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Research review

The non-advertising effects of screen-based sedentary activities on acute eating behaviours in children, adolescents, and young adults. A systematic review

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ABSTRACT

Sedentary screen time may be an important determinant of childhood obesity. A number of potential mechanisms to explain the link between screen time and increased bodyweight have been proposed; however, the relationship appears to be best explained by the effects on dietary intake, which is attributed to either food advertising or effects independent of food advertising. Technological advances have allowed for greater accessibility and exposure to advertisement-free screen-based media. This review was conducted to systematically synthesise the evidence from laboratory based studies which have investigated the non-advertising effects of screen time (TV viewing, sedentary video games, and computer use) on dietary intake in children, adolescents, and young adults. MEDLINE, PubMed, PsychInfo, CINAHL, and Embase were searched from inception through 5 July 2013. Ten trials met the inclusion criteria and were included in the review. Risk of study bias was judged to range from low to high. Screen time in the absence of food advertising was consistently found to be associated with increased dietary intake compared with non-screen behaviours. Suggested explanations for this relationship included: distraction, interruption of physiologic food regulation, screen time as a conditioned cue to eat, disruption of memory formation, and the effects of the stress-induced reward system. Due to the limited number of high-quality studies available for this review, our findings are preliminary. More work is required to better establish the link between dietary intake and advertisement-free screen time and assess whether differences exist between the different screen-based activities.

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Introduction

The aetiology of obesity is complex (Michael, Rudolph, & Jules, 1997). Yet despite this complexity, environmental changes, rather than genetic, have been identified as the most important determinant for the increase in adiposity in recent years (Rey-Lopez, Vicente-Rodriguez, Biosca, & Moreno, 2008), with screen-based sedentary behaviour acknowledged as one such critical environmental change (Kautiainen, Koivusilta, Lintonen, Virtanen, & Rimpelä, 2005). While sedentary behaviours include any waking activities requiring very little energy expenditure (⩽1.5 metabolic equivalents) and which involve sitting or lying down (Sedentary Behaviour Research Network., 2012), screen-based sedentary behaviours refer to a sub-set of these activities and include watching television (TV), playing video games, or using a computer. Accessibility to these screen-based sedentary activities has increased at an alarming rate in recent decades and has been linked with a dramatic increase in sedentary time (Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006). This issue of sedentariness due to increased screen time is a growing public health concern. Evidence from longitudinal studies has linked screen-based sedentary behaviours with increased body mass index (BMI) in children, even after adjusting for physical activity levels (Elgar, Roberts, Moore, & Tudor-Smith, 2005; Proctor et al., 2003; Robinson, 1999). The implications of this are compounded by the finding that screen time appears to be a relatively stable behaviour, tracking from childhood to both adolescence (Valerio et al., 2006) and adulthood (Biddle, Pearson, Ross, & Braithwaite, 2010).

A large number of interventions have been conducted in recent years in an attempt to curb the effects of screen-based sedentary behaviours on obesity. Despite such interventions tending to produce statistically significant improvements in measures of both sedentary time and BMI, improvements have often been small and of little clinical significance (DeMattia, Lemont, & Meurer, 2007; Leung, Agaronov, Grytsenko, & Yeh, 2012). This inability of interventions to effect large changes in outcomes may be the consequence of our limited understanding of the specific mechanisms by which screen-based sedentary behaviours and obesity are linked. A better appreciation of these mechanisms may allow targeting of specific health-related behaviours responsible for the relationship between screen time and obesity. It is therefore proposed that in order to design and implement more effective screen-based sedentary behaviour interventions, we first need to better describe the mechanisms by which these activities are linked with obesity.

Two main mechanisms have been proposed for the link between screen-based activities and obesity: (1) the effects of screen time on decreased physical activity levels (Jenvey, 2007; Robinson, 2001), and (2) the effects of screen time on increased energy intake (Boulos, Vikre, Oppenheimer, Chang, & Kanarek, 2012; Hastings et al., 2003; Robinson, 2001). Evidence for the displacement of physical activity is conflicting, (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004), and data suggest that even independent of physical activity, TV watching remains an important risk factor for adiposity (Ekelund et al., 2006; Gebremariam et al., 2013). Indeed, the connection between screen time and increased energy intake appears better substantiated by research.

Food advertising has been shown to influence both food consumption and food preferences, especially in children (Boyland et al., 2011; Harris, Bargh, & Brownell, 2009; Robinson, 2001). An important finding is that food advertising is not only positively associated with food intake (Bellisle, Dalix, & Slama, 2004; Blass et al., 2006; Jackson, Djafarian, Stewart, & Speakman, 2009), but that it is also associated with decreased consumption of fruit and vegetable intake (Boynton-Jarrett et al., 2003; Coon, Goldberg, Rogers, & Tucker, 2001). Within a laboratory setting, children have also been shown to consume greater amounts of sweet foods (high and low in fat) and high-fat savoury foods following exposure to food advertisements on TV compared with children who only viewed non-food advertisements (Halford, Gillespie, Brown, Pontin, & Dovey, 2004). These findings are particularly disturbing given that food companies often target children, as evidenced by the pervasiveness of food advertisements during children's programming (Boyland, Harrold, Kirkham, & Halford, 2011; Effertz & Wilcke, 2012; Haug et al., 2009; Kelly, Chapman, King, & Hebden, 2011).

However, there is also a growing body of evidence to suggest that screen-based activities, even in the absence of TV food advertising, increase dietary intake (Chaput et al., 2011; Volkow, Wang, Fowler, Tomasi, & Baler, 2012). This is of significance for two main reasons: (1) accessibility to video content without TV food advertisements has increased, and (2) youth are now exposed to a number of competing screen-based activities that may draw attention away from TV advertisements. Firstly, with respect to accessibility, technological advances have enabled consumption of greater amounts of advertisement-free video content via video-on-demand technologies (Carlson, 2006). Such technologies allow advertisement-free video content to be streamed or downloaded to media devices, such as computers or portable media players. This has resulted in young people now having some control over how much TV advertising they are exposed to. Secondly, with respect to competing screen-based behaviours, there is evidence to suggest that TV viewing is now combined with other screen-based activities, which may distract the viewer's attention away from advertising. In 2003 it was reported that 46% of time spent watching TV was actually spent engaged in a secondary behaviour, such as social interactions and playing, with non-TV viewing behaviours occurring most during programming which required less visual attention, such as advertisements. This effect was greatest amongst children (Schmitt, Woolf, & Anderson, 2003). More recently, the mobile functionality of newer screen-based media devices, included smartphones and tablets (e.g. iPads), has increased the accessibility to competing screen-based behaviours and has created a multi-screen world (Phalen & Ducey, 2012), where adolescents report using multiple screens to facilitate filtering out of unwanted content, including advertisements (Jago, Sebire, Gorely, Cillero, & Biddle, 2011).

Within this contemporary screen environment, differences exist in the way adolescents, young adults, and older adults

(⩾30 years) use and interact with media. Recent data suggest that young adults use social media in a similar fashion to adolescents, while older adults interact with social media differently (Lenhart, Purcell, Smith, & Zickuhr, 2010). This difference in media use is consistent with the notion of a generation digital divide, whereby adolescents and young adults feel more comfortable using and interacting with digital media compared with older adults (Vie, 2008). Emerging adulthood, defined as 18–25 years (Padilla-Walker, Nelson, Carroll, & Jensen, 2010), is evolving as an important age group with respect to screen-based media use. It is characterised by greater flexibility in schedules and lack of parental supervision, which is thought to contribute to the high rate of video game use in this age group (Anand, 2007). Given that younger generations who have grown up in an environment saturated with screen-based media interact and use screen-based media differently compared with older generations, it is reasonable that the effects of screens on health-related behaviours may differ between generations and should therefore be investigated separately.

As technology increasingly allows for greater control over exposure to advertising, and youth divide their attention between multiple media devices simultaneously, it seems timely to review the evidence on the non-advertising effects of screen-based activities on dietary intake. As such, a review of laboratory-based, experimental studies was conducted to determine the non-advertising effects of screen-based sedentary behaviours on energy intake in normal and overweight children, adolescents, and young adults. A systematic review of randomised controlled trials (RCTs) and quasi-experimental studies was undertaken according to the PRISMA Statement (Transparent Reporting of Systematic Reviews and Meta-analyses) (Liberati et al., 2009).

Methods

Eligibility criteria

Eligible studies included RCTs and quasi-experimental studies that investigated the effects of screen-based sedentary behaviours, including TV viewing, sedentary video game play, and recreational computer use, on energy intake in children, adolescents, and young adults. The review was limited to laboratory studies, as the experimental setting allowed for the removal of advertisements during the exposure, and therefore allowed for assessment of the non-advertising effects of screen time on energy intake. Included studies had to report dietary intake, either as amount of food and drink consumed or energy consumed, as an outcome measure. Male and female participants aged 5–24 years were included in the review. Younger participants were excluded as there is evidence to suggest that TV exposure during meals and snacks may actually decrease energy intake in preschool children (Francis & Birch, 2006). Older participants were excluded due to disparities in the way they use and interact with screen-based media compared with younger individuals (Lenhart et al., 2010). Although there is no agreed upon age range that defines young adulthood, for the purpose of this study we have aligned our definition with that of the World Health Organization (World Health Organization., 1993), and have therefore set our upper limit of young adult as 24 years. However, in acknowledgement of this arbitrary age limit we also included studies that specifically looked at young adults even if their upper age limit exceeded 24 years, provided the mean age of included participants fell between 5 and 24 years (inclusively). Inclusion of trials was not restricted by publication date or country. Systematic reviews and observational studies were not included.

Table 1
Search strategy utilised for MEDLINE (from inception to July 2013).

Search	Search term	Combination	Result
1	Television/ or Video Games/ or Computers/ or Internet/ or Sedentary Lifestyle/		113,301
2	Television.tw.		10,078
3	Video Gam*.tw.		1496
4	Computer Gam*.tw.		725
5	Active Video Gam*.tw.		63
6	Active Gam*.tw.		232
7	Exergam*.tw.		73
8	Exertainment.tw		4
9	Screen-Time.tw.		483
10	(Screen Based OR Screen-Based).tw.		374
11	Sedentary Behavio*.tw.		1756
12	Sedentar*.tw.		17,495
13	((Chair or Sitting or Screen or Computer) adj Time).tw.		1176
14	((Television adj Watch*) or TV Watch*).tw.		441
15		1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14	135,667
16	Clinical Trial/ or Cross-over studies/ or Randomized Controlled Trial.mp.		669,952
17	Experiment*.tw.		1,431,375
18	Laboratory.tw.		357,299
19	(cross adj2 over).tw		18,013
20	Random*.mp.		889,901
21		16 OR 17 OR 18 OR 19 OR 20	339,759
22	Energy Intake/ or Feeding Behavior/ or Food Preferences/ or Hunger/ or Eating/ or Satiety Response/ or Satiation/ or Appetite/ or Food/ or Drinking/		144,810
23	Food.tw.		246,198
24	(energy adj5 dense).tw.		1030
25	Satiety.tw.		6277
26	Satiation.tw.		1723
27	(food adj5 intake).tw.		38,960
28		22 OR 23 OR 24 OR	339,759
29		15 AND 21 AND 29	907
30		Limit 29 to (english language and humans and ("child (6 to 12 years)" or "adolescent (13 to 18 years)" or "young adult (19 to 24 years)"))	316

Table 2
Risk of bias within included studies. Studies reported according to risk of bias, with lowest risk of bias first.

Study	Selection bias				Attrition bias		Detection bias		Reporting bias	
	Random sequence generation		Allocation concealment		Attrition		Assessor blinded		Selective outcome reporting	
	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence
RCTs										
Lyons et al. (2012)	Unclear	Method of randomisation not stated	Unclear	Method not described	Low risk	Low risk assumed due to parallel study design (participants only attended one session)	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Mekhmoukh et al. (2012)	Low risk	Conditions presented in random order according to an incomplete Latin square design	Unclear	Method not described	Low risk	Attrition reported and equal across groups	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Chaput et al. (2011)	Low risk	Computerised randomisation scheme used	Unclear	Method not described	Low risk	All participants completed both sessions	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Moray et al. (2006)	Low risk	A coin was flipped to determine treatment sequence	Unclear	Method not described	Low risk	No withdrawal/loss to follow-up	Unclear	Method not reported	Unclear	Insufficient information
Bellissimo et al. (2007)	Unclear	Method of randomisation not stated	Unclear	Method not described	Unclear	Details not provided	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Patel et al. (2011)	Unclear	Method of randomisation not stated	Unclear	Method not described	Unclear	Details not provided	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Peneau et al. (2009)	Unclear	Method of randomisation not stated	Unclear	Method not described	Unclear	Details not provided	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Temple et al. (2007)	Unclear	Method of randomisation not stated	Unclear	Method not described	Low risk	Low risk assumed due to parallel study design (participants only attended one session)	Unclear	Method not reported	High risk	Outcomes reported incompletely
Non-RCTs										
Mittal et al. (2011)	High risk	Not stated as being randomised	High	Method not described but probably not done as non-randomised	Low risk	Low risk assumed due to parallel study design (participants only attended one session)	Unclear	Method not reported	Low risk	Appears that all expected outcomes were reported
Mellecker et al. (2010)	High risk	Not randomised	High risk	Participants were “free to choose” their condition	Unclear	Details not provided	Unclear	Method not reported	Unclear	Insufficient information

Search strategy

MEDLINE, PubMed, PsychInfo, and Embase were searched from inception through 05 July 2013. Reference lists of selected studies and reviews were searched for additional trials, and authors were contacted for any additional relevant unpublished information. The searches were limited to human studies and English language articles. Full details of the MEDLINE search strategy are provided in Table 1.

Study selection

For all the retrieved studies, citations and abstracts were downloaded to Endnote X5 and duplicates removed. The author [SM] then reviewed the titles and abstracts for inclusion using the following criteria: (1) an experimental study (RCT or quasi-randomised study), (2) at least one arm that investigated the non-advertising effects of a screen-based sedentary behaviour (including TV viewing, sedentary video game play, or recreational computer use), (3) an eligible comparison group, which could include active controls (exposure to a different screen-based sedentary behaviour) or controls (non-screen based sedentary activities), (4) dietary intake as an outcome (outlined above), and (5) participants aged 5–24 years. Studies investigating either overweight or non-overweight participants were included. Observational studies, reviews, and studies which specifically investigated the effects of TV advertising were excluded. Full-text articles of potentially relevant citations were retrieved and were again assessed for inclusion by the same author.

Data collection process

For each included trial, the author extracted the following data using an extraction form that was informed by the PRISMA statement for reporting systematic reviews (Liberati et al., 2009) and the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011): characteristics of trial participants (sample size, age range, mean age, and bodyweight status), (2) study design, (3) study details (attrition and setting), (4) details of comparison and control groups, and (5) dietary intake outcomes. Study authors were contacted if additional information was required.

Data items

Dietary intake could be reported as either amount of food and/or drink consumed or energy consumed (either as kcal or kJ). Participants were classified as children, adolescents, or young adults. Screen-based sedentary behaviours included TV watching, computer use, and video game play.

Risk of bias assessment

Study quality was assessed according to how the studies had minimised bias and error in their methods (Table 2). The Cochrane Handbook guidelines were used to assess risk of selection bias (random sequence generation and allocation concealment), attrition bias, detection bias, and reporting bias (Higgins & Green, 2011). Reporting bias was assessed by comparing the reported outcomes in the results to those listed in the methods section and, where possible, those reported in the study protocol. Criteria related to blinding of investigators and participants were not assessed as the nature of the exposure prevented researchers and participants from being blinded to exposure assignment; however, assessor blinding (detection blinding) was considered. A judgement of high risk, low risk, or unclear risk could be given, with unclear risk assigned when there was lack of information or uncertainty over the potential for bias.

Synthesis of results

Using data from the extraction form, study characteristics were summarised and tabulated (Table 3). The heterogeneity of study designs, participants, and experimental conditions precluded combination of statistical results and quantitative data synthesis. A narrative review of the included studies was therefore conducted.

Results

Study selection

A total of 1218 studies were identified from the database search, of which 463 were duplicates, leaving 755 abstracts that were assessed for eligibility. A total of 730 were deemed not relevant to the review based on the inclusion criteria. Twenty-five full-text articles were assessed for eligibility; however, 15 were excluded for the following reasons: primarily investigated the effects of food advertising or did not remove advertisements from the programming ($n = 6$), age group outside the pre-specified range for the review (5), dietary intake not reported as an outcome (2), no screen-based sedentary behaviour arm (1), and dietary intake was not assessed either concurrently or immediately after exposure (1). Figure 1 illustrates the different steps of the data collection process.

Study characteristics

Ten trials met the inclusion criteria and were included in the review: eight RCTs (Bellissimo, Pencharz, Thomas, & Anderson, 2007; Chaput, Visby, et al., 2011; Lyons, Tate, Ward, & Wang, 2012; Mekhmoukh, Chapelot, & Bellisle, 2012; Moray, 2006; Patel, Bellissimo, Thomas, Hamilton, & Anderson, 2011; Peneau et al., 2009; Temple, Giacomelli, Kent, Roemmich, & Epstein, 2007) and two quasi-experimental studies (Mellecker, Lanningham-Foster, Levine, & McManus, 2010; Mittal, Stevenson, Oaten, & Miller, 2011). They ranged in size from 14 to 120 participants. Eight studies specifically investigated the effects of TV viewing on either concurrent or subsequent food intake in children, adolescents, and young adults (Bellissimo et al., 2007; Mekhmoukh et al., 2012; Mittal et al., 2011; Moray, 2006; Patel et al., 2011; Peneau et al., 2009; Temple, Giacomelli, Kent, et al., 2007), two studies assessed the effects of video games (Chaput, Visby, et al., 2011; Mellecker et al., 2010), and one study compared the effects of TV viewing, sedentary video game play, and active video game play (Lyons et al., 2012). No trials were identified that investigated the effects of computer use. Table 4 presents dietary intake outcomes and the main study conclusions for the included trials. All ten trials were conducted in high-income countries, including France, Denmark, USA, Canada, and Australia.

Validity assessment

All but two studies (Mellecker et al., 2010; Mittal et al., 2011) used randomisation to assign participants to the exposure conditions; however, only three studies described the randomisation process (Chaput, Visby, et al., 2011; Mekhmoukh et al., 2012; Moray, 2006). A total of four studies were considered to be at low risk of bias (Chaput, Visby, et al., 2011; Lyons et al., 2012; Mekhmoukh et al., 2012; Moray, 2006), three at moderate risk (Bellissimo et al., 2007; Patel et al., 2011; Peneau et al., 2009), two at moderate-to-high risk (Mittal et al., 2011; Temple, Giacomelli, Kent, et al.,

Table 3
Characteristics of included studies. Studies presented according to risk of bias, with lowest risk of bias reported first.

Study	Methods	Participants	Conditions	Experimental meal	Outcome measurement of interest
RCTs					
Lyons et al. (2012)	RCT	*N* = 120	Arm 1: TV (selection of shows)	Access to selection of snacks and beverages	EI (kcal [food, soda, total])
	Parallel	*N* = 60	Arm 2: SVG (selection of games)	Snack = Candy + chips + mix of nuts and dried fruit + water + soda	
	3 arms USA	*F* = 60 Normal weight, overweight, and obese	Arm 3. ACG (selection of games)		
Mekhmoukh et al. (2012)	RCT	*N* = 38	Arm 1: TV (stand-up comedy with no food-related cues)	*Ad libitum* lunch served during condition	EI (kJ, volume)
	Crossover	*M* = 38	Arm 2: Eating alone	Meal = Main dish (casserole of beef and potatoes) + dessert (chocolate brownie) + water + orange juice + soda	
	4 arms France	Age: 15-17 (mean 16.5) years Normal weight and overweight	Arm 3: Eating in group Arm 4: Listening to music		
Chaput et al. (2011)	RCT	*N* = 22	Arm 1: SVG (FIFA 09; Xbox)	An *ad libitum* lunch was served after exposure	EI (kJ [total, fat, carbohydrate, protein])
	Crossover 2 arms Denmark	*M* = 22 Age: 15–19 (mean 16.7) years Normal weight	Arm 2: Resting in a sitting position	Meal = Spaghetti bolognese + water	
Moray et al. (2006)	RCT Crossover 2 arms USA	*N* = 20 *M* = 10 *F* = 10 18–23 (mean 20.8) years Not stated	Arm 1:TV (*Seinfeld* episode) Arm 2:No TV	*Ad libitum* meal served during condition Meal = Macaroni and cheese	EI (weight)
Bellissimo et al. (2007)	RCT	*N* = 14	Arm 1: Control drink then TV (2x*The Simpsons episodes*)	30 Minutes after the preload participants had a pizza meal, with or without TV	EI (weight [meal and water], kcal, caloric compensation)
	Crossover 4 arms Canada	*M* = 14 Age: 9-14 (mean 12.6) years Normal weight	Arm 3: Glucose drink then TV Arm 3: Control drink Arm 4: Glucose drink	Meal = Pizza + water	
Patel et al. (2011)	RCT	*N* = 25	Arm 1: Control drink then TV (*Hannah Montana*)	30 Minutes after the preload participants had a pizza meal, with or without TV	EI (weight [meal and water], kcal, cumulative EI)
	Crossover 4 arms Canada	*F* = 25 Age: 9-14 (mean 11.5) years No weight restrictions	Arm 3: Glucose drink then TV Arm 3: Control drink Arm 4: Glucose drink	Meal = Pizza + water	
Peneau et al. (2009)	RCT	*N* = 29	Arm 1: TV (programme with no food-related cues)	*Ad libitum* lunch served during condition	EI (kJ)
	Crossover	*M* = 14	Arm 2: Eating alone	Meal = Main dish (beef and potatoes) + dessert (chocolate cake) + water + orange juice + soda	
	4 arms France	*F* = 15 Age: 15–16 years Normal weight	Arm 3: Eating in group Arm 4: Listening to music		
Temple et al. (2007)	RCT	*N* = 26	Arm 1: Continuous TV show (*The Muppet Show, Punky Brewster*, and *Diff'rent Strokes*)	Access to 1000 kcal of preferred snack food during condition	EI (kcal, weight)
	Parallel	*M* = 12	Arm 2: No TV	Meal = participants ranked 4 snack foods and their favourite was used in the experiment.	
	3 arms USA	*F* = 14 Age: 9-12 (mean 11.2) years Normal weight	Arm 3: Repeated segment of TV show		

Non-RCTs					
Mittal et al. (2011)	Not randomised	$N = 32$	Arm 1: TV + snack (*Seinfeld* or *Friends*)	~1 h after the exposure participants were served an *ad libitum* test meal	EI (kJ)
	Parallel	$F = 32$	Arm 2: No TV + snack	Meal = Snack (chocolate balls + Pringles + Coke/orange juice). Test meal (sandwiches + biscuits + crackers & dip)	
	2 arms Australia	Mean 20.6 years Normal weight			
Mellecker et al. (2010)	Not randomised	$N = 27$	Arm 1: SVG (Xbox)	*Ad libitum* snack served during condition	EI (calories)
	Crossover	$M = 27$	Arm 2: Activity enhanced VG	Meal = Participants chose one of four available snacks (biscuits, pizza shapes, crackers, or cookies)	
	2 arms (4 free-choice sessions)	Age 9–13 (mean 11) years No restrictions			

SVG = Sedentary Video Game; AVG = Active Video Game; EI = Energy Intake.

2007), and the remaining one study were considered to be at high risk of bias (Mellecker et al., 2010), as assessed by selection, attrition, detection, and reporting bias (Table 2). Only three of the studies reported power calculations based on the primary endpoint of energy intake (Chaput, Visby, et al., 2011; Mekhmoukh et al., 2012; Peneau et al., 2009); it is therefore unknown whether the remaining studies were adequately powered to detect differences in dietary intake that were statistically significant. Attrition, defined by the difference in the number of participants assigned to exposure and the number of participants for who study outcomes were presented, was reported in two of the studies (Mekhmoukh et al., 2012; Mellecker et al., 2010). In the studies utilising a parallel study design (Lyons et al., 2012; Mittal et al., 2011; Temple, Giacomelli, Kent, et al., 2007) groups were comparable at baseline. Active control conditions were included in two studies (Lyons et al., 2012; Mellecker et al., 2010). All studies used objective measures of dietary intake.

Effects of TV on energy intake

Two randomised crossover trials (Mekhmoukh et al., 2012; Peneau et al., 2009) investigated the effects of four different environmental conditions, namely eating alone, eating in a group of three familiar peers, eating alone while listening to music, and eating alone while watching TV, on intake of highly palatable food in adolescents. The high-quality study conducted by Mekhmoukh et al. (2012) was designed to assess whether overweight adolescents consume more food and/or beverages in response to external cues than normal weight controls. According to a power calculation, inclusion of 19 participants was necessary to show a significant 10% difference with mean intake of 3344 kJ (SD 418 kJ). Total energy intake in overweight participants ($n = 19$) was significantly increased when viewing TV compared with eating in a group and listening to music (8527 kJ vs 7348 kJ and 7532 kJ; $p < 0.039$ and $p < 0.049$, respectively); however, this finding was not observed in normal-weight participants ($n = 19$). Volume of fluids consumed and post-exposure hunger and thirst ratings did not differ according to environmental condition or weight status (Mekhmoukh et al., 2012).

Similarly, the study conducted by Peneau et al. (2009) found that, in 29 normal weight male and female teenagers, energy intake was not significantly increased in the TV watching condition compared with eating alone, eating in a group, or eating while listening to music. However, in contrast to the findings from the first study, TV viewing significantly increased intake of soda drink compared with the other three conditions (eating in a group $p = 0.05$, eating while listening to music $p = 0.005$, and eating alone $p = 0.02$) (Peneau et al., 2009). Between-sex differences were observed in this study, with males eating more solid foods and consuming more soda drink compared with females. Importantly, while this study was powered to detect a 10% difference in energy intake between the conditions, it was not powered to investigate differences in outcomes between male and female participants. This may be of importance given the evidence for a complex relationship between adolescent girls' pubertal status and the effects of environmental factors on food intake (Patel et al., 2011).

A 2-arm, randomised, crossover trial conducted in undergraduate studies ($n = 20$) was designed to investigate how cognitive involvement associated with viewing TV might affect an individual's ability to perceive and track the amount of food consumed while watching TV (Moray, 2006). Overall, food intake did not differ significantly between TV and no TV; however, TV appeared to impair participants' ability to accurately estimate food intake. The lack of effect on dietary intake may be attributable to two important methodological issues. Firstly, the study was susceptible to a ceiling effect, as additional food was not offered once the

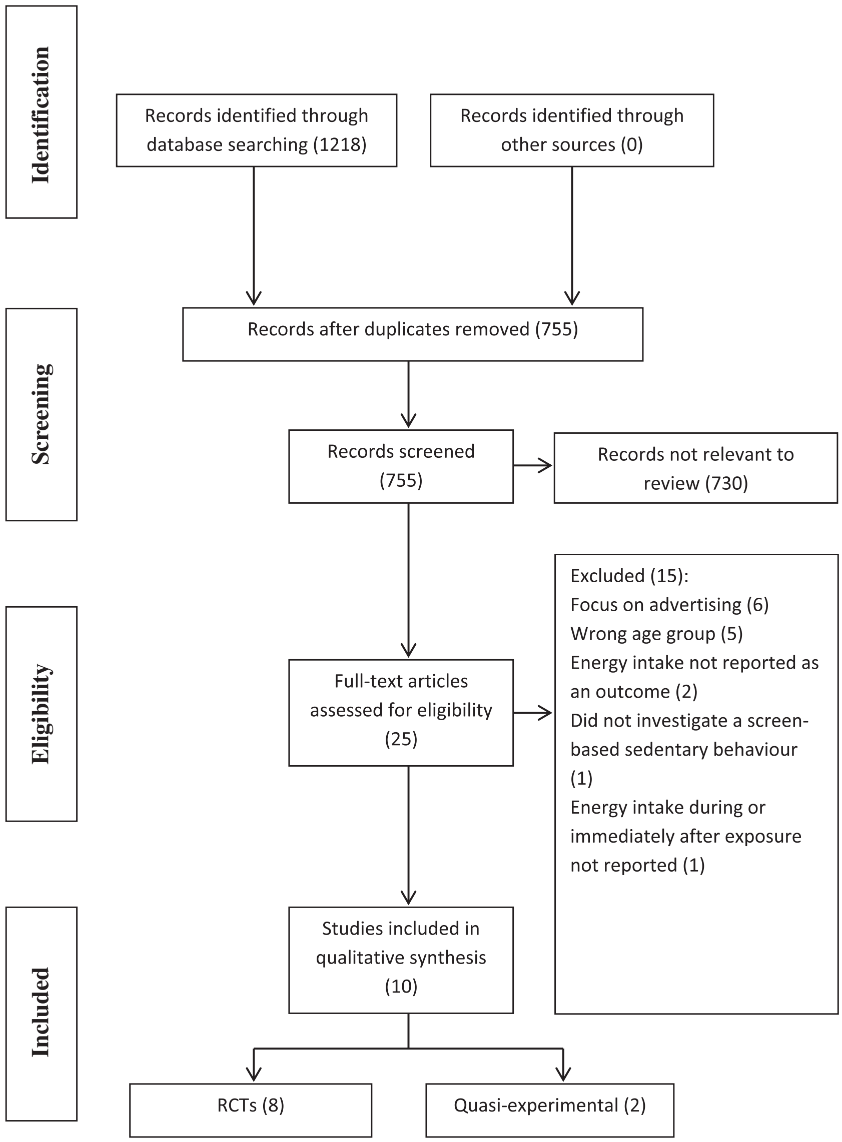

Fig. 1. PRISMA flow diagram of literature search.

participant had finished their plate, and secondly, there were large differences in hunger ratings between participants at the beginning of the experimental condition. Both of these could have affected energy intake and in turn the validity of the study findings.

Four studies were conducted to investigate the specific mechanisms by which exposure to TV may lead to increased energy consumption. Specifically, the studies investigated the effects of TV on: (1) physiologic signals that affect satiety and satiation in males ($n = 14$) (Bellissimo et al., 2007) and females ($n = 25$) (Patel et al., 2011), (2) disruption of habituation to food cues (Temple, Giacomelli, Kent, et al., 2007), and (3) memory impairment (Mittal et al., 2011). These three mechanisms will be discussed in turn. Firstly, two studies looked at how TV affects satiety and satiation (Bellissimo et al., 2007; Patel et al., 2011). Both studies utilised a randomised, crossover, factorial study design in order to assess the effects of two factors, a glucose preload and TV exposure, on energy intake. Participants were given equally sweetened preloads of either glucose or Splenda sucralose (control) and then 30 min later ate a pizza lunch with and without TV. The two studies aimed to assess whether TV would decrease the effect of a glucose drink on subjective feelings of satiety, thereby resulting in increased food intake at the meal. The study conducted in girls (Patel et al., 2011) was also designed to test whether hormonal changes associated with puberty would affect the relationship between TV and energy intake.

In males, both a glucose preload and exposure to TV affected food intake (Bellissimo et al., 2007). In the absence of TV, the glucose preload significantly decreased the amount of food eaten at the meal compared with the control drink group (502 g vs 606 g, respectively; $p < 0.05$); however, significant differences between the glucose and control drink groups were not observed during the TV condition (624 g vs 693 g, respectively). A more complex relationship was observed in females (Patel et al., 2011). Overall, TV at mealtime had no effect on food intake. However, a glucose preload suppressed food intake to a greater extent in the no TV versus TV condition (24% vs 10%, respectively; $p < 0.001$). This was primarily due to the effect in peripubertal girls ($p < 0.05$). Caloric compensations for the no TV and TV conditions were unchanged in postpubertal girls (both 27%) but significantly different in peripubertal girls (22% vs 1%), suggesting that the effects of environmental factors on food intake may be affected by pubertal status in females (Patel et al., 2011). Taken together these studies suggest that TV may increase energy intake by impairing physiologic

Table 4
Table of outcomes. Studies presented according to risk of bias, with lowest risk of bias reported first.

Study	Conditions	Energy intake results	Conclusions
RCTs			
Lyons et al. (2012)	Arm 1: TV Arm 2: SVG Arm 3. AVG	Total EI in the TV, SVG, and AVG conditions were 716, 747, and 553 kcal, respectively. Energy surplus was greater in the TV and SVG conditions compared with the AVG (638 and 655 vs 376 kcal/h, respectively; both $p < 0.05$)	Although energy surplus was lower an AVG compared with TV and SVG, it was still associated with a positive energy balance
Mekhmoukh et al. (2012)	Arm 1: TV Arm 2: Eating alone Arm 3: Eating in group Arm 4: Listening to music	Total EI at lunch was increased in overweight, but not normal weight, participants when viewing TV compared to eating in groups or listening to music (8527kJ vs 7348kJ and 7532 kJ, respectively; both p<0.05).	TV increased total EI in overweight but not normal weight participants
Chaput et al. (2011)	Arm 1: SVG Arm 2: Resting	Total EI was greater in the SVG versus controls (between-group difference 335kj; p<0.05).	SVGs increase EI at a subsequent meal.
Moray et al. (2006)	Arm 1:TV Arm 2:No TV	No differences between groups with respect to EI.	TV does not increase EI; however, this finding may be due to a ceiling effect.
Bellissimo et al. (2007)	Arm 1: Control + TV Arm 2: Glucose + TV Arm 3: Control Arm 4: Glucose	EI was lower in the glucose drink group compared with the control drink, control drink + TV, and glucose drink + TV groups (1097 vs 1332, 1514, and 1371 kcal, respectively; p<0.05). Caloric compensation after the glucose preload was 112% in the no TV group vs 66% in the TV group.	TV increases food intake and possibly overrides physiologic signals of satiation and satiety.
Patel et al. (2011)	Arm 1: Control + TV Arm 2: Glucose + TV Arm 3: Control Arm 4: Glucose	TV at mealtime had no effect on FI; however, glucose suppressed FI more with no TV vs TV (24% vs 10%, respectively; p<0.001).	TV decreases caloric compensation after consumption of a glucose preload in peripubertal, but not postpubertal, girls.
Peneau et al. (2009)	Arm 1: TV Arm 2: Eating alone Arm 3: Eating in group Arm 4: Listening to music	EI from solid foods did not differ between the groups; however, intake of soda was greater in the TV condition than in the music and control conditions	TV increases soda, but not food, intake in teenagers
Temple et al. (2007)	Arm 1: Continuous TV Arm 2: No TV Arm 3: Repeated segment of TV show	The continuous TV group consumed significantly more energy compared with the two control groups (no TV and repeated segment TV). Outcomes did not differ between the two control groups	TV appears to disrupt habituation, which leads to increased EI
Mittal et al. (2011)	Arm 1: TV + snack Arm 2: No TV + snack	The TV + snack group consumed more food on the test meal than those in the no TV + snack group (1584.6 kJ vs 1354.9 kJ; p<0.05)	Eating while watching TV appears to impact on later food intake
Mellecker et al. (2010)	Arm 1: SVG Arm 2: Activity enhanced VG	EI did not differ significantly between the seated and active conditions (374 vs 383 kcal/h, respectively)	Both seated and activity enhanced VGs are associated with high calorific consumption

EI = Energy Intake; FI = Food Intake.

signals that affect satiety and satiation in males (Bellissimo et al., 2007) and peripubertal, but not postpubertal, girls (Patel et al., 2011).

A number of methodological issues were identified in the study conducted in girls (Patel et al., 2011). Firstly, bodyweight of the study participants ranged from normal to obese. It has not yet been established whether the effects of screen-based sedentary activities on energy intake differ according to bodyweight status; however, it has been shown that obese children are more susceptible to food-related cues (Halford et al., 2004). Secondly, participants were only given one type of food and one TV show option during each condition. Therefore, participants' food and TV show preferences may have influenced study outcomes. Despite these limitations, this was the only experimental study identified that investigated the effects of TV viewing on energy intake exclusively in girls, and introduces the importance of considering pubertal status when investigating the effects of the mealtime environment on energy intake in children.

The ability of TV to disrupt habituation to food cues was investigated in a randomised, 3-arm, parallel study, where 26 children were permitted access to a preferred snack food during one of three conditions: (1) continuous TV show, (2) repeated segment of TV, or (3) no TV (Temple, Giacomelli, Kent, et al., 2007). The repeated segment group consisted of a 1.5-min segment of a TV show that was repeated on a loop. This group was included to control for the presence of audio-visual stimulation, ensuring that any difference between the two TV groups was due to the amount of attention allocated to TV watching. Overall, participants in the continuous TV group spent more time eating ($p < 0.001$) and consumed a greater amount of energy ($p < 0.007$) compared with participants in the two control conditions. Outcomes did not differ significantly between the two control groups, suggesting that TV viewing increased energy intake only when it required allocation of attention i.e. after controlling for audio-visual stimulation (Temple, Giacomelli, Kent, et al., 2007). Post-session hunger ratings did not differ between the three groups, despite participants in the continuous TV group consuming significantly more food during the session. The study outcomes suggest that TV leads to disruption of habituation to food cues resulting in overconsumption of food. Importantly, each study arm only included 8–9 participants, and no details of a power calculation were reported.

A non-randomised, 2-arm, parallel study conducted in 32 female undergraduates investigated whether TV increased food consumption by impairing memory formation (Mittal et al., 2011). Participants ate a snack in the presence or absence of TV and then food intake at a meal 1 h later was assessed. Although energy consumption during the snack phase did not differ significantly between the two groups, it tended to be greater in participants in the TV group versus the no TV group (1855.9 kJ vs 1667.7 kJ). Furthermore, participants who watched TV under-reported energy consumption during the snack phase to a greater extent than the no TV group (−620.5 kJ vs −410.1 kJ; $p < 0.05$); Energy consumption at the test meal 1 h later was significantly greater in the TV group compared with the no TV group (1584.6 kJ vs 1354.9 kJ; $p < 0.05$) (Mittal et al., 2011). The study findings suggest that TV may lead to overconsumption at a subsequent meal by impairing memory formation.

Effects of video games on energy intake

In contrast to the comparatively large number of studies that have investigated the link between TV viewing and energy intake, only three studies were identified that assessed the effects of video games (Chaput, Visby, et al., 2011; Lyons et al., 2012; Mellecker et al., 2010).

A high-quality, randomised, 2-arm, crossover study investigated the acute effects of a sedentary video game on energy balance in 22 adolescent males aged 15–17 years (Chaput, Visby, et al., 2011). Participants either played a video game or sat quietly in a chair (controls) for 1 h and then were served an *ad libitum* meal immediately after the exposure. Compared with the control condition, blood pressure, heart rate, sympathetic tone, mental workload, energy expenditure and energy intake were significantly greater during the video game condition (all $p < 0.05$). Importantly, although energy expenditure was greater in the video game group compared with controls, energy intake was also greater, resulting in a positive energy balance of 246 kJ in the video game group compared with controls ($p < 0.05$) (Chaput, Visby, et al., 2011). Despite this there were no between-group differences in sensations of hunger, appetite or energy intake during the rest of the day (as assessed by a dietary record). The authors reported that it was unclear whether the increase in energy intake was due to impairment of satiety signals or to the stress-induced reward system (Chaput, Visby, et al., 2011). The video game play condition was associated with increases in stress markers, and it has been reported that pleasurable feeding may help reduce such a stress response (Dallman, 2010); this pattern of stress and reward may be referred to as the stress-induced reward system. A potential limitation of the study was that it only looked at energy intake after the exposure; however, the finding, that post-exposure energy intake was significantly increased in the sedentary video game condition compared with controls is also of interest. A second limitation was that, in order to assess respiratory and biochemical outcomes, each participant had an indwelling catheter in the forearm and was required to wear a face mask, which may have compromised the ecological validity of the study.

Another high-quality study was recently published that utilised a 3-arm, parallel study design to compare the effects of TV watching, sedentary video game play, and active video game play in 120 young adults aged 18–35 years (Lyons et al., 2012). While there was only a trend towards significantly greater energy intake in the TV and sedentary video game conditions compared with active video games, active video game play was associated with significantly greater energy expenditure and significantly lower energy surplus compared with the other two active conditions. Furthermore, when the two sedentary conditions were collapsed into one group and compared with the active condition, energy intake was shown to be significantly greater in the sedentary group (178 kcal; 95% CI 8, 349). The odds of consuming at least 500 kcal during the 1-h condition was also significantly greater in the TV watching versus active video game condition (odds ratio 3.2; 95% CI 1.2, 8.4). This study had a number of strengths, including provision of a wide variety of food, drink, TV content, and gaming options, and assessment not only of energy intake but also of energy expenditure Furthermore, unlike the study conducted by Chaput, Klingenberg, Astrup, and Sjodin (2011), this study looked at concurrent, rather than subsequent, energy intake during video game play. However, one limitation was that the study did not investigate whether compensatory eating occurred later in the day, that is, did participants in the motion-controlled video game group eat a greater amount later in the day to compensate for their decreased consumption during the exposure or their increased energy expenditure. Overall, this was a well-designed, large study, and the first to compare differences in energy intake between different screen-based behaviours.

The third video game study utilised a non-randomised, 2-arm crossover design to compare the effects of a sedentary video game and an activity enhanced video game on concurrent snack food consumption in 27 males aged 9–13 years (Mellecker et al., 2010). Energy intake did not differ significantly between the two conditions; however, both conditions were associated with relatively high calorie consumption, 374 kcal/h in the seated condition and 383 kcal/h in the activity enhanced condition (approximately 20% of daily calorie intake recommendations for boys in this age group) (Lichtenstein et al., 2006). A number of important limitations were identified. A small convenience sample was used and participants were not randomised. Furthermore, rather than using an active video game, a sedentary video game was adapted with the addition of a treadmill. This may have affected the ecological validity of the study as a treadmill may not adequately imitate the active video gaming experience. Also, the study did not assess energy intake after playing the two different types of video games, and it is unknown whether compensatory energy intake later in the day would have differed between the two conditions. Finally, the study did not include a non-screen-based control condition. Despite these limitations, the study provides preliminary evidence to suggest that energy intake during concurrent video game play may not altered by the addition of a physical activity component (Mellecker et al., 2010).

Discussion

To our knowledge, this is the first systematic review to bring together the evidence concerning the non-advertising effects of screen-based sedentary activities on acute eating behaviours in children, adolescents and young adults. This review builds on conclusions drawn in previous papers, specifically that sedentary behaviours are associated with overconsumption of food (Chaput, Klingenberg, et al., 2011; Pearson & Biddle, 2011), and highlights the consistency with which screen-based activities in the absence of food advertising increase acute energy consumption in a laboratory setting. Historically, the effects of screen time on energy intake have been attributed to the effects of food advertising. The evidence presented in this review suggests that energy consumption during screen-based behaviours, particularly TV viewing, may not be exclusively related to food advertising and furthermore, that screen-based activities may be an important stimulus in the modern food environment.

Although TV appears to increase intake of highly palatable, energy-dense foods, only three studies investigated the effects of video game play on energy intake (Chaput, Visby, et al., 2011; Lyons et al., 2012; Mellecker et al., 2010) and therefore it is more difficult to draw conclusions about the effects of video games on food consumption. However, two of the studies were of high quality and showed significantly greater subsequent energy intake in the video game group compared with controls (Chaput, Visby, et al., 2011), and a trend towards significantly greater concurrent energy intake in the sedentary video game group compared with the active video game (Lyons et al., 2012). Alternatively, the third study was not randomised, did not contain a non-screen-based control group, and the active video game condition added a treadmill component to the sedentary video game rather than using an actual active video game, which may limit the ecological validity of the study (Mellecker et al., 2010). Despite these limitations, the study suggested that energy intake during concurrent video game play was not altered by the addition of a physical activity component. Based on the very limited available evidence it is too early to make any informed statements regarding the relationship between video games and increase energy intake other than that preliminary evidence does not preclude an association between the two. More research is required to supplement the current findings.

Non-advertising mechanisms

Distraction and attentional allocation

A number of explanations for the observed link between food intake and screen-based sedentary behaviours have been suggested. One of the most commonly cited explanations is that screen-based activities act as distractors, potentially increasing energy intake via two mechanisms: diverting attention away from the participant's habitual control of food intake, or distracting the participant from physiologic signals of satiety and satiation (Bellissimo et al., 2007; Hetherington, Anderson, Norton, & Newson, 2006; Higgs & Woodward, 2009; Temple, Giacomelli, Kent, et al., 2007). In the presence of distracting stimuli, such as playing computerised solitaire, adult participants report feeling less full after lunch and consume significantly more biscuits at a later taste test compared with undistracted participants (Oldham-Cooper, Hardman, Nicoll, Rogers, & Brunstrom, 2011). Similarly, the presence of music, another distracting stimulus, has also been shown to be associated with increased food intake when listened to at the same time as eating a meal (Stroebele & de Castro, 2006). Brunstrom and Mitchell (2006) conducted two experiments to assess whether distraction causes decreased sensitivity to physiological and sensory cues that signal the end of a meal. It was shown that desire to eat an eaten food relative to an uneaten food, defined as food-specific satiety, decreased in non-distracted participants, while distracted participants (those playing a computer game) maintained a desire to eat all foods. Between-group differences remained 5 and 10 min following termination of the eating episode. Finally, the results from the study conducted by Temple et al. (2007) suggest that the extent of attention allocated to TV viewing may be important in explaining how TV watching increases energy intake. In the study, energy intake was greater when participants watched a continuous TV show compared with a group, which watched a repeated segment of a TV show. This repeated segment group, which controlled for audio-visual stimulation, required less attentional allocation than the continuous TV group, suggesting that the increase in energy intake in the TV group was due to the amount of attentional allocation.

These findings are consistent with the information processing model of habituation. According to this model, a person is continuously exposed to olfactory, visual and gustatory cues while consuming a meal, with repeated exposures leading to habituation to the various stimuli. This model of how repeated exposures affect responding represents a model of habituation, and explains how decreases in behavioural and physiological responses to eating occur as a meal progresses; potentially providing a model for explaining the factors important for satiation and cessation of eating a meal (Epstein, Temple, Roemmich, & Bouton, 2009). According to the distractor paradigm of habituation models, a distractor may slow the rate of habituation to food cues, thus preventing the development of response decrements. Importantly, evidence suggests that the effects of a distractor are maximised with increased working memory or attentional involvement (Epstein, Paluch, Smith, & Sayette, 1997; Temple, Giacomelli, Kent, et al., 2007). The distractor paradigm is therefore of particular importance when investigating the effects of environmental stimuli, such as TV, on eating.

Interruption of physiologic food regulation

By utilising a preload study design, Bellisimo et al. (2007) was able to evaluate the interaction between TV viewing and physiologic signals in the regulation of energy intake. The researchers found that energy intake was increased, and the ability of a glucose preload to suppress food intake was diminished, in the presence of a TV. Following a preload of glucose, TV inhibited caloric compensation by either decreasing the effect of glucose on satiety or delaying satiation. These findings provide evidence that, by acting as a distractor, TV may override the physiological signals of satiety and satiation. However, a recent study showed that although distractibility, as assessed by the Conner's Continuous Performance Test II, was associated with bodyweight, the relationship between energy intake and distractibility while watching TV was not statistically significant (Martin, Coulon, Markward, Greenway, & Anton, 2009).

Screen-based activities as conditioned cues to eat

Another explanation for the effects of screen-based sedentary behaviours on energy intake is that these activities have become conditioned cues to eat, resulting in overconsumption of energy-dense foods. According to a recently published meta-analysis, the acute effects of TV on food intake potentially contribute to obesity by encouraging excessive eating (Chapman, Benedict, Brooks, & Schiöth, 2012). The authors of the review suggest that TV affects cognitive functions involved in reward saliency and inhibitory control. According to this model, TV abnormally increases the saliency value of food, which in turn overwhelms the brain's homeostatic control mechanisms associated with eating (Volkow et al., 2012). Thus, environmental factors, such as watching TV, may amplify the reward value of food (Volkow et al., 2012).

It has also been proposed that the matching of certain foods with certain use-contexts over time become integrated into a system of cues that motivate individuals' desires to eat specific foods within that context (Mela, 2001). Therefore, the desire to eat energy-dense foods may be increased in the presence of TV due to pairing of energy-dense foods with this use-context over time. Recurrent consumption of rewarding foods within a particular environment may promote formation of new linked memories, leading to anticipation of the reward in response to both the food and any environmental stimulus that is frequently paired with the food. For individuals who habitually eat while watching TV, TV may become a conditioned cue to eat energy-dense foods (Chapman et al., 2012). In an attempt to explain their study findings, a number of authors pointed out the possibility that TV may have become a conditioned cue to eat and drink highly palatability food and drinks (Peneau et al., 2009; Temple, Giacomelli, Kent, et al., 2007); however, this conditioning may also be related to a history of exposure to TV food advertisements.

Memory

There is also evidence that memory may affect regulation of food intake in humans, and that screen-based sedentary activities may interfere with this regulatory role resulting in increased energy intake. According to earlier studies conducted in amnesiac patients, participants readily consumed a second meal after consumption of a first meal (Hebben, Corkin, Eichenbaum, & Shedlack, 1985; Rozin, Dow, Moscovitch, & Rajaram, 1998). Importantly, it was later shown that this increased consumption in amnesic patients was not due to impaired sensory-specific satiety (Higgs, Williamson, & Attwood, 2008). The effect of memory on food consumption has also been demonstrated in non-patient populations. In a series of experiments, Higgs (2002) showed that being reminded of a recent eating episode was enough to decrease subsequent food intake in non-patient participants, a finding that was later confirmed by Brunstrom et al. (2012). Further, according to a recent review of studies investigating the effects of attention and memory on food intake, decreased attention while eating was shown to be associated with increases in both immediate and later energy intake, while enhancing memory for food consumption was associated with a decrease in later intake (Robinson et al., 2013). This effect of memory on later food intake may be of particular importance when considering the effects of screen-based behaviours on dietary intake.

The potential role of memory impairment as a mechanism by which TV viewing increases energy intake was first explored in a study in young women, which investigated whether watching TV with lunch would increase afternoon snack intake due to impairment of memory formation (Higgs & Woodward, 2009). It was shown that participants who watched TV during lunch not only consumed significantly more cookies during a later test meal but also reported decreased vividness ratings of the memory of the lunch, when compared with participants who did not watch TV during lunch. The study conducted by Mittal et al. (2011) supports these initial findings. Furthermore, in the study conducted by Moray, Brill, and Mayoral (2006) TV appeared to impair participants' ability to accurately estimate food intake, with participants tending to underestimate total food intake when they ate while watching TV. The authors suggested that this finding was due to the cognitive involvement required with watching TV, and that this underestimation of food intake may result in unintentional consumption of more calories and fat, potentially leading to an increased risk of being overweight or obese (Moray, 2006). It has therefore been proposed that TV increases intake of food by making it difficult to attend to how much food is being eaten during a meal and/or making it difficult to consolidate memories of food intake (Mittal et al., 2011).

Stress-induced reward system

Finally, there is preliminary evidence to suggest that the effects of screen-based activities on energy intake may be related to the mental stress-induced reward system. As reported by Chaput, Klingenberg, et al. (2011), sympathetic tone and mental workload were increased in children who played video games compared with controls. This finding is consistent with recent studies that have found that computer-based activities characterise a specific type of sedentary activity that is stressful and biologically demanding (Chaput, Drapeau, Poirier, Teasdale, & Tremblay, 2008; Chaput & Tremblay, 2007). These studies also found that computer use was associated with overconsumption of food in the absence of increased hunger and appetite. However, although the study conducted by Chaput, Klingenberg, et al. (2011) showed that the increase in energy intake was not accompanied by increased subjective sensations of hunger and appetite, the authors warned that it could not be established whether this phenomenon was due to impairment of satiety signals or to the mental stress-induced reward system.

Potential for at-risk populations

This review also revealed certain populations that may be at increased risk for increased energy intake when engaged in screen-based behaviours. The strongest evidence for the link between screen time and increased food and soda intake was seen in children (Bellissimo et al., 2007; Chaput, Visby, et al., 2011; Temple, Giacomelli, Kent, et al., 2007), as opposed to adolescents and young adults (Mittal et al., 2011; Moray, 2006; Peneau et al., 2009). While this link seemed to be relatively consistent in boys, a more complex relationship was observed in girls, whereby peripubertal girls had a greater response to environmental cues to eat compared with postpubertal girls (Patel et al., 2011). However, only one study investigated the effects of pubertal status on the relationship between TV viewing and energy intake; more studies are required before any conclusions can be drawn about the nature of this relationship. Similarly, the stimulatory effects of TV on energy intake appeared to be more pronounced in overweight boys compared with their normal-weight counterparts (Mekhmoukh et al., 2012). This is not surprising given that obese children appear to be more susceptible to environmental cues to eat (Halford et al., 2004) and that overweight children appear to habituate slower to food compared with non-overweight children (Temple, Giacomelli, Roemmich, & Epstein, 2007). Although future studies are needed to confirm these observations, it appears that certain characteristics, including age, sex, pubertal status, and bodyweight, may place certain individuals at greater risk for the negative effects of screen-based activities on energy intake.

Limitations of review

Perhaps the greatest limitation of this review was the reliance on studies that looked at TV viewing rather than other screen-based activities. Only three studies were identified that investigated the effects of video games, and no studies assessed the effects of computer use. As this review aimed to assess the effects of sedentary screen-based behaviours in general, rather than TV specifically, any discussion of the broader implications of these other screen-based activities is highly speculative. Furthermore, it would be unwise to generalise the findings from studies with a TV focus to other screen-based activities, as it remains unknown whether the relationship between TV viewing and energy is due, at least in part, to conditioned responses to TV watching or other TV-specific processes. Finally, as only 10 studies met the inclusion criteria for this review, any conclusions drawn regarding screens in general, or TV specifically, must be considered somewhat preliminary.

As with any review, this paper is also limited by the quality of the included studies. The studies available for inclusion ranged in quality from low to high; however, this may be due to inadequate reporting of methodologies by many of the authors. Although eight studies reported using randomisation to allocate participants to the exposure groups, only three discussed the process by which the random sequence was generated (Chaput, Visby, et al., 2011; Mekhmoukh et al., 2012; Moray, 2006). Furthermore, allocation concealment and assessor blinding were not reported in any of the studies, resulting in an assigned risk of bias of 'unclear'. Of note, the study authors were not contacted for further details regarding risk of bias. Despite this, virtually all studies reported an association between sedentary screen-based activities and increased energy intake. Another limitation of the review was the inclusion of both RCTs and quasi-experimental studies. Due to the small number of studies available for inclusion in the review, it was decided that including quasi-experimental studies was justified to ensure a greater depth of understanding into this relatively new area of research. Unfortunately, inclusion of non-randomised studies means that lower quality studies were presented alongside those of higher quality.

The inclusion of only laboratory-based studies may compromise external validity due to their highly controlled setting, resulting in issues with generalisability to real-word settings. However, laboratory-based studies enable researchers to investigate behaviour in a controlled environment. Since the behaviour can be directly observed by the investigator, issues of participant recall and response bias associated with measures of self-report can be eliminated. Therefore, the focus on laboratory-based studies may be considered both a limitation and strength of this review.

Finally, although TV food advertising was controlled for in the laboratory setting, food advertising may have been present in the video game and/or computer game exposures. With the growing popularity of these activities, video and computer games are emerging as a new platform for advertisers and marketers to target children and adolescents through product placement (Glass, 2007; Moray, 2006; Weber, Story, & Harnack, 2006). It is unknown whether the studies that included video game arms controlled for food advertising. With the growing use of online games and social networking sites, this issue of product placement is of particular importance, especially from a research perspective where the removal or avoidance of online advertising is more challenging than simply removing food advertisements from recorded TV programmes.

Implications for future research

The studies included in this review report a wide range of effect sizes, with some studies failing to demonstrate a significant stimulatory effect at all (Moray, 2006; Peneau et al., 2009). The discrepancies in outcomes may be due to the highly variable relationship between screen-based behaviours and energy intake and/or design or methodological issues. For example, the comparison group in a number of studies required the participant to sit in silence/rest in a chair, which may not be a true representation of what an adolescent/young adult would normally do. Furthermore, it has been reported that boredom and other low-arousal states may actually increase dietary intake (Abramson & Stinson, 1977; Macht, 2008). Future studies may benefit from including more feasible non-screen-based control conditions to address this issue. Future studies also need to provide more food and programming/gaming options, to ensure individual preferences do not influence the outcomes, and also make sure there is an unlimited supply of food offered to avoid a ceiling effect. High-quality studies are also required to better establish the factors that moderate the relationship between screen-based behaviours and energy intake, including age, sex, pubertal status, and bodyweight. Studies may also show greater, more consistent effects if they focus on specific at-risk groups.

Although TV viewing and, to a lesser extent, video games have been linked with increased energy intake, the comparative effects of these activities are largely unknown. Only one study was identified that compared the effects of TV viewing and video game play on energy intake (Lyons et al., 2012). However, the results from this study differed from those from a recent study in older males, which showed that active video game play was associated with significantly greater energy intake compared with sedentary video game play (Simons, de Vet, & de Groot, 2013). Furthermore, no studies were identified that investigated the effects of recreational computer use on energy intake in adolescents and young adults. Future research will therefore need to focus on other types of sedentary screen-based activities, such as video games and computer use, and also investigate whether these different activities affect energy intake differently.

Experimental studies to date have shown that intake of highly palatable, energy-dense foods is increased in the presence of screen-based activities (Mekhmoukh et al., 2012); however, studies have not investigated whether intake of healthy foods is also increased by screen time. In a non-randomised crossover trial conducted in undergraduate students ($n = 20$), TV viewing was associated with a significant increase in cola intake compared with a controls (listening to music), while water intake did not differ significantly between the two conditions (Blass et al., 2006). However, as this study did not remove the original advertisements from the programming it cannot be said whether differences in outcomes were due to advertising or mechanisms unrelated to advertising. It may be necessary to investigate whether screen-based activities in the absence of food advertising increase energy intake of all food types, including healthy foods, or whether it primarily increases intake of energy-dense foods. Finally, to our knowledge no research to date has investigated how the use of multiple screens at once affects energy intake in children. Given the recent increase in children's multi-screening behaviours, future research should address this.

Conclusions

The screen-time environment is changing at an unprecedented rate. Children now have greater control over their exposure to TV advertisements and increasingly divide their attention between multiple devices. With this in mind, the importance of the non-advertising effects of screen-based behaviours on energy intake has never been so important. Preliminary evidence suggests that, even in the absence of advertising, screen-based behaviours can increase energy consumption in children, adolescents, and young adults; however, findings to date have been highly variable, and the limited amount of research in this area has almost exclusively focused on the effects of TV viewing. More well-designed, high-quality studies are required to better establish the effects of video games and computer use on energy intake, and also assess whether different sedentary screen-based behaviours affect energy intake differently.

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