-up. Our findings are similar to recent studies that showed that time spent in a composite marker of screen-based behavior and also computer use and video game play increased over time.[12,39–41] Interestingly, our findings on TV viewing partially contrasts with prior research reporting a decrease by a relatively small amount in traditional TV viewing over time,[12,42] but this was not tested statistically. In contradiction with earlier findings, a previous review of longitudinal studies looking at TV viewing found increases in boys and girls over time but the results were mixed in boys and girls according to weight status.[18] Most studies in the current review focused on traditional sedentary behaviors, such as TV viewing and video games, with very few describing changes in contemporary behaviors, such as tablet and phone use. The number of devices through which young people may access the internet and/or audiovisual media has expanded rapidly in recent years. Recent data showed that the proportion of children and adolescents aged 5–15 years old watching TV programs on tablets increased from 27% in 2015 to 43% in 2019 and on mobiles from 15% in 2015 to 26% in 2019.[43] Further research is needed to examine how the duration of time spent in newer screen-based behaviors changes over time and whether this is displacing time previously spent watching broadcast television. Alongside this, there is a need for qualitative studies to explore how adolescents' attitudes and preferences for different screen- and non-screen based behaviors change over time.

The data for non-screen-based behaviors showed that academic-related activities and travel by car/bus increased over time, while time spent reading for school declined, but this was assessed in only three studies. Change in car/bus perhaps reflects greater engagement in social and recreational activities away from home as children age.[44,45] The concurrent increase in academic activities and the decline in school-related reading appears contradictory. These contradictions may reflect the transition from reading being an academic activity in its own right to been a routine activity required to fulfill other school-related tasks. The lack of studies reporting age-related changes in these behaviors is a clear gap in the evidence, and further research would provide a richer picture of changes in young people's sedentary behavior patterns and preferences over time. In particular, only two studies were identified that assessed time spent in academic-related activities with and without a computer or tablet. As we seek to further disentangle the detrimental and beneficial associations of sedentary behavior with physical and mental health, this topic in particular would be worthy of further study.

A key strength of this review is the inclusion of studies that used either device-based or questionnaire-based methods of measurement and use of meta-analysis to synthesize the data. In addition, we used broad search criteria to identify relevant articles across 10 electronic databases and the manual searches without publication date restrictions. Our protocol was registered with PROSPERO and the review is reported in accordance with PRISMA guidelines[23] and MOOSE.[24] We included and summarized evidence from studies that measured a broad range of sedentary behaviors, both individually and in combination, providing a comprehensive overview of the published literature and highlighting gaps to be addressed in future research. Limitations of this work include the restriction to English language publications in peer-reviewed journals, which may have resulted in the exclusion of relevant articles. In addition, we deviated from our published protocol by not searching the Global Health database (not available in our institution). We did duplicate appraisal of study quality for 20% of studies. We found a high level of agreement when duplicate screening papers for inclusion, with no evidence of high levels of discrepancy for particular items. As a result, we deemed it necessary to only duplicate screen 20% of papers, but an implication of this is that there may have been some discrepancies in those not duplicate screened. Finally, we report selected accelerometer data collection and processing criteria in our summary tables but did not include/exclude papers from the meta-analysis on the basis of these factors. Variability in data processing methods and compliance with study protocols may have contributed to heterogeneity in the estimates of change that were synthesized.

The current study highlights several areas that would benefit from further research. Few of the included studies conducted stratified analyses to examine whether change in sedentary behavior varied according to social, demographic, or anthropometric factors, such as socio-economic position, ethnicity, or BMI. This information would aid in the identification of at-risk populations for intervention. Additionally, observational longitudinal studies are needed to collect data on the wide range of electronic media devices used by young people, moving beyond simplistic assessments of computer use or broadcast television. One in four young people (5–15 years old) do not watch live broadcast TV at all and smartphone ownership increased by 10% from 2015 to 2019.[43] Further research is also warranted to examine multi-tasking of portable devices and the context in which such devices are used, which may moderate how these behaviors influence health. This may necessitate the development and validation of new tools to capture the diversity of electronic media devices being used, in combination with information on content and context.

5 | CONCLUSION

This is the first systematic review to summarize published evidence on age-related change in sedentary behavior in children and adolescents. Our findings show that device-measured sedentary time increases with age; with no evidence that the magnitude of change varied by gender or age, though few studies provided the required data for these analyses. Synthesis of data on screen-based sedentary behavior assessed by questionnaire also indicated an increase with age. Although the evidence base linking sedentary behavior with mental and physical health outcomes requires further development, our findings suggest that the development and evaluation of interventions to limit age-related increases in specific sedentary behaviors may be appropriate. Further research into patterns of contemporary sedentary behavior use and to identify population sub-groups that may accumulate higher amounts of sedentary behavior with age would be beneficial for the targeting of behavior change programs.

ACKNOWLEDGMENTS

With thanks to Dr. Kirsten Corder and Dr. Kathryn Richardson for their input on search methodology and data analysis. Elli Kontostoli is partially supported by an Academy of Medical Sciences/the British Heart Foundation/the Government Department of Business, Energy and Industrial Strategy/the Wellcome Trust Springboard Award [SBF003\1015], held by Dr. Andrew Atkin. Additional funding from the University of East Anglia, Faculty of Medicine and Health Sciences is gratefully acknowledged.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ORCID

Elli Kontostoli https://orcid.org/0000-0003-4285-4808
Andy P. Jones https://orcid.org/0000-0002-3130-9313
Natalie Pearson https://orcid.org/0000-0003-2060-5966
Louise Foley https://orcid.org/0000-0003-3028-7340
Stuart J. H. Biddle https://orcid.org/0000-0002-7663-6895
Andrew J. Atkin https://orcid.org/0000-0002-3819-3448

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How to cite this article: Kontostoli E, Jones AP, Pearson N, Foley L, Biddle SJH, Atkin AJ. Age-related change in sedentary behavior during childhood and adolescence: A systematic review and meta-analysis. *Obesity Reviews*. 2021;1–11. https://doi.org/10.1111/obr.13263