



# The Role of Recreational Online Activities in School-Based Screen Time Sedentary Behaviour Interventions for Adolescents: A Systematic and Critical Literature Review

Melina A. Throuvala<sup>1</sup>  · Mark D. Griffiths<sup>1</sup> · Mike Rennoldson<sup>2</sup> · Daria J. Kuss<sup>1</sup>

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## Abstract

Sedentary behaviours are highly associated with obesity and other important health outcomes in adolescence. This paper reviews screen time and its role within school-based behavioural interventions targeting adolescents between the years 2007 and 2019. A systematic literature review following PRISMA guidelines was conducted across five major databases to identify interventions targeting screen time—in addition to TV/DVD viewing. The review identified a total of 30 papers analysing 15 studies across 16 countries aiming at addressing reduction of recreational screen time (internet use and gaming) in addition to television/DVD viewing. All of the interventions focused exclusively on behaviour change, targeting in the majority both reduction of sedentary behaviours along with strategies to increase physical activity levels. A mix of intervention effects were found in the reviewed studies. Findings suggest aiming only for reduction in time spent on screen-based behaviour within interventions could be a limited strategy in ameliorating excessive screen use, if not targeted, in parallel, with strategies to address other developmental, contextual and motivational factors that are key components in driving the occurrence and maintenance of adolescent online behaviours. Additionally, it raises the need for a differential treatment and assessment of each online activity within the interventions due to the heterogeneity of the construct of screen time. Recommendations for enhancing the effectiveness of school-based sedentary behaviour interventions and implications for public policy are discussed.

**Keywords** Screen time · Sedentary behaviours · Adolescents · Interventions · Prevention

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✉ Melina A. Throuvala  
melina.throuvala@ntu.ac.uk

<sup>1</sup> International Gaming Research Unit, Psychology Department, Nottingham Trent University, Nottingham, UK

<sup>2</sup> Psychology Department, Nottingham Trent University, Nottingham, UK

Recent evidence from nationally representative US adolescent samples suggests that psychological wellbeing has decreased since 2012 due to more time being spent on electronic media and screen time (Twenge et al. 2018). The proliferation of media use (Council on Communications and Media 2016) and the increase in the time spent using media (Rideout et al. 2010; Wahi 2011) has brought about an overall increase in screen-based sedentary behaviour (SB). SB has been increasingly linked to obesity and other physical and mental health concerns. Prevalence rates for obesity have risen ten times in the last four decades and assuming the current trend continues, there will be more obese children and adolescents than moderately to severely underweight adolescents by 2022 (World Health Organization 2017) in spite of efforts to define prevention priorities (Moreno et al. 2011; Pratt et al. 2008). Currently, in the US, about one in six children and adolescents aged two to 19 years are considered obese (National Institute of Diabetes and Digestive and Kidney Diseases 2017), with a 17% prevalence of obesity and 5.8% of extreme obesity (for ages two to 19 years) (Ogden et al. 2016). In the UK, over one in five children in reception class, and over one in three children in sixth grade, were found to be obese or overweight (NHS England 2017).

Television (TV) viewing accounts for one-third of the share in SB time and is considered the most studied behaviour to date and the one most strongly related to overweight conditions (Heilmann et al. 2017). However, there is a significant increase in new media consumption leading to SB (Robert Wood Johnson Foundation 2014), with screen time (ST) and internet use still requiring further investigation (Vandelanotte et al. 2009). Current revised UK public health guidelines (UK Chief Medical Officers 2019) recommend an average of at least 60 daily minutes of moderate to vigorous physical activity (MVPA) across the week for school-aged children and adolescents using a variety of types and intensities and with an emphasis on minimizing SBs and increasing break up of long periods of sedentariness. Increasingly SB recommendations include (in addition to MVPA) a focus on ST reduction strategies also reflected in lifestyle interventions for obesity and the increase of physical activity (PA). The Canadian Paediatric Society (Ponti and Digital Health Task Force 2019) recently announced a new position statement providing evidence-based guidance for clinicians and parents stressing four main pillars (i.e. healthy management, meaningful ST, positive modelling and balanced, informed monitoring of ST and signs of problematic behaviours), suggesting a transition from restrictive-only strategies to the inclusion of advice on qualitative assessment of time spent online and screening. Equally, following a comprehensive review, the Royal College of Paediatrics and Child Health (Royal College of Paediatrics and Child Health (RCPCH) 2019) in the UK recommended an approach to ST tailored to the child, while the French Academy of Paediatrics (Picherot et al. 2018) recommended developing parental awareness of risks and benefits and an active involvement in alternative activities, endorsing balanced use of ST. All expert advice provision contains a healthy mix of restrictive and active mediation approaches, following the updated guidelines of the American Academy of Paediatrics (Council on Communications and Media 2016). However, uptake is still poor with evidence of only 37% of US children meeting ST recommendations (Walsh et al. 2018).

Evidence to date for ST harm is still weak with potential confounding factors (i.e. low PA, high sugar intake, data deriving from low socio-economic samples). However, risks appear to be involved in increased ST (Ashton and Beattie 2019). Prevalence rates from 30 large and population-representative studies demonstrated an average of 8.1 h/day for SBs, which increased from childhood to adolescence and exceeding the daily recommendations average of 2.9 h/day for ST (Bauman et al. 2018). Children and adolescents in the US have been found to spend an average of 6 to 8 h daily engaged in SB, during and out of school, with 32.4% of

children and adolescents on an average school day devoting about 3 to 4 h on TV, playing video games, or on using a computer for leisure activities, with 95% reporting having access to a smartphone, and 45% being online almost constantly (Pew Research Center 2018; Robert Wood Johnson Foundation 2014). The amount of time children (5–15 years) in the UK spend daily is approximately 2 h online and 2 h TV watching, with online access exceeding TV viewing by 20 min (Ofcom 2019). ST behaviours, internet use and gaming are particularly attractive to young people because they involve the active engagement of the individual rather than the passive nature of TV consumption, and there are rising parental concerns over use (Ofcom 2016, 2018). It is still unclear how different ST behaviours are related to obesity (Coombs and Stamatakis 2015) since the aetiology of obesity is complex and multi-faceted (Griffiths 2004)—similar to ST behaviours—that constitute different activities with common, but also different motivations, risk factors and clinical manifestation (Kuss et al. 2014).

Screen time—being a relatively new phenomenon (Coombs and Stamatakis 2015; Griffiths 2010)—has recently been operationalized by the Sedentary Behaviour Research Network (SBRN), who conducted a terminology consensus project to account for sedentary and active time spent on screen-based behaviours. This time is divided into the following categories: (i) *recreational* ST (not related to school or work), (ii) *stationary* ST (time spent on screen-based devices [smartphone, tablet, computer, television] in stationary situations regardless of context [i.e. school or work]), (iii) *sedentary* ST (time spent on screen devices in sedentary situations regardless of context) and (iv) *active* ST (time spent on screen devices not being stationary regardless of context, i.e. playing videogames, running on treadmill while watching TV) (Tremblay et al. 2017). This is differentiated from SBs, a broader construct, increasingly connected to leisure time (Griffiths 2010; Vandelanotte et al. 2009) and operationally defined as “any waking behaviour characterized by an expenditure  $\leq 1.5$  Metabolic Equivalents (METs) while in a sitting or reclining posture” (Sedentary Behaviour Research Network 2012, p. 540). These are behaviours that involve limited energy expenditure, such as sit-down activities (i.e. reading, listening to music) as well as involvement in ST.

Research has demonstrated the relationship between ST and obesity in overweight and obese adolescents and in young adults (18–25 years) (Maher et al. 2012; Mitchell et al. 2013; Vaterlaus et al. 2015). However, the evidence is inconclusive concerning the role of PA in SBs. SBs accompanied by a lack of PA have been identified as a potential risk factor for adolescent obesity (Griffiths 2010) and to partially displace physical exercise (Liu et al. 2015) as well as face-to-face time spent with friends and family, resulting in lower levels of psychological wellbeing (Liu et al. 2015; Mannell et al. 2005; Nie et al. 2002; Twenge et al. 2018). Other findings claim obesity to be irrespective of PA levels and not associated with less engagement in leisure-time physical activities (Gebremariam et al. 2013; Mendoza et al. 2007). Given the multi-factorial nature of obesity (Hamulka et al. 2018), various intrapersonal and interpersonal correlates interact, touching upon individual, social and environmental factors, which have been evidenced as protective or risk functions (Amarasinghe and D’Souza 2012). ST has been associated with other lifestyle choices (such as sleep, diet and sedentariness), which interact promoting obesity, arguably in a dose-response manner, suggesting there is a need for integrated efforts in prevention (Chaput 2017), with attention to the specific activities because correlates differ between television and computer use (Babey et al. 2013), but with significant confounding variables (Busch et al. 2013).

Therefore, despite the advantages of adolescent media use documented in several studies (Council on Communications and Media 2016), there are many studies demonstrating the widespread negative impacts that excessive ST has on adolescent wellbeing, the increasing

prevalence rates of problematic use, and the risk factors that are associated with the development and maintenance of addictive internet use (Durkee et al. 2012; Kaess et al. 2016; Kuss and Griffiths 2011; Kuss et al. 2014; Kuss et al. 2013). Apart from the negative physical impacts of ST sedentary behaviour, there is an emerging literature on the relationship of prolonged SB and mental health problems (i.e. depression and anxiety) (Asare 2015; Boers et al. 2019; Liu et al. 2015; Teychenne et al. 2015) including severe depressive symptomatology in obese adolescents (Goldfield et al. 2016; Liu et al. 2015); body weight perception, weight control behaviours and problematic internet use (Park and Lee 2017), leisure internet and computer use, weight status, time spent in leisure time PA and other SBs (Vandelanotte et al. 2009); and, various negative correlates (i.e. bullying, less PA, truanting from school, alcohol use and unhealthy eating habits), and compulsive and excessive screen use with psychosocial problems and being overweight (Busch et al. 2013).

Additionally, SBs have been associated with psychological distress and decreased quality of life, sleep deprivation (primarily shortened duration and delayed timing) among school-aged children and adolescents (Hale and Guan 2015), and unfavourable changes in dietary habits (Gebremariam et al. 2013). Mobile phone dependency has been found to negatively predict attention and positively predict depression in adolescents, which in turn affected social relationships with friends, as well as language, arts and mathematics achievement (Seo et al. 2016). Additionally, adolescents with problematic social media use presented with low self-esteem, depression symptoms and elevated social media use levels in a nationally representative sample (Bányai et al. 2017). Video game playing has also been found to trigger central nervous system arousal (Wang and Perry 2006) that is in turn potentially associated with increased levels of anxiety. To reduce ST therefore requires more than time restriction in addressing problematic content and activities. This may be achieved by providing parental and child media literacy, focus on screen-free recreational activities, and skill enhancement in older children and adolescents (Bleckmann and Mößle 2014).

It has been argued that adolescents are potentially the most appropriate target groups for interventions due to (i) their vulnerability to addictive and excessive behaviours (Chambers et al. 2003; Kuss et al. 2013), (ii) a decrease in the engagement with PA compared to previous activity levels (Hankonen et al. 2017; Hynynen et al. 2016; Todd et al. 2015), (iii) a significant increase in their media engagement and autonomy over recreational time (highest media and videogame use in late childhood and early adolescence) (Babic et al. 2015; Garcia et al. 2017; Rideout et al. 2010) and (iv) an identified need for more research in this age group for the reduction of SBs (Biddle et al. 2014). Additionally, there is an increasing scientific focus on the developmental aetiology or precursors of problems (Catalano et al. 2004), highlighting the importance of targeting this age group.

The aforementioned concerns and other negative health outcomes (Moreno et al. 2011) (i.e. cardiovascular disease, type two diabetes), crucial health indicators (Chinapaw et al. 2011; Tremblay et al. 2011), and shorter sleep duration particularly for portable devices (Hysing et al. 2015; Twenge et al. 2019) require interventions that attend to ST correlates, whether social, physical or emotional (Huffman and Szafron 2017). This, in turn, has led to a growing number of intervention studies that aim to reduce ST and SBs either as a primary or a secondary outcome (Cong et al. 2012) along with other health-compromising behaviours (i.e. physical inactivity, and poor nutrition). School-based interventions are increasingly suggested as an effective vehicle for the implementation of these programmes

and a growing number of studies document the potential and the effectiveness of programmes by targeting multiple health behaviours (Hale et al. 2014; Van Grieken et al. 2012). However, the evidence is still mixed (Hynynen et al. 2016). Previous reviews and meta-analyses on sedentary intervention studies have reported mixed effects ranging from no effects (Wahi 2011) to small to medium effect sizes (Biddle et al. 2015; Maniccia et al. 2011; Schmidt et al. 2012), to significant intervention effects for some of the studies reported (Altenburg et al. 2016; Friedrich et al. 2014; Tremblay et al. 2011; Van Grieken et al. 2012), suggesting a need for optimizing effects.

To further understand the role of recreational ST in SBs and the obesogenic environment (Egger and Swinburn 1997)—which is considered an evolving risk factor given the increasing habitual involvement of adolescents in these behaviours—and the way these activities are addressed in school-based interventions, a systematic literature review was conducted for adolescents. The aim of the present review was to identify school-based programmes for adolescents that include recreational ST behaviours additional to TV viewing, and to assess the ways these are targeted within the interventions and their contribution in reducing SB or increasing PA in obesity-reducing interventions, which has been increasingly recognized as a significant determinant of a host of health behaviours, including sleep, cognitive and behavioural outcomes (Martin et al. 2018).

## Methods

A systematic literature review was conducted, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines (Moher et al. 2009). Eligibility criteria were based on the PICOS (Participants, Intervention, Comparison, Outcome and Study Design) framework to inform the review objectives (outlined in Tables 1 and 2).

### Literature Search

The systematic literature review identified school-based interventions for ST in SBs, where reduction of ST beyond TV/DVD viewing (i.e. computer/internet use and gaming) was an outcome. The systematic search consisted of selecting papers from the following electronic databases: *Web of Science*, *PsycInfo*, *PubMed*, *Science Direct*, and *Google Scholar*, and was conducted using the following broad search terms: prevent\*, intervention, program\*, “randomized controlled trial”, trial, adolescents, school\*, “screen time”, “sedentary behaviour”, gam\*, addict\*, “internet use”, “social media”, and “social networking sites”. Excessive internet use and other internet-related pathological activities with addictive proclivity (compulsive, problematic or excessive Internet use) could be a result of excessive ST and were therefore used as a related construct for the purposes of the review.

### Inclusion/Exclusion Criteria

Eligible for inclusion were (i) protocol studies or studies that evaluated school-delivered ST or SB interventions targeting a reduction of screen-based SBs alone or with other physical and mental health issues that included other media use apart from TV viewing (i.e. computer, smartphone, and other media use, online or offline gaming), (ii) effectiveness SB studies that

**Table 1** School-based interventions for screen time included in the review

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Babic et al. 2015, 2016	<i>n</i> = 8 secondary schools <i>n</i> = 322 students <i>M</i> <sub>age</sub> = 14.4 ± 0.6 years	Baseline + 6 months post-test Adolescent sedentary activity Q (ASAQ) (Howard et al. 2007b)	Primary: Recreational screen time (ST)	Reduction in ST for both the intervention group (IG) and control group (CG) ( <i>M</i> = -50 min/day, <i>p</i> < 0.05 vs. <i>M</i> = -29 min/day, <i>p</i> < 0.05) but no statistically significant adjusted difference between the groups ( <i>M</i> = -21.3 min/day, <i>p</i> = 0.255). No intervention effects for other psychological outcomes (i.e. well-being, psychological distress, self-perceptions), PA, and BMI. Mediation effects for autonomous motivation.
“Switch-off for Healthy Minds” Australia Protocol + Registered Randomized controlled trial (RCT)	Duration: 6 months TG: students, parents Consolidated Standards of Reporting Trials (CONSORT) (Campbell et al. 2004)	The 10-item Kessler psychological distress scale (Kessler et al. 2002) The aggression scale (Oppinas and Frankowski 2001) The strength and difficulties Q. (SDQ) (Truman et al. 2003) The physical self-description Q. (PSDQ) (Marsh 1996) Household screen time rules (Ramirez et al. 2011) The pathological video gaming scale (Gentile 2009) The motivation to limit screen time Q (MLSQ) (Lubans et al. 2013) Process evaluation (student retention, adherence, feasibility, satisfaction data)	Secondary: Self-report: self-reported psychological wellbeing, psychological distress, global physical self-concept, resilience, pathological video gaming and aggression Objective: physical activity (PA) (measured by accelerometer), body mass index (BMI) Cost-effectiveness of intervention	
Hankonen et al. 2016, 2017	For future RCT: <i>n</i> = 6 vocational schools <i>n</i> = 57 classes, <i>n</i> = 30 IG, <i>n</i> = 27 CG, <i>n</i> = 1123	Baseline, 2-month, 14-month follow-ups Objective measures (i.e. accelerometer, body composition) Self-report PA, sedentary behaviour (SB) and breaks measures adapted from national monitoring reports (i.e. Nordic monitoring of diet, PA and overweight) (Nordic Council of Ministers et al. 2012)	Primary: Self-report: PA & sedentary behaviours (SB) + breaks in SB Objective: moderate to vigorous physical activity (MVPA) + breaks in SB Secondary: BMI, ST, breaks in ST (accelerometry), physical and mental wellbeing, and psychological variables (e.g. behavioural automaticity) Teachers: Self-report: sitting reduction activities + observed student behaviour Feasibility primary:	Recruitment rate 64% (for students), 88.9% (for teachers). Post-intervention student retention 76.7% teacher retention 93.8%. High acceptability ratings of sessions ( <i>M</i> = 6.29 on a scale 1–7) and teachers ( <i>M</i> = 89.18, 89.83 and <i>SD</i> = 7.36, 5.31 respectively) feasibility of data collection procedures. Intervention group: increased use of BCTs [ <i>M</i> ( <i>SD</i> ) = 3.3 (1.0) in T3 vs. 2.6 (1.5) in T1] with higher use for some (self-monitoring, graded tasks, and barrier identification) but sub-optimal utilization of key BCTs (i.e. self-regulation, self-monitoring, coping planning)
Registered Cluster feasibility RCT	Age = 15–17 years Target group (TG): students, teachers Duration: 2 years Feasibility study: <i>n</i> = 64 students randomized in matched pairs <i>n</i> = 18 teachers CONSORT guidelines (Campbell et al. 2004)	A sedentary behaviour measure-SIT-Q (Lynch et al. 2014) Other health-related outcomes/covariates (body composition measures, health somatic symptoms, dietary habits, sleep): Self-reported health & physical fitness (National Institute for Health and Welfare 2016) Somatic symptoms (Karvonen et al. 2005; Merikanto et al. 2013; Ståhl et al. 2014), dietary habits (Hopppu et al. 2008; Hopppu et al. 2010)		

Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Smith et al. 2014, 2017	<i>n</i> = 14 secondary schools <i>n</i> = 361 adolescent boys, <i>n</i> = 180 IG, <i>n</i> = 181 CG	<p>Psychosocial correlates of PA &amp; restricting SB:</p> <p>Behavioural beliefs (Fishbein and Adjen 2011; Francis et al. 2004; Hagger et al. 2003)</p> <p>PA intention, PA self-efficacy/perceived behavioural control (Francis et al. 2004; Hagger et al. 2003; Markland and Tobin 2004)</p> <p>Autonomous and controlled motivation (Markland and Tobin 2004); integrated regulation subscale (Wilson et al. 2006)</p> <p>Automaticity (Gardner et al. 2012)</p> <p>PA action and coping planning (Snehotta et al. 2005)</p> <p>Big five personality traits, brief measure (Gosling et al. 2003)</p> <p>Student group climate (Richer and Vallerand 1998)</p> <p>Behaviour Change Technique (BCT) use (Abraham and Michie 2008) PA &amp; SB related BCT use: i.e. frequency</p> <p>Acceptance &amp; evaluation (i.e. recall, satisfaction)</p> <p>Perceived teacher behaviour and group climate</p> <p>Adverse effects (i.e. injuries, illnesses)</p> <p>Perceived opportunities for SB reduction within school, perceived teacher actions to reduce students' sitting</p> <p>Teacher: sitting reduction behaviour, motivational behaviour for reducing student SB</p> <p>Intervention arm only measures:</p> <p>Recalled number of intervention sessions attended, intervention satisfaction, evaluation and use of home workout videos, workbook &amp; website</p> <p>The perceived autonomy support scale for exercise settings: (PASSES) (Hagger et al. 2007)</p> <p>BCTs high vs. low engagement (Hankonen et al. 2015)</p>	<p>Student and teacher acceptability of allocation procedures (i.e. examining reasons of drop-outs) and feasibility of procedures for recruitment, measurement, retention</p> <p>Feasibility secondary: PA and SB, BMI, ST, well-being, use of BCTs</p> <p>Student perceptions of teacher sitting reduction activities</p>	<p>BCT use correlated highly with objective measures of PA (<math>r = .57, p = .011</math>)</p> <p>Teachers in the intervention arm increased the use of sitting reduction strategies at post-intervention and T4 follow-up. Adjustments on BCTs were made for trial phase.</p>
Smith et al. 2014, 2017	<i>n</i> = 14 secondary schools <i>n</i> = 361 adolescent boys, <i>n</i> = 180 IG, <i>n</i> = 181 CG	<p>Baseline, 8- (post-intervention) and 18-month (follow-up)</p>	<p>Primary: Height, weight, waist circumference,</p>	<p>Significant intervention effects for ST (<math>M = -30</math> min/day <math>\pm 10.08</math>; <math>p = .03</math>) for beverage consumption, muscular fitness and</p>

Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Lubans et al. 2016a "Active Teen Leaders Avoiding Screen Time (ATLAS)" Australia Protocol + Registered RCT	$M_{age} = 12.7 \pm 0.5$ years CONSORT guidelines (Campbell et al. 2004) Duration: 20 weeks	Resistance training skills battery (Lubans et al. 2014) Behavioural Regulation in Exercise Questionnaire—version 2—(BREQ-2) (Markland and Tobin 2004) Adolescent sedentary activity Q (ASAQ) (Hardy et al. 2007b) Sugar-sweetened beverage consumption based on 2 items from NSW schools Physical Activity and Nutrition Survey (SPANS) (Hardy et al. 2011) The physical self-description Q (PSDQ) (Marsh 1996) The psychological flourishing scale (for subjective well-being) (Diener et al. 2010) The pathological video gaming scale (Gentile 2009) The aggression scale (Orpinas and Frankowski 2001) The paediatric daytime sleepiness scale (PDSS) (Drake et al. 2003) Hypothesized mediators: Motivation in school sport Q. (Goudas et al. 1994) Psychological needs satisfaction (19 items from existing validated scales) (Ng et al. 2011; Standage et al. 2003) The motivation to limit screen time Q (MLSQ) (Lubans et al. 2013) Screen time rules (Ramirez et al. 2011) Process evaluation: student attendance, leadership accreditation, teacher satisfaction (with workshop evaluation Qs), parental involvement, satisfaction for all groups, intervention fidelity ST (self-report and accelerometer-based) Assessed as (hours per day of TV/DVD watching and computer/games console use self-reported, on (i) frequency (ii) what they did "yesterday" (i.e. the day	resistance training skills competence Secondary: objectively measured body composition, muscular fitness, resistance training skill competency, muscular fitness (grip strength and push-ups), ST, sugar-sweetened beverage consumption, resistance training skill competency, daytime sleepiness, subjective wellbeing, physical self-perception, recreational ST, pathological video gaming, and aggression.	resistance training skills. No effects for BMI, WC, % body fat, PA. Sustained intervention effects for secondary outcomes 18-month post-intervention: ST ( $M = -32$ min/day, $p < .01$ ), training skill competency and self-regulation. 70% of boys reported using the app for goal setting of ST.
Vik et al. 2015 "UP4FUN"	$n = 62$ schools, $n = 31$ IG, $n = 31$ CG $n = 3147$ students Age: 10–12 years	Primary: ST (for TV/DVD and computer/games playing) and breaking up sitting time No significant intervention effects: self-reported TV/DVD ( $\beta = -0.03$ ; 95% CI $-0.12$ – $0.05$ , $p = 0.42$ ), computer/game console time ( $\beta = 0.01$ ; 95% CI, $-0.10$ – $0.09$ ,		



Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Belgium, Germany, Greece, Hungary, Norway Registered RCT	Duration: 3 years CONSORTI guidelines (Campbell et al. 2004)	before the survey, 24 h-recall (iii) the number of breaks from sitting time during 1 h of TV/DVD watching, breaks/hour sitting and breaks/school hour. Child, parent, school management Qs, audit instrument and staff interviews Instruments for ST behaviours and potential determinants (44 items operationalized as statements) were developed and pre-tested for comprehension and duration of completion. Student instrument was based on a child Q. used in the study of the “ENERGY” project (Van Stralen et al. 2011) Process evaluation Baseline, 3 months, 7 months PA & SB:	Secondary: 44 potential determinants [personal (i.e. awareness, attitude) and family environment (i.e. parental practices, rule setting)] of ST involvement and 4 of breaking up sitting time	$p = 0.90$ accelerometer-assessed total sedentary time ( $\beta = 0.11$ ; 95% CI, $-0.18$ – $1.52$ , $p = 0.34$ ) and number of breaks in sitting time ( $\beta = 0.17$ ; 95% CI, $-0.11$ – $0.33$ , $p = 0.81$ ). Intervention group reported more positive attitudes preferences/liking for ( $\beta = 0.20$ ; 95% CI, $0.08$ – $0.32$ , $p < 0.002$ ) breaking up sitting time than the control group. Authors do not propose wider dissemination of the present intervention.
Cui et al. 2012 Beijing, China Registered RCT (pilot phase)	$n = 4$ schools $n = 346$ IG, $n = 336$ CG trained peer leaders, $M_{age} = 12.7 \pm 0.5$ years weekly 40-min lessons to their classmates Duration: 4 weeks	A modification of a validated 7-day youth PA questionnaire (Liu et al. 2003) (MVPA, commuting, SBs; TV/DVD viewing, computer usage, electronic game playing, extracurricular reading, drawing/writing/-listening to music, sitting to phone call or chat, playing instruments—for weekdays and weekends) (Stevänen et al. 2014) Process evaluation (direct observation and focus groups, in-depth interviews with principals) Baseline, 18 months, 28 months Validated ST self-report Q. (Mark and Janssen 2008) Assessment on TV, playing videogames, using computer (Van Rooyen et al. 2015) BMI-z scores, socio-economic status of household (as covariates) >% of adolescents not meeting ST recommendations (American Academy of Pediatrics 2001)	PA and SB	A significant decrease in time in sedentary behaviour on weekdays, ( $M = -20$ min/day, $p = 0.020$ ) at 7 months for IG—reflected primarily from a reduction ( $M = -14$ min/day, $p = 0.009$ ) in computer usage on weekdays. No effects for other SBs (i.e. TV, DVD, videogames, extracurricular reading, writing, drawing), MVPA.
Andrade et al. 2014, 2015 Ecuador Registered RCT	$n = 20$ schools $n = 1370$ IG, $n = 684$ CG First stage: $n = 1224$ IG, $n = 608$ CG Second stage: $n = 1078$ IG, $n = 531$ CG $M_{age} = 12.8 \pm 0.8$ years Duration: 3 years	Process evaluation (direct observation and focus groups, in-depth interviews with principals) Validated ST self-report Q. (Mark and Janssen 2008) Assessment on TV, playing videogames, using computer (Van Rooyen et al. 2015) BMI-z scores, socio-economic status of household (as covariates) >% of adolescents not meeting ST recommendations (American Academy of Pediatrics 2001)	ST, PA, healthy diet	Overall intervention effect: TV time on a weekday ( $\beta = -14.8$ min/day, $p = 0.02$ ), ST on a weekend day ( $\beta = -25$ min/day, $p = 0.03$ ), proportion of adolescents that did not reach the recommended ST ( $\beta = -6\%$ points, $p = 0.01$ ). First stage (0–18 months) ( $n = 1224$ ; $n = 608$ CG): Less increase for IG vs CG, TV time on a weekday ( $\beta = -15.7$ min/day; $p = 0.003$ ) or weekend day ( $\beta = -18.9$ min/day; $p = 0.005$ ), total ST on a weekend day ( $\beta = -25.9$ min; $p = 0.03$ ) and the

Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Majumdar et al. 2013 "Creature 101" USA	$n = 8$ schools $n = 590$ , $n = 359$ IG, $n = 172$ CG $M_{age} = 11.3 \pm 0.74$ years, low socio-economic status (SES) Duration: 7 sessions	Pre-post intervention study The Eat-Move Q, adapted instrument for food, ST and other behaviours from the Beverage and Snack Q. (BSQ) (Neuhouser et al. 2009) and other studies (Contento et al. 2010)	Frequency and amount of: sweetened beverages, water, processed snacks, fruits and vegetables, recreational ST, PA	proportion of adolescents that did not meet the ST ( $\beta = -4$ ; $p = 0.01$ ) Second stage (18–28 months) ( $n = 1078$ adolescents, $n = 531$ CG): effects were not maintained in the second stage (targeted only PA and healthy diet). A significant intervention effect for TV on a weekday ( $\beta = -13.1$ min/day; $p = 0.02$ ) in CG—increase in TV time on weekday ( $\beta = 21.4$ min/day; $p = 0.03$ ) 0–28 months: No intervention effects No significant intervention effects for ST or the other behaviours ( $F = 0.99$ , $p = 0.32$ ) for frequency and duration ( $F = 3.32$ , $p = 0.69$ ). Significant intervention effects were observed only for the frequency and amount of consumption of sweetened beverages and processed snacks.
Baghermiya et al. 2018 Iran Registered RCT	$n = 172$ overweight and obese girls, $n = 87$ IG, $n = 85$ CG $M_{age} = 13.53 \pm 0.67$ years CONSORT guidelines (Campbell et al. 2004) Duration: 7 months	PA questionnaire and SCT constructs (self-efficacy, social support, outcome expectations (i.e. perceived benefits) and expectancies (i.e. values placed on benefits), intention and perceived barriers. Type and time of PA, duration of SBs (hours of watching TV and hours of playing computer games per day) (Baghermiya et al. 2015; Dewar et al. 2013; Taymoori et al. 2010)	Primary: BMI and WC Secondary: self-efficacy, social support, outcome expectations (i.e. perceived benefits) and outcome expectancies (i.e. values placed on benefits), intention (i.e. proximal goals) and perceived barriers, SBs Nutrition knowledge, attitudes towards nutrition, diet quality, SBs, body composition	Intervention effects for hours of TV watching and computer playing IG ( $M = 3.2$ vs. 2.8, $p < 0.001$ ), PA and psychological outcomes (self-efficacy, intention, social support).
Wadolowska et al. 2019; Hamulka et al. 2018 Poland	$n = 464$ adolescents, $n = 216$ boys, $n = 248$ girls Age = 11–12 years Duration: 5 topics	4 time points: baseline, 3-weeks (IG only), 3 months post follow-up, 9 months follow-up 3 weeks $\times$ 4 h/topic The Food Frequency Questionnaire for Polish Children (SF-FFQ)—short form: diet, sedentary and active lifestyle, nutrition	No intervention effects for ST between groups in the post-9-month period: ( $M = -0.01$ , ns), No effects for IG ( $M = 0.12$ change; 95% CI, $-0.02$ – $0.23$ , ns), or CG ( $M = 0.13$ change; 95% CI, $-0.03$ – $0.29$ , ns). Tendency for an increase in ST was	

Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Barbosa Filho et al. 2019	<i>n</i> = 6 schools total: <i>n</i> = 3 IG, <i>n</i> = 3 CG	knowledge and socio-demographic characteristics (Hamulka et al. 2018); Nutrition Knowledge (Whati et al. 2005), healthy/non-healthy diet index, body weight (kg), height (cm) and WC	PA measure (Barbosa Filho et al. 2016) The Youth Risk Behaviour Survey Questionnaire	Intervention effects for % of adolescents who reported watching less than 2 h of TV (6.4% change; 95% CI, 1.9–10.8, <i>p</i> = 0.004), and % using the computer less than 2 h per day (8.6% change; 95% CI, 3.8–13.4), <i>p</i> < 0.001). Also increase in % meeting PA recommendations. Intervention effects were sustainable only for PA.
Brazil	<i>n</i> = 1085 adolescents,	Three-factor eating questionnaire (TEFQ-13) (Dzielska et al. 2009)	Secondary: different health factors (e.g. nutritional status, health behaviour, quality of life, and other lifestyle components (e.g. eating habits, substance use), psychological (e.g. self-rated health, body satisfaction) and biological (general and abdominal obesity) aspects, academic performance	
Registered cluster RCT	<i>n</i> = 548 IG, <i>n</i> = 537 CG) Age = 11–18 years CONSORT guidelines (Campbell et al. 2004) Duration: 4 months	Attitudes towards nutrition (Dzielska et al. 2009) One frequency question to assess ST (duration of TV and/or computer time) Socio-demographic assessment was based on the Polish adaptation of the Family Affluence Scale (FAS) (Mazur 2013) developed for the Polish Health Behaviour of School-aged Children (HBSC) study (Mazur 2015)	For obese students: depressive symptoms, eating disorders, sleep quality, objectively measured PA, and sedentary time	

Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Singh et al. 2006, 2007, 2009 The Dutch Obesity Intervention in Teenagers programme (NIG-DOIT) RCT	$n = 1108$ adolescents $n = 10$ schools IG $n = 8$ schools CG $M_{age} = 12.7 \pm 0.5$ years prevocational secondary schools, in their first year Duration: 11 lessons	Baseline, 8, 12 and 20 months Objective measures for body composition The short food frequency questionnaire (FFQ) (Van Assema et al. 2001; Van Assema et al. 2002) SBs (playing videogames, watching TV etc.) and parental accounts of ST based on previous obesity prevention study (Robinson 1999) Process evaluation (of content, attractiveness, intervention materials)	Primary: Body composition (height, weight), WC, skinfold thickness Secondary: consumption of sugar-sweetened beverages/snacks, SB, PA, and aerobic fitness	Significant intervention effects for ST for boys only in the 20-month follow-up [ $M = -25$ min/day; 95% CI, $-50$ to $-0.3$ ], and reductions in ST observed also in 8- and 12-month follow-up. Also, intervention effects for body composition and reduction of sugar-containing beverages for boys at 8- and 20-month follow-up. No intervention effects for consumption of snacks and active commuting to school
Tarro et al. 2019 EYTO-Kids project Spain Registered cluster RCT (pilot)	$n = 8$ primary schools, $n = 4$ high schools, $n = 375$ students, $n = 94$ peer leaders $M_{age} = 9.22 \pm 0.57$ years (children), $13.1 \pm 0.59$ years (adolescents) CONSORT (Campbell et al. 2004), standard protocol items: recommendations for interventional trials (SPIRIT) (Chan et al. 2013), template for intervention description and replication protocol and guidelines (TIDier) (Hoffmann et al. 2014) Duration: 10 months	The EnKid questionnaire (fruit/vegetable and fast food frequency) (Serra Majem et al. 2003) The AVall questionnaire (PA) (Llargués et al. 2009) The Health Behaviour in School-aged children (HBSC) questionnaire (Currie et al. 2010) The HABITS questionnaire (sugary drinks consumption) (Wright et al. 2011)	Fruit/vegetable/sugary drink consumption, fast food, PA, SBs	Intervention effects in % of male children in the intervention group who followed the recommendations of $\leq 2$ h/weekday of (8.2% change, $p = 0.003$ ) compared to the control group. Also increase for PA and reduction of sweets, soft drinks and fast food but no increase for recommended food consumption.
Aittasalo et al. 2019, Jussila et al. 2015 Finland 'Kids Out' Protocol + Registered RCT	$n = 14$ schools, $n = 36$ classes IG, $n = 41$ classes CG, $n = 696$ IG, $n = 860$ CG, teachers $n = 14$ $M_{age} = 13.9 \pm 0.5$ years CONSORT guidelines (Campbell et al. 2004)	Pre-intervention and 9-month post-intervention Evaluation based on RE-AIM (Reach, Effectiveness, Adoption, Implementation and Maintenance) (Glasgow et al. 1999) World Health Organization (WHO) HSBC (Currie et al. 2010) Objective assessment (accelerometer)	Primary: PA, SBs Secondary: Psychosocial factors (family norm, short-term behavioural intention, confidence to execute the behavioural intention) related to school, leisure PA and ST	Intervention effects in proportion of students reporting that their family sets limitations for ST (5.4% change; 95% CI, 3.3–7.4, $p < 0.05$ ), number of days intending to engage in leisure PA, parental knowledge in ST recommendations higher but not significant.

Table 1 (continued)

Authors/country	Intervention characteristics	Assessment periods + measures	Objectives/outcomes	Results
Foley et al. 2017 (SALSA) Australia (retrospectively) Registered RCT	+ TIDieR checklist (Hoffmann et al. 2014) Duration: 3 lessons Adapted from prior intervention on asthma (Al-Sheyab et al. 2012) $n = 22$ secondary schools, $n = 519$ Year 10 SALSA peer leaders who trained $n = 3800$ Year 8 peers Age = 13–14 years 96 University student SALSA trainers Duration: 4 lessons $n = 10$ public technical schools, $n = 253$ ; $M_{age} = 16.3 \pm 0.06$ years adolescent girls CONSORT guidelines (Campbell et al. 2004) Duration: 6 months	Baseline and 2-week post assessment Online self-report assessment based on a short food frequency questionnaire (Dewar et al. 2013; Flood et al. 2005; Gwynn et al. 2011) The motivation to limit screen time questionnaire (MLSQ) Lubans et al. 2013 for adolescents a single-item PA measure for adolescents (Scott et al. 2015) Process evaluation (i.e. lesson delivery dates, number of peer leaders)	Food/beverage, PA, and recreational ST, intentions to change	No significant intervention effects for meeting recreational ST recommendations (1.4% change; 95% CI, -3.8–6.6, $p = 0.59$ ). Meeting ST recommendations was moderated by socio-economic status; decreased for above average SES communities by -2.9% while it increased for lower SES communities (6.0%). Effects in peer leaders' intentions for reduction of recreational ST (9.7% change; 95% CI, 3.2–16.1, $p < 0.05$ )
Leme and Philippi 2015 - "Healthy Habits, Healthy Girls"—H3G Brazil Registered RCT	Duration: 6 months	Baseline, 6 and 12 months BMI-z score, WC The Godin-Shepherd Leisure-Time Physical Activity Questionnaire for use [Brazilian adaptation (São-João et al. 2013)] A validated food frequency questionnaire (FFQ) for adolescents (Martinez et al. 2013) Modified measure from another obesity prevention study on adolescent girls (Neumark-Sztainer et al. 2010) Process evaluation	Primary: BMI Secondary: BMI-z score, waist circumference, and various sedentary and dietary health-related behaviours SBs: the time spent during the weekdays and weekends in the following activities: watching TV/video/DVD and computer use for leisure activities and reading/homework	Significant intervention effects for computer ST on the weekends ( $M = -0.63$ min/day, $p = 0.015$ ), total sedentary activities on the weekends ( $M = -0.92$ min/day, $p < 0.01$ ), WC and vegetable intake

IG, intervention group; CG, control group; TG, target group; RCT, randomized controlled trial; SES, socio-economic status; SB, sedentary behaviours; ST, screen time; PA, physical activity; Q, questionnaire; BMI, body mass index; MVPA, moderate to vigorous physical activity; CONSORT, consolidated standards of reporting trials; SPIRIT, standard protocol items: recommendations for interventional trials; (TIDieR), template for intervention description and replication protocol guidelines;  $M_{age}$ , mean age; BCITs, behaviour change techniques; SES, socio-economic status; Kg, kilos in body weight; Cm, height; EBRBs, energy balance-related behaviours

**Table 2** Intervention principles, components and risk of bias of studies reviewed

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Babic et al. 2015, 2016	Self-determination theory (SDT) (Deci and Ryan 1985): Emphasis on goal content and autonomous motivation to limit ST	ST eligibility Q: reporting of $\geq 2$ h/day of recreational ST (exceeding ST recommendation)	Individual level: 60' interactive seminar (consequences of exceeding limits, benefits and barriers of reducing ST, solutions to barriers, use of interactive polling) Choice of personalized e-health social media messages for self-monitoring and goal setting: 50 prompts/6 months, bi-weekly Behavioural contract Appropriate replacement behaviour Creation of a list of potential ST rules Consequences of exceeding ST limits Environmental level: Monthly parental newsletters (1 × 6 months): on household ST rules, consequences, strategies to manage parent/child conflict for ST rules, home challenges to reduce recreational ST Assessment workshop for research assistants	Provide information on consequences & behaviour health link Provide instruction & general encouragement Prompt intention formation Prompt self-monitoring and barrier identification Specific goal setting Identification of a role model	Motivation to limit ST, PA (school sport) - Perceived autonomy, competence, relatedness	Randomization: Allocation: (matched pairs) by independent researcher and assessors blinded. Potential issue of ecological validity due to sample (Catholic secondary schools and a greater representation of female students)	Incorporated a social media component for ST reduction Adjusted strategies according to SDT tenets to focus on autonomy and support contrary to rewards

**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Hankonen et al. 2016, 2017	Comprehensive needs assessment, acceptability + feasibility trial for reducing SB and increasing PA Preliminary research on target group evidence synthesis (systematic interventions effectiveness/practices in health contexts (Hynynen et al. 2016) Based on prior intervention on PA (Andrade et al. 2014) SDT (Deci and Ryan 1985): (Emphasis on autonomous motivation) self-regulation (control theory) and planning theories (Carver and Sheier 1982; Deci and Ryan 2000; Hagger and Luszczynska 2014; McEachan et al. 2011). motivational interviewing principles (Howard et al. 2012)	Low/moderate baseline PA by self-report Inclusion and exclusion criteria applied for schools, classes, students, teachers Attendance in a compulsory health education Baseline Q Bioimpedance measurements Practiced all components 3 × 90-min workshops	Protocol manual/instructions for assessments Individual level: 6 hourly group sessions (PA motivation + self-regulation skills) 45'-60' each Activity breaks workshops (workbook + online, email newsletters) Booster session for maintenance (i.e. encourage programmes' social media use with tips) Poster campaign for retention of content (based on specific BC'Ts from assessment phase) reminders in various venues (i.e. school canteens) Environmental level: 2-h training teacher workshops (i.e. benefits of sitting reduction, how to perform sitting reduction and goal-setting strategies, practical tips to increase motivation) Increased opportunities to access PA facilities and other environmental opportunities (altering class architecture, equipment for light-intensity exercise, gym balls	Key BC'Ts from BCT Taxonomy v1 (Michie et al. 2013): Self-monitoring Info about consequences and emotional impacts Goal setting Action planning Feedback on behaviour Intervention facilitators continually trained with role play and revisions, self-assessment for quality of delivery. Emphasis on use of self-motivational strategies rather than on self-regulation strategies Information about health, social, environmental, emotional consequences and salience, information about others' approval, framing/reframing, problem solving, information about antecedents of behaviour, social support,	Manage PA motivation Self-regulate Classroom environment Encouraging for more PA & new ways of PA Knowledge, outcome expectations autonomous motivation (integrated regulation), self-efficacy (i.e. perceived benefits) and outcome expectancies (i.e. values placed on benefits), intention (i.e. proximal goals) and perceived barriers	Randomization: blinded, school is the unit of cluster randomization Allocation: (student groups-matched pairs) Performance bias addressed with strict protocol procedures Contamination bias Recruitment and completion rates informed the RCT power calculations and the RCT design Low recruitment success of one of the classes led to further adjustment in the procedure groups	A comprehensive feasibility study for reduction of SB and increase of PA Addressed both individual and environmental features Provided evidence regarding the causal mechanisms and implementation (linking intervention components to hypothesized mediating processes and their relation to outcomes) Small group dynamics of class cluster Stakeholder participation in the

Table 2 (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
			instead of chairs and standing desks) Partnerships with community organizations 6 online exercise videos to encourage home-based training Teacher led activity breaks Other SB reduction practices Active teaching methods, activity equipment, online exercise videos	identification of self as role model			creation of content with high potential for dissemination Use of BCT as methodology for acceptability and feasibility testing identification of most and least used BCTs and identification of weak points before the implementation of the full phase trial
Smith et al. 2014a, 2017	Social cognitive theory SCT (Bandura 1986), SDT (Deci and Ryan 1985), the trans-contextual model of motivation (Hagger et al. 2003); increasing motivation for PA will have a spill	At risk of obesity based on Australian guidelines (i.e. $\geq 2$ h of ST/day and/or 7 days per week of MVPA of at least 60 min duration per	Enhanced school-sport sessions 20 × 90' sessions Researcher-led seminars 3 × 20' Lunchtime PA mentoring sessions 6 × 20' sessions	Provide information on consequences & behaviour health link instruction & general encouragement Prompt intention formation	Autonomy need satisfaction: Competence Relatedness-motivation for PA and school sports PA behaviour strategies Household ST rules	Recruitment and baseline assessments preceded randomization Randomization: by independent	First study to target adolescent boys (apart from a pilot study, screening for eligibility)



**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
	over effect to other contexts (i.e. home), Reach, Effectiveness, Adoption, Implementation and Maintenance (RE-AIM)	day)—information sent to eligible students	Pedometers for self-monitoring —17 weeks Provision of equipment to schools Smartphone application and website—15 weeks Environmental level: Teacher professional development to ensure students' psychological needs are met: Two 6-h workshops, one fitness instructor session Four parental newsletters Adjusted components (modified from original for scalability): increased focus on resistance training, removal of parent newsletters, removal of pedometer component; and 10-week structured PA programme from 20 weeks to fit within one school term.	prompt self-monitoring barrier identification Specific goal setting Identification of a role model Plan social support or social change Provide feedback on performance Behaviour contract	Motivation to limit ST	researcher through a computer-based randomizer Allocation: (matched pairs), SES index and geographic location	+ to target strength and muscular fitness (leading to enhanced self-esteem in young males)
Vik et al. 2015	Socio-ecological framework (Sallis et al. 2008); changing SB determinants (i.e. awareness, attitude, self-efficacy) to promote self-efficacy (required due to increasing unsupervised time spent in older adolescents)	Teacher training + manual	Individual level: Registering sitting time Counting steps with a pedometer Making a list of fun non-sedentary activities Writing and evaluating personal goals to reduce ST	Increase awareness Goal setting Encourage break up of sitting time at home Register sitting time Write and evaluate personal goals Solutions for difficulties	50 determinants were included in the analysis (but not explicitly discussed in the study)	Randomization: Allocation: (schools-matched pairs) independent from evaluating country Poor to moderate test-retest reliability of items	Systematic development of intervention with large cross-cultural sample across Europe

Table 2 (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
	Five steps of the Model of Planned Promotion for Population Health (Brug et al. 2005) Intervention Mapping Protocol (Bartholomew et al. 2016) CONSORT guidelines (Campbell et al. 2004) BCT use (Michie et al. 2013) Part of an EU prevention programme		Difficulties regarding achieving their goal and proposing solutions Writing down rules about ST + examples Discussing family ST rules Brainstorming ideas for non-sedentary recess activities and making a poster 2-min activity breaks per sitting lesson Motivation to try the activity breaks at home and encouragement to practice active transportation to school. Environmental level: 1 or 2 × 45-min lessons/6 weeks (Week 1: introduction to programme; Week 2: Increasing awareness about SBs; Week 3: goal setting related to SB; Week 4: Influence of the home environment on ST; Week 5: Breaking up prolonged ST and practicing active transportation to school; Week 6: Summary of the intervention) Six newsletters—one per week/theme 40 peer educ. lessons to students/4 weeks	Encourage dialogue for ST within the family Write down ST rules Discuss family time Motivate to take activity breaks outside of school		developed for breaking up sitting time and its determinants—a threat for the representativeness and the accurate representation of the data or whether intervention effects were detected	
Cui et al. 2012	Peer-to-peer leaders approach based on evidence for efficacy	Peer leader's manual		Student personal goals	N/A	Trained medical students to	A manualized peer education

**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Andrade et al. 2014, 2015	SCT (Bandura 1986) An empowerment educational approach (Wallerstein and Bernstein 1988)	School doctors or class teachers had a meeting with peer leaders to clarify each peer leader's responsibility	integrated to existing health education courses students encouraged to maintain healthy habits Four components: food choice, PA, SB, carbonated drinks, goal setting Lessons included: presentation, video watching, group discussion, games, experiments, lifestyle practice, skit playing, quiz show Key messages re PA and ST Strategies to reduce ST An educational package for classroom use (textbook for teachers and workbook for adolescents) Environmental level: Parental workshop Modifications of the school environment Two key messages regarding PA and ST behaviour: (i) be active for at least 60 min/day, and (ii) spend maximum 2 h/day on watching TV Pep talks with famous young sportsmen (encouraged adolescents to be active and	Individual: Introduce notion that more than 2 h on TV/day is not healthy Create awareness re the importance of an adequate PA throughout adolescence Increase knowledge and enhance decision making skills Environmental: Increase parental awareness for need to decrease TV time and of regular PA for adolescents Support healthy behaviour regarding PA and TV time of adolescents at home	N/A	administer questionnaire Blinded to the assignment of the intervention Only two schools in each arm/potential confounders Randomization, exclusion criteria, sample size calculation, allocation, blinding procedure based in previous intervention for PA (Andrade et al. 2014)	programme with minimal interference in school activities

Table 2 (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Majumdar et al. 2013	SDT (Deci and Ryan 1985) and SCT (Bandura 1991), BCTs (i.e. Autonomy support, outcome expectations, competence) (Michie et al. 2008) provision of scientific evidence through minigames, educational videos, and slideshows and were motivated with interactive dialogues with game characters	Schools from low-income areas of NYC Matched pairs based on free lunch, reading and math scores and ethnicity distribution	Intervention group: 9 sessions × 30 min 2 × week–1 month ‘Creature 101’ Game with health science curriculum: Completion of game levels attaining energy balance of their creatures, reporting on game levels, essays on learning outcomes Control group: Different online game with neutral knowledge outcomes (arts and sciences)	Encourage PA through the positive influence of social models Encourage students to be active and eat healthy Give ideas on how to deal with barriers to be physically active at home Increase availability and accessibility to opportunities for PA inside the schools Motivate the students to walk more during recess Knowledge acquisition/Information about outcomes/behaviour Action planning Rewards/points Personal consequences	Motivational messaging Problem solving Self-monitoring Skills mastery	Not a randomized controlled trial only pre-post design, moderate psychometric quality of instrument, varying intervention dose in conditions (IG–7 sessions, CG–2 sessions)	Gamification and educational games appear promising in promoting healthy dietary behaviours among middle school adolescents, offering possibilities for wide implementation in school or home contexts and with limited resources required.

**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Bagheriyya et al. 2018	SCT (Bandura 1986)	Overweight and obese adolescent girls	Individual level: Sports workshops, private physical-activity consultation sessions, practical and competitive sports sessions Environmental level: family exercise sessions, text messages, SMS newsletters, SMS text alerts for parents and students, parental newsletters, increasing facilities of PA in the school	Knowledge acquisition/Information about outcomes/behaviour Action planning Rewards/poins Personal consequences	Psychological skills (i.e. self-efficacy) Social support Intention and perceived barriers Outcome expectancies	Lack of randomization at baseline between intervention and control group Self-report measures except from anthropometric measures—potential measurement bias	Effective intervention in increasing the duration of PA and reduction in the duration of ST overweight and obese adolescent girls. BMI and WC decreased but not statistically significant
Wadolowska et al. 2019	The integrated theory of health behaviour change	Location and proximity, school agreement, parental consent, age 11 or 12 years.	3-week education-based intervention, 5 topics (15 h)—delivered by researchers—talks and seminars on: nutrition, dietary, sensory-consumer, hygiene, culinary	Nutrition knowledge Sensory and interactive learning Observation Testing Discussions	N/A	Sample size justification Lack of randomization Self-report assessment—measurement bias	A cross-behavioural approach (clustering) of health and lifestyle behaviours for adolescents and
Hamulka et al. 2018	(Jezewska-Zychowicz et al. 2017; Ryan 2009)	Exclusion: disability and at school-level previous participation in other					

Table 2 (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Barbosa Filho et al. 2019	The socio-ecological theory (Sallis et al. 2008) and SCT (Bandura 2004) and the concept of health promoting schools (Guedes and Lopes 2010)	nutrition–health education programmes	issues, health consequences, recommendations for healthy eating and PA. Brochures, puzzles, crosswords, website	Education on implications of lifestyle factors (i.e. excessive ST, overeating) for health, academic performance, school relations, environmental changes	IP: intrapersonal mediators (e.g. knowledge, types of PA or ST, risks and benefits, self-efficacy, perceived barriers); EP: interpersonal mediators (e.g. peers, teachers and parents modelling, support and norms); ENV: environmental mediators (e.g. family environment, school environment and environmental)	Self-report assessment, potential measurement bias, no blinding of participants/controls, potential confounders (national diet programme)	Multi-component programme highlighting difficulties in school interventions addressing health behaviours
		Adolescents, Age, full-time attendance in public schools in Fortaleza, Brazil and in the School Health Programme	Environmental level: provision of specific PA training to PA teachers, health education, environmental changes (banners, health messages, provision of additional PA classes) in the formal school curriculum, health values, attitudes and opportunities promoted within the school, and schools seeking to engage with families, outside agencies and the wider community				identification of dietary and lifestyle habits

**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Singh et al. 2009	The diffusion of innovations theory (Rogers 1995) IM protocol (Bartholomew et al. 2001) The self-regulation theory (Zimmerman 2000) Needs assessment/lit review/focus groups with teachers	Provocational secondary schools Adolescents from low SES School provision of three classes devoted to the programme, appointment of contact person for the duration of the trial, stick to the same lessons during the trial period for the control group, and provision of IT support/computer provision for the lessons	Individual level: adapted curriculum for 11 lessons in biology and PA and environmental change options. Environmental level: i.e. suggestions for more availability of PA and school snacks options	Knowledge enhancing (self-monitoring and feedback) Skills development (guided practice) Social support (social/peer modelling/social comparison) Habit breaking (automatic stimulus-response, awareness of habitual behaviour) Self-efficacy (goal setting), Reinforcement	Provision of written and verbal information Evaluation of understanding Self-monitoring Skills training feedback Info provision Environment changes Prompts Personalized feedback provision Change process evaluation Facilitation of healthy behaviours	Self-selection bias	Evidence of an interdisciplinary school-based programme grounded in theory for obesity prevention
Tarro et al. 2019	Health promotion and social marketing principles	Adolescents in the first and second year of Spanish secondary high school (age: 12–14 years) and belong to one of the randomly	(1) customer orientation: aiming the intervention towards younger school peers in primary schools (by the researchers); (2) behaviour: focusing on encouraging healthy	Encouraging healthy lifestyles using knowledge-based theories Involvement of adolescents in the projects, evaluate the costs, to motivate the younger students, identify difficulties and	N/A	No allocation concealment	The role of peer to peer interventions to promote healthy lifestyles

Table 2 (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
		selected high schools	lifestyles (by the adolescents); (3) theory: usage of youth involvement strategies in peer-4signed sessions (by the researchers); (4) insight: designing activities for the younger school peers by considering the things that children enjoy (by the adolescents); (5) exchange: evaluation of the costs and benefits of healthy lifestyle changes (by the researchers and adolescents); (6) competition: identifying the difficulties of younger school peers in adhering to a healthy lifestyle while considering which stakeholders	involve stakeholders, communicate healthy messages Employment of a mix of activities, visual material, and products tasting			



**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Aittasalo et al. 2019 Jussila et al. 2015	The health action process approach model (Schwarzer 2008)	All schools in the area of Tampere	could be involved in the intervention (by the adolescents); (7) segmentation: selection of the specific population (by the researchers) and (8) methods mix: usage of different methods to transmit healthy lifestyle messages (activities designed as funny games, visual material for support and food product tasting by the adolescents)	*RE-AIM*: Reach, Adoption and Implementation strategies: orientation, motivational (intention building), volitional phase (action planning) Homework Internet-based self-assessment Action plans	Self-efficacy Intention to change Confidence in execution Family support	High drop-out rate may have affected effect sizes and risk of ecological validity Use of non-validated questions for ST and parental norms	Comprehensive evaluation procedure, identifying critical intervention components on self-reported PA and intention to do PA, alerting

**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
Foley et al. 2017	SCT (Bandura 1986), Freier's empowerment education approach (Wallenstein and Bernstein 1988), World Health Organization's Health Promoting Schools Framework (Langford et al. 2014)	Year 8 secondary school students (13–14 years) Year 10 students (15–16 years) trained as SALSAs peer leaders	Lesson 3: Goal setting and action planning 1-day peer leaders' training workshop 4 × 70-min SALSAs lessons	Modelling Self-efficacy in implementation, Peer pressure and environmental changes	Modelling Group process facilitation Encourage inquiry Critical thinking and reasoning skills in younger students	Quasi-experimental design—no randomization of schools or students	family norm of setting limits for ST. Positive shift in ERBRs for boys and recreational ST of SALSAs peer leaders for above average SES adolescents Highlighted the need for multiple targeting of health behaviours both at the individual and environmental level to enhance motivation and support healthy eating and increase of PA for girls of low
Leme and Philippi 2015	SCT (Bandura 1986)	10 schools match paired (based on location, size, and demographics) Girls at risk of obesity	Enhanced PE classes—40 × 45 min PA during recess/school break—14 × 15 min Weekly nutritional and PA key messages—10 × 20 min Nutrition and PA handbook—10 weeks Interactive seminars—3 × 60 min Nutrition workshops—3 × 90 min Parents' newsletter—4 total Text health messages (via WhatsApp) —twice/week (Term 2 & 3)	Goal development and setting, self-monitoring, health information provision, efficient intention formation, instructions on the health behaviours, overcoming barriers, general motivation, progressive tasks, motivation, peer modelling behaviours, performance feedback, family support on healthy behaviours	Self-efficacy, social support, intentions, home environment, outcome expectations	School randomization only (no participant randomization)	

**Table 2** (continued)

Study	Theory/evidence-based	Eligibility screening	Intervention components	Behaviour change strategies	Hypothesized mediating processes	Risk of bias	Study contribution
			Dietary/PA diaries -Term 3				SES in developing countries.
							RCT, randomized controlled trial; SES, socio-economic status; SB, sedentary behaviours; ST, screen time; PA, physical activity; Q., questionnaire; BMI, body mass index; MVPA, moderate to vigorous physical activity; EBRBs, energy balance-related behaviours; CONSORT, consolidated standards of reporting trials; SPIRIT, standard protocol items; recommendations for interventional trials; (TIDier), template for intervention description and replication protocol guidelines; BCIs, behaviour change techniques; SES index, socioeconomic status index; BCT Taxonomy v1, Behaviour Change taxonomy v1; Kg, kilos in body weight; Cm, height; SCT, social cognitive theory; SDT, self-determination theory; Q, questionnaire; RE-AIM, reach, effectiveness, adoption, implementation and maintenance; CPPE, comprehensive participatory planning and evaluation protocol; IM protocol, intervention mapping protocol; TV, television; DVD, digital versatile disc

targeted adolescents aged 10–16 years, published between 2007 and 2019, as SBs have recently started to attract scientific attention (Coombs and Stamatakis 2015) and prior SB interventions mainly examined TV viewing in terms of recreational behaviour (Tremblay et al. 2011), (iii) interventions where reduction of ST was an outcome, and (iv) studies for which a full-text was available, were published in the English, German, Greek or Polish language (the native languages of the authors) and which were peer-reviewed. Obesity intervention and PA increase studies that included reduction of online-related screen time behaviours as an outcome were also included.

Excluded were studies that involved only PA as an outcome or SB that assessed only TV viewing or other non-screen (non-internet), sitting down, related to leisure time (i.e. reading, and listening to music). Additionally, school-based interventions targeting internet use/addiction and problem gaming or gaming addiction focus, and multiple-risk behaviour intervention studies—which included other than obesity or PA-related risk behaviours (i.e. substance use, and alcohol)—were excluded because these have been critically examined in other reviews (Throuvala et al. 2019b).

## Data Extraction and Synthesis

Study selection of ST school-based intervention studies consisted of two phases: an initial search for titles and abstracts followed by a detailed examination of the full-text studies and their references. Eligibility assessment was performed by two assessors through an unblinded review process. Occasions where subjective judgments differed were resolved by consensus. A data extraction sheet [based on the Cochrane Consumers and Communication Review Group's data extraction template (Higgins and Green 2011)] was developed and adapted to account for trials in education settings. Studies were assessed for their (i) objectives, SB outcomes, and methodological integrity, (ii) intervention content and strategies, and (iii) effectiveness. A synthesis of the most critical findings was undertaken. Reviews and meta-analyses were not included but were consulted in the analysis of the studies identified. All tasks undertaken were reported in a flow diagram identifying and documenting all processes of literature searching and the sifting process that led to a specification of the full-text papers. These were extracted and reviewed by all authors before the preparation of the manuscript.

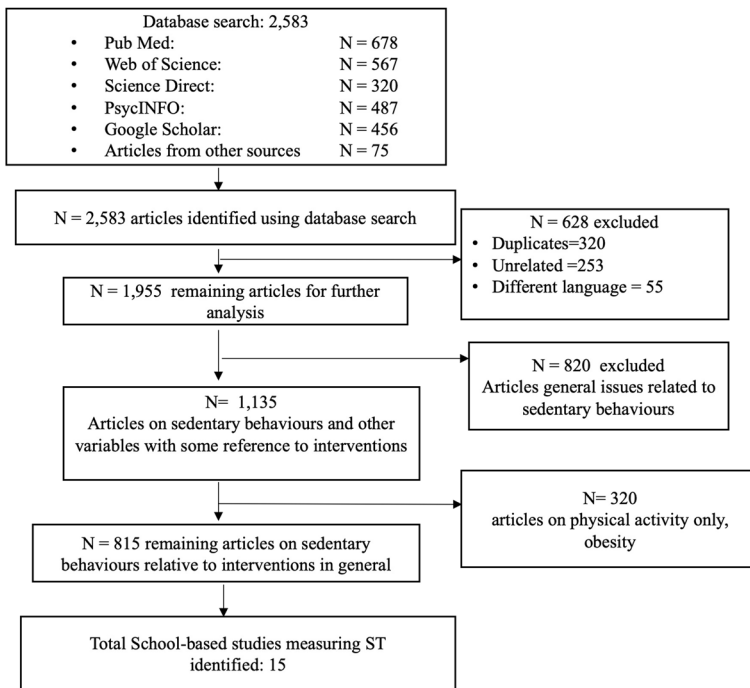
Since the studies were randomized controlled trials (RCTs) and protocols of these RCTs, two reviewers independently assessed their validity and risk of bias based on the following domains: (i) randomization/sequence generation (including comparability of baseline characteristics), (ii) allocation concealment, (iii) blinding of students, providers/assessors and outcome assessment, (iv) incomplete data, (v) attrition and selective reporting bias, and (vi) other sources of bias (i.e. sample size justification). Effectiveness results varied for ST reduction and a critical evaluation of the intervention components and the rationale of the studies was undertaken in order to explore reasons for this potential variability in the results.

## Results

In spite of the plethora of obesity and sedentary behaviour school-based interventions for children and adolescents, few studies have included ST behaviours additional to TV/DVD viewing in their assessments, limiting the number of studies that met the inclusion criteria of the present review. The search resulted in 2583 items (see flow diagram in Fig. 1), and

identified 30 published papers analysing 15 intervention studies (12 registered RCTs, three pre-post designs) that met the criteria for inclusion in the review (Aittasalo et al. 2019; Andrade et al. 2014, 2015; Babic et al. 2016; Babic et al. 2015; Bagherniya et al. 2018; Barbosa Filho et al. 2019; Barbosa Filho et al. 2016; Barbosa Filho et al. 2015; Cui et al. 2012; Foley et al. 2017; Hamulka et al. 2018; Hankonen et al. 2016, 2017; Jussila et al. 2015; Leme et al. 2016; Leme and Philippi 2015; Lubans et al. 2016a; Lubans et al. 2016b; Majumdar et al. 2013; Singh et al. 2006, 2009, 2007; Smith et al. 2017; Smith et al. 2014a, 2014b; Tarro et al. 2017, Tarro et al. 2019; Vik et al. 2015; Wadolowska et al. 2019). Out of the 15 studies, eight were analysed in more than one paper, presenting a separate rationale/study protocol or protocol and baseline results and additional effectiveness of RCT papers (Table 1). The studies spanned 16 countries: USA, Australia, Brazil, Ecuador, Finland, Belgium, the Netherlands, Poland, Germany, Greece, Spain, Hungary, Norway, Finland, Iran and China. All studies targeted the reduction of SB and ST as a primary or secondary outcome among other outcomes, accompanied in the majority with parallel strategies to increase PA, or other health behaviours.

All interventions were conducted in a school setting, were evidence-based, theory-driven, multi-component, employing both individual, systemic (i.e. parents) and environmental resources (i.e. school architecture). The interventions were delivered by the research teams (research assistants) and teachers (PE), with the exception of three studies (Cui et al. 2012; Foley et al. 2017; Tarro et al. 2017), which utilized a peer-education perspective in the implementation of the protocol. The statistical analysis to assess intervention effects applied in the majority of the studies was multi-level modelling. The control condition was the standard curriculum delivered in the schools and few studies provided a neutral task to the control group following the completion of the intervention. Goal setting was applied within the interventions and a variety of related strategies, hypothesized mediating processes (i.e. knowledge enhancement, and engaging in self-monitoring), and determinants of screen behaviours (i.e. competence, and need satisfaction) to achieve the targeted reductions in screen use (Table 2), and other health behaviours were assessed. Few studies conducted review synthesis and explored the stakeholder perspective (i.e. with students and parents) prior to the development of the intervention (Andrade et al. 2014; Hankonen et al. 2016, 2017; Singh et al. 2009; Vik et al. 2015) or were based on prior pilot studies or interventions (Babic et al. 2015; Foley et al. 2017; Hankonen et al. 2016; Leme et al. 2016; Smith et al. 2014a, 2014b; Vik et al. 2015). The age of the samples ranged from 10 to 19 years, and sample sizes varied from  $n=172$  (Bagherniya et al. 2018) to  $n=3147$  (Vik et al. 2015). The duration of the interventions lasted from three sessions (Aittasalo et al. 2019) to 28 months (Andrade et al. 2015) with two (pre-post intervention) to four assessment periods. Assessment included objective (i.e. accelerometer-based), self-report measures, and process evaluations. In terms of effectiveness, four studies were effective in reducing ST (Bagherniya et al. 2018; Barbosa Filho et al. 2019; Cui et al. 2012; Smith et al. 2014a, 2014b), eight studies presented with mixed findings with part reduction in ST (reduction in one specific assessment period, weekend/weekdays or gender-based) (Aittasalo et al. 2019; Andrade et al. 2015; Babic et al. 2016; Foley et al. 2017; Leme et al. 2016; Singh et al. 2009; Tarro et al. 2017), and three studies did not find significant intervention effects in reducing ST (Majumdar et al. 2013; Vik et al. 2015; Wadolowska et al. 2019). Hankonen et al. (2016) reported good participation, response and acceptability of protocol.



**Fig. 1** The flow diagram of the selection process

## Objectives

The studies' objectives focused on increasing PA and decreasing SB simultaneously while increasing health knowledge outcomes. Based on eligibility criteria for adolescents exceeding ST recommendations, with low PA engagement or at risk for obesity, the studies aimed to assess the effect of the intervention on adolescents' television time, videogame time, computer time, and total ST and/or changes in MVPA, energy balance-related behaviours (EBRBs) (PA, SB, diet/nutrition), and other physical measures [i.e. body mass index (BMI), waist circumference (WC)] or fruit and vegetable intake. Objectives were further developed and informed in three studies (Andrade et al. 2015; Hankonen et al. 2016, 2017; Vik et al. 2015) by systematic literature reviews, previous quantitative study findings in their respective cohorts, qualitative/stakeholder views (focus groups), and the application of evidence-based behaviour change protocols or theory-driven applications (e.g. increasing motivation, intention to change).

## Methodological Quality/Assessment of Risk of Bias

In terms of methodological quality, all studies indicated adequate designs, with exclusion criteria, and sample sizes determined by power calculations for adequacy. All studies presented high risk of bias in one or two domains, with an overall medium to high methodological quality. To account for the quality of risk of bias assessment and reporting, eight studies utilized the Consolidated Standards of Reporting Trials (CONSORT; Campbell et al. 2004) to ensure comprehensive reporting. More specifically, the studies provided descriptions of the

blinding procedures for participants and assessors and for the methods of randomization (i.e. use of computerized random number generator) to assign control and intervention groups, allocation concealment procedures for student recruitment with pairing to avoid baseline differences, and attrition rates across intervention periods. Outcome data were reported per assessment period and as overall intervention effects (in Table 2). However, the samples were not representative in terms of gender, socio-economic status and general education: for gender (Bagherniya et al. 2018; Leme et al. 2016; Smith et al. 2014a, 2014b); low socio-economic family status (Andrade et al. 2015; Babic et al. 2015; Leme and Philippi 2015; Singh et al. 2009; Smith et al. 2014a, 2014b), use of a vocational school, not representing general secondary education (Hankonen et al. 2016, 2017; Singh et al. 2009); use of Catholic schools only (Babic et al. 2015), and potential biased parental involvement due to their children's participation status and lower socio-economic status that has been found to be a predictor of heavier recreational ST use (Babic et al. 2015), posing a threat to ecological validity, with the exception of Vik et al.' (2015) international study with a large cohort. There was no reference to attribution of intervention components to outcomes or of identification of the most effective behaviour change mechanisms, with the exception of Hankonen et al. (2016) study that identified behaviour change techniques with higher uptake than others. However, studies included process evaluations at post-intervention to assess strategies and methodological shortcomings. Self-report measures for ST were utilized in all studies that presented social desirability and recall biases. In Barbosa Filho et al.'s study (2019), no blinding procedures of participants were reported with potential contamination of the subjective outcome measures (Page and Persch 2013). Self-selection bias was reported in Singh et al.'s study (2009) and lack of randomization in Wadolowska and colleagues' study (2019).

## Outcomes and Assessment

Primary outcomes for the studies were MVPA, PA and related physical outcomes, and recreational ST, with various activities specified within the construct (i.e. video game playing, TV viewing and limits, and ST recommendations). Other outcomes assessed in the studies were combinations of psychological, physical, dietary consumption-related, and home rule-setting: body fat percentage, psychological distress, pathological video game use, aggression, psychological wellbeing, physical self-concept and PA, household ST rules; fruit and sugar-sweetened beverage consumption, nutrition knowledge, attitudes, dietary behaviours and lifestyle choices; muscular fitness, resistance training skill competency, body mass index (BMI) and waist circumference (WC); daytime sleepiness; psychological outcomes (i.e. self-efficacy, intention, and subjective wellbeing), and hypothesized mediators were examined for their impact on the assessed behaviours: motivation to limit recreational ST, in school sport, psychological needs satisfaction, and PA behavioural strategies.

To evaluate the ST effects of the intervention, a variety of quantitative measures including self-report and objective (accelerometer-based) measures were employed (outlined in Table 1). Tools used assessed: recreational ST, pathological video gaming, ST rules within the family home, ST of TV/DVD and computer/games playing and breaks per hour sitting at school and at home, number of hours spent on TV watching, videogames playing and computer use during a usual weekday and during the weekend, and total amount of ST on weekdays and on a weekend day, media multi-tasking, multiple screen devices used for recreational purposes and proportion of adolescents exceeding the daily recommendation on weekdays and weekends. Feasibility and acceptability of the intervention were the outcome measures for the feasibility

study by Hankonen et al. (2017). PA was measured with accelerometers across all studies in activities (except from water sports in the main), and during sleep time for seven consecutive days. These have been found to provide a reliable estimate of PA with potential higher compliance (Babic et al. 2015). Additionally, weight, height, BMI measures, and BMI-z scores were calculated in studies in order to assess differences post-intervention. Process evaluation was part of the assessment procedures for five interventions and was conducted by direct observation, focus group discussions or questionnaires, student retention, adherence, feasibility, satisfaction data, and identification of successful intervention components.

### Intervention Components/Strategies/Mode of Delivery

Twelve studies employed strategies grounded in behaviour change with the use of hypothesized intrapersonal, interpersonal and environmental mediators, providing a structured framework for an objective assessment of intervention effectiveness. Social cognitive theory (SCT) (Bandura 1986), self-determination theory (SDT) (Deci and Ryan 1985), and motivational and self-regulatory theories (Carver and Sheier 1982; Deci and Ryan 2000; McEachan et al. 2011) were the theoretical frameworks of choice, as is frequently encountered in the PA interventions literature (Bagherniya et al. 2018). Two of the studies (Babic et al. 2015; Hankonen et al. 2016, 2017) utilized the Behaviour Change Technique Taxonomy (BCT) (Michie et al. 2013) and Wadolowska and colleagues used the integrated theory of health behaviour change (Ryan 2009). A detailed account of the behaviour change techniques (BCTs) and the accompanying mediating strategies are presented in Table 2. A BCT is defined as “an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an ‘active ingredient’ (e.g. feedback, self-monitoring and reinforcement)” (Michie et al. 2013, p.82). In Hankonen and colleagues’ study Hankonen et al. (2017), BCTs were combined with the new guidelines by the UK Medical Research Council for developing and evaluating interventions (Danner et al. 2008), and empowerment educational approaches (Ruiter et al. 2013) were utilized in two studies (Cui et al. 2012; Foley et al. 2017). Other studies (Andrade et al. 2015) were based on behaviour change protocols, such as Intervention Mapping (IM) (Bartholomew et al. 2016), and the Comprehensive Participatory Planning and Evaluation approach (CPPE) (Lefevre et al. 2001). The IM protocol (Bartholomew et al. 2016) provides a theory and evidence-based methodology to building effective health promotion interventions and prevention initiatives across stages of planning, implementation and evaluation, following a systematic procedure of behaviour change processes (Ruiter et al. 2013). The CPPE (Lefevre et al. 2001) refers to an approach involving community participation and empowerment in the engagement of significant stakeholders in the planning and evaluation of health initiatives. Additionally, two studies embraced whole school health promotion approaches in addition to theoretical frameworks (Barbosa Filho et al. 2015; Foley et al. 2017). Social marketing principles were utilized by Tarro and colleagues (2019) based on segmentation, insight, youth engagement, and a mix of communication methods to convey lifestyle messages.

Ten studies comprised of a synergy of individual-based strategies (i.e. educational package, key messages regarding PA and ST behaviour delivered via textbook curriculum) and environmental strategies (i.e. modifications in the school environment, and parental workshops) (Cui et al. 2012; Hankonen et al. 2016, 2017), for the delivery of health information (Cui et al. 2012). Strategies also involved psychological and cognitive mechanisms of behaviour change and other potential mediators: motivation to reduce ST and engage in school sport, parental mediation, ST



rules, PA, psychological needs satisfaction, motivation to limit ST, ST rules, and PA behavioural strategies accompanied by muscular fitness enhancement.

An innovative intervention component in the study by Smith and colleagues (Smith et al. 2014a, 2014b) was the development of a smartphone application that provided fitness and ST measurements: (i) PA monitoring through recording daily step counts from pedometers; (ii) recording and review of fitness challenge results; (iii) peer assessment of resistance training skill competency; (iv) goal setting for ST and PA; and (v) tailored motivational messaging. Other strategies were enhanced school sport sessions, lunchtime leadership sessions, parent/caregiver strategies, and assessing behaviour change via specific psychological and cognitive mediators. Eight studies employed a combination of self-monitoring, knowledge, self-efficacy and intention enhancement.

## Effectiveness

The included interventions reported a mix of results, from small, yet significant, effects in four studies (detailed results are presented in Table 1), to mixed effects in eight studies—reporting effectiveness in specific time points during or post-intervention or effects in specific segments of the target group (Andrade et al. 2015; Barbosa Filho et al. 2019; Foley et al. 2017) to three reporting no intervention effects for ST at any time points. More specifically, Vik et al. (2015) reported a school-based, family-engaged intervention aimed at reducing sedentary behaviour and involved 3147 adolescents from five European countries. No significant intervention effects were observed, neither for self-reported TV/DVD or computer/game console time, nor for objective total sedentary time and number of breaks in sitting time. However, positive effects for self-reported attitude (beliefs and preferences) were reported, showing a positive shift in relation to introducing breaks in sitting down times. Similarly, no significant difference in ST was observed in the period post-9 months in Wadolowska et al.'s study (Wadolowska et al. 2019).

Andrade et al. (2015) conducted and evaluated a school-based health promotion intervention on screen time behaviour among 12- to 15-year-old adolescents. In the first stage of the intervention, the intervention group presented with a lower increase in television time on a week and weekend day than the control group, and in total screen time on a weekday, compared to the control group. Contrary, in the second part of the intervention that involved only PA strategies (e.g. healthy dieting, and PA), reductions in ST were not maintained. During this phase, screen use increased (Andrade et al. 2015). Peer-led education in Cui and colleagues' study (2017) appeared to be a promising strategy with positive results in the reduction of SBs. No differences were observed for time spent on SBs initially at 3 months. At 7 months, a significant reduction was observed in total SBs of 20 min per day in the intervention group, mainly attributed to a decrease in computer use in the intervention group of 14 min per day (for weekdays). There was a non-significant difference in total SBs by 22 min per day for time spent on other SBs, including television and DVD, video game, extracurricular reading, writing, drawing and listening to music, passive commuting and sitting to talk. However, the intervention was tested across two schools on each arm (intervention-control) only, with potential confounding factors limiting the generalizability of results.

The feasibility study of Hankonen et al. (2017) had high acceptability rates, and feasibility for data collection with increased use of BCTs (Michie et al. 2013) that correlated with PA measures, showing criterion validity. However, uptake of BCTs, despite the acceptability of the intervention, was considered moderate and BCTs related to motivation (self-monitoring) were found to be used more often than BCTs involving self-regulation (coping planning, and graded

tasks), identifying a gap between perception and action. Teacher and student evaluations were positive for the increase of sitting reduction strategies in the classroom.

The study of Smith and colleagues (Smith et al. 2014a, 2014b) exhibited only significant intervention effects for ST, with an approximate 30-min reduction per day for recreational screen use, but not for the other intervention targets (body composition, and PA). The opposite was found in Manjumdar et al.'s study (2019), with significant effects for the other intervention objectives (sweetened beverages and snacks) and no changes for ST. Positive intervention effects with increased percentages in those meeting daily recommendations for duration of watching TV and computer use were found in the studies by Barbosa Filho et al. (2019) and Tarro et al. (2019). The Singh et al. (2009) study reported ST reduction for boys 20 months post intervention.

## Discussion

Sedentary behaviour and screen-based activities are potential determinants of obesity (Phan et al. 2019). Research in this field is expanding along with a demand for impactful interventions that contribute to public health improvement (Vik et al. 2015). The present systematic review critically summarized the evidence for the effectiveness of school-based intervention strategies that targeted reduction of ST in adolescents in addition to time spent watching TV. A total of 30 papers analysing 15 intervention studies were identified that met the inclusion criteria, signalling a relative scarcity of interventions targeting adolescents and assessing ST use within SBs/PA/obesity studies, in line with previous review findings and despite evidence suggesting a need for differential treatment for PA and ST (Babic et al. 2015; Hynynen et al. 2016; Mark and Janssen 2008; Sedentary Behaviour Research Network 2012). Studies presented evidence-based designs, with four studies demonstrating effectiveness, eight partial effectiveness, and three no effectiveness in achieving the expected outcomes of ST or maintaining the effects, raising issues for the challenges and the long-term impact of these interventions (Huffman and Szafron 2017).

There are many potential explanations for the partial effectiveness in the findings. The first concerns the heterogeneity of online activities within the construct of ST, because reduction in one activity but not in others suggests that specific intervention strategies were not effective for some behaviours, in line with previous research (Hynynen et al. 2016; Tremblay et al. 2011). Second, this could reflect a potential inadequacy of the interventions alone to sufficiently challenge long-held habits and lead to behaviour change. It has been claimed that where screen behaviours are habitual, these are inherently more difficult to change and when they involve simpler actions, require constant targeting to produce effects (Bayer and LaRose 2018). Third, effectiveness and long-term sustainability of results may be impeded by the choice of reduction only in time spent on media, as a main outcome variable in these interventions. Additionally, it is increasingly recognized that PA interventions should target screen-based activities concurrently in order to limit SBs among children and adolescents (Chen et al. 2018). However, ST has not been sufficiently studied and operationalized to date and the evidence base for its determinants, correlates, and interventions is weak in determining the optimal mix of strategies to curb this behaviour.

The first limitation has to do with the operational definition of ST as a construct, because it only focuses on the manifestation of the problem—the excessive amount of *time* that the adolescent devotes to the activity—and does not account for the specific content consumed or

activity engaged in and lacks specificity (Hietajärvi et al. 2019; Nie et al. 2002). Gaming and social media share commonalities, but also present significant differences (i.e. key motivations, correlates, structural characteristics, risk factors, and clinical image) (Kuss and Billieux 2017; Marshall et al. 2006). Equally, SBs include both an array of passive (TV viewing) and more active behaviours (i.e. computer games), because adolescents may seek out more sensation-rich and arousing experiences to fuel the increased risk taking and novelty seeking needs of adolescence (Kuss and Billieux 2017) and more socially driven behaviours responding to peer culture (i.e. engagement in social media) (Garcia et al. 2017). Evidence has supported that *context* (where, how, when, impacts), *content* (what is accessed or used), and *relationship formation* (i.e. type and quality) may be more critical factors than *time* (Griffiths and Szabo 2014; Livingstone and Helsper 2008). These factors were not addressed within the reviewed interventions. Contrary, the focus was on behaviour change and the hypothesized mediators relating to motivation, self-regulation and intention to change the behaviour.

Second, reduction objectives may be conflicting with adolescent developmental needs and milestones (i.e. for autonomy and interpersonal communication) that have been found to be facilitated by the online environment (Borca et al. 2015). The developmental trajectory from early childhood to late adolescence demonstrates a decline in PA (Dumith et al. 2011) and an increase in recreational screen behaviours in the transition from early to mid-adolescence (Hardy et al. 2007a; Raudsepp 2016; Todd et al. 2015) and spending increasingly unsupervised time at home (Vik et al. 2015). As a result and due to the lengthy follow-up assessment periods of these interventions (few lasted more than 2 years), ST reduction objectives are potentially not being met, because during this period, adolescents are known to increase their ST addressing a normative need. Unlike other mental health issues (i.e. in suicide or eating disorders) where the health outcomes can be detrimental or even life-threatening for the adolescent, gaming or internet use is not perceived as inherently harmful and is an enjoyable activity. Perceived enjoyment is amplified by the context-specific characteristics (i.e. in games: discovery/novelty, levelling up, wealth acquisition, formation of gamer social groups; in social media: the 'likes', nomophobia, fear of missing out [FOMO], etc.) that tap into powerful key motivations, reinforcing the salience and maintenance of the behaviours (Hussain et al. 2015; King et al. 2018; Kuss and Griffiths 2017; Kuss et al. 2012).

Similarly, assessing sedentary vs. non-sedentary time does not account for content, activity engaged in, or level of intensity of use. Studies followed the principle of triangulation (Adams et al. 2015) with objective and subjective outcome evaluation and process evaluation measures. However, self-report assessment tools used result in underreporting of time spent online also failing to account for differences in the content or context of adolescent engagement (Katapally and Chu 2019). Additionally, objective measures only provide an accurate measurement of sedentariness and PA, but do not report how this sedentary time is distributed (Sigerson and Cheng 2018), leading to an incomplete assessment of these diverse activities. Potentially, other methods should complement interventions to provide more accuracy and specificity, similar to the use of experience sampling in time-use research or the use of instant emotion detection sensors (Kanjo et al. 2017; Sonnenberg et al. 2012; Twenge and Park 2017). The incorporation of push prompt messages used was evaluated via a smartphone application only in the study of Smith and colleagues (2015) and was considered a positive strategy to reduce ST in adolescents. These types of data can act as a self-monitoring tool, providing some feedback and offering a degree of control over the behaviour, serving two functions: that of assessment and of an intervention component. Lessons can be learned from gambling research, where behavioural tracking data have been used to capture actual and real time behaviours (Griffiths and Whitty 2010) and to evaluate the degree

of responsiveness to personalized behavioural feedback, that has been found to lead to reduced gambling activity (Auer and Griffiths 2015).

Reduction objectives may also potentially be perceived by adolescents as an external regulation that compromises their gradual autonomy, afforded by electronic media that provide them with opportunities for recreation, socialization, validation, and achievement (Boyd 2014; Livingstone 2008; Loos et al. 2012). However, three studies (Andrade et al. 2015; Hankonen et al. 2016, 2017; Vik et al. 2015) assessed needs and stakeholder perspectives (i.e. students and parents) to inform the development of the respective interventions—a critical step in ST intervention development (Kidd et al. 2003; Kok et al. 2017; Prochaska et al. 1992; Rodda et al. 2018). BCTs were then used to link determinants to intervention components. However, tailoring BCTs (i.e. “goal-setting”, “self-monitoring”, and “thinking about one’s own motives”) is crucial not only at intervention level, but also at activity level (Schaalma and Kok 2009), justifying BCT use and testing their uptake and effectiveness prior to a full extent trial (Altenburg et al. 2016; Greaves 2015). Hankonen et al. (2017) followed this approach and identified the most effective BCTs for participants in their feasibility study in order to optimize intervention content, a factor that enhances further the evaluative intervention process (Greaves 2015; Pesseau et al. 2015). With the exception of this study, there was no reference to attribution of intervention components to outcomes or of identification of the most effective behaviour change mechanisms, which was also reported by the studies as a limitation. This appeared to be a common methodological weakness underpinning all interventions examined in the present review which was partially addressed in process evaluations to assess the methodological shortcomings. Additionally, health knowledge dissemination—a long-held strategy employed in health interventions—appears to be a weak strategy to achieve ST reduction objectives and needs to be reconceptualized given the positive and functional aspects of online engagement (Lafrenière et al. 2013).

All studies presented high risk of bias in one or two domains. However, most studies were of overall medium to high methodological quality. To account for the quality of risk of bias assessment and reporting, studies utilized internationally recognized standards of reporting trials (i.e. the CONSORT statement [Campbell et al. 2004]) to ensure comprehensive reporting and the majority were prospectively registered clinical trials, following stringent guidelines as to risk of bias assessment. Self-report measures for ST were utilized in all studies that present social desirability and recall biases. Additionally, representativeness was not assumed in the majority of studies (with sample size, geographic, socio-economic or gender-specific restrictions), limiting further the generalizability of the results, with the exception of Vik and colleagues’ study (Vik et al. 2015) which was an international study with a large cohort.

Finally, the studies reviewed stressed the association of potential physical risks, neglecting significant research conducted on psychosocial impacts of online use. Following evidence concerning the increase in prevalence of problematic/addictive use (Kuss et al. 2014), an interdisciplinary integration of research evidence (Colder Carras et al. 2017; Tremblay et al. 2011) is required. This should examine (i) the way these separate activities interact (Pesseau et al. 2015), (ii) the way they contribute uniquely to the physical and psycho-emotional impacts experienced by adolescents, (iii) understand the motivations that potentially lead to an increase of sedentary lifestyles (Griffiths 2010), (iv) apply longitudinal research and updated assessment tools per activity (Altenburg et al. 2016; Brug et al. 2010), (v) assess the contribution of the different intervention components in effecting change (Smith et al. 2014a, 2014b), and targeting attitude and breaking habit strength (Chinapaw et al. 2008), and (vi) reflect on normative developmental tasks facilitated by online affordances (Huffman and

Szafron 2017). Primarily, the construct of ST requires re-definition because the time investment refers and addresses only part of the problematic use involved in obesity and other non-communicable diseases, which in order to address effectively in interventions needs to target the content, the context, the motivations driving excessive involvement, and the provision of alternative screen-free sources of satisfaction holistically (Griffiths et al. 2018; Throuvala et al. 2019a).

Additionally, it appears that school-based interventions require a more systematic implementation with follow-up periods or an integration into the school programme to achieve long-term effectiveness (Nie et al. 2002; Norman et al. 2019). Targeting specific behaviours with the involvement of family and friends/peers has been found to aid reduction of ST levels (Biddle et al. 2014; Garcia et al. 2019) with evidence-based parental mediation (Bleckmann and Mößle 2014; Livingstone and Helsper 2008) and was emphasized in the studies examined. The role of gender and SES is another aspect that requires further investigation, because it appeared that a differentiation based on these factors is critical for the success of such interventions (Dong et al. 2018; Leme and Philippi 2015; Milani et al. 2018; Smith et al. 2014a, 2014b).

A major limitation of this review was the relatively small number of studies (compared to the wealth of interventions addressing obesity/PA prevention, which do not cover ST as part of the SBs) meeting the inclusion criteria, and the heterogeneity in the type of studies, assessment periods, and outcomes reported in the studies that did not allow for a direct comparison between the intervention effects. Additionally, the lack of longitudinal data does not allow the drawing of conclusions with regard to the longer-term maintenance of the effects. In Andrade et al.'s study (Andrade et al. 2015), ST reduction was not maintained in the absence of the intervention component targeting ST exclusively. This suggests that these habitual behaviours need to be further investigated in terms of how they interact within the mix of SBs, and to determine how and under which conditions an adolescent engages in excessive use. Addressing the specific activities differentially, their structural characteristics and the social processes that determine them, supported by whole school approaches and regular booster sessions within the school curriculum (and not as one-off interventions) may be conducive to achieving ST outcomes.

Overall, the present systematic review highlights a scarcity of adolescent ST interventions that target online activities and suggests a pressing need to reconceptualise adolescent ST health promotion in future prevention designs (Morton et al. 2017). The acquisition of a developmental and ecological approach addressing psychosocial and maturational processes and mediators (Hesketh et al. 2017; Smith et al. 2017) and communication challenges arising from use can potentially address the correlates and lead to higher adolescent commitment to calls for behavioural change (Brug et al. 2010).

## Conclusion

SBs are implicated in a variety of serious physical health problems—primarily in the context of obesity—and psychopathological conditions. Given the increasing prevalence of severe obesity and time spent gaming (Phan et al. 2019), and the increasing recognition of the role of screen-based activities as a major contributor to the obesity epidemic (Sánchez-Oliva et al. 2018; Tang et al. 2018), the need to address prevention measures and evaluate the efficacy of respective interventions is timely. The purpose of the present review was to identify interventions on screen-based SBs and to elucidate the role of recreational screen behaviours and the way these are targeted within the interventions. The review highlights that the mix of ST behaviours has

changed, yet interventions have not yet effectively accounted for this change in terms of definition, objective-setting, assessment, and intervention components that target these behaviours differentially. In addition, sustainable ST reduction can only be achieved by addressing the variables associated with excessive use, the content, context, and motivations underlying excessive involvement at the expense of other recreational alternatives. Partial effectiveness in the reviewed studies with no sustainable findings could reflect, among other factors, the potential failure to understand and embed the adolescent perspective that is facilitated by the online environment or the setting of appropriate goals in the interventions.

There is a pressing need for more integrated, health promoting prevention programmes in school environments and targeting of problematic/excessive use, differentiating between content and activity rather than just frequency of ST being a primary or secondary intervention outcome in obesity, PA, and/or ST school-based programmes. Intervention effectiveness research can provide evidence on best practices that can be used by policymakers to develop guidelines for schools, parents and practitioners for dealing with digital technologies, and the competing online activities that contribute to sedentary lifestyles and pose health risks for adolescents. These guidelines should be integrated in school settings and complement school-based initiatives. The design of more effective interventions can in turn help target key health epidemics related to these behaviours, such as obesity or physical inactivity related to multiple health risks.

**Compliance with ethical standard** The study conducted with the approval of the research team's university ethics committee.

**Conflict of Interest** The authors declare that they have no conflict of interest.

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