Systematic review of sedentary behaviour and health indicators in the early years (aged 0–4 years)

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Abstract: Accumulating evidence suggests that young children spend excessive time being sedentary. The purpose of this systematic review was to determine the relationship between sedentary behaviours and health indicators during the early years (ages 0–4 years). Using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework, this review aimed to present the best available evidence on the threshold of sedentary behaviour associated with healthy measures of adiposity, bone health, motor skill development, psychosocial health, cognitive development, and cardiometabolic health indicators in infants, toddlers, and preschoolers. Online databases, personal libraries, and government documents were searched for relevant studies. Studies that included an intervention (or experimental) group or prospective analysis were included. Twenty-one unique studies, representing 23 papers and 22 417 participants, met inclusion criteria; 7 studies included information on infants, 13 on toddlers, and 10 on preschoolers. Of these, 11, 6, and 8 studies reported data on adiposity, psychosocial health, and cognitive development, respectively. No included study reported on motor skill development, bone, or cardiometabolic health indicators. In conclusion, this review found low- to moderate-quality evidence to suggest that increased television viewing is associated with unfavourable measures of adiposity and decreased scores on measures of psychosocial health and cognitive development. No evidence existed to indicate that television viewing is beneficial for improving psychosocial health or cognitive development. In several instances a dose–response relationship was evident between increased time spent watching television and decreased psychosocial health or cognitive development. This work may be used as evidence to inform public health guidelines. (PROSPERO registration: CRD4011001280.)

Key words: infants, toddlers, preschoolers, inactivity, sitting, television, adiposity, psychosocial health, cognitive development, motor skill development, bone and skeletal health, cardiometabolic health indicators.

Résumé : De plus en plus d'études mettent à jour le fait que les jeunes enfants consacrent trop de temps en mode sédentaire. Cette analyse documentaire se propose d'établir la relation entre les comportements sédentaires et des indicateurs de santé au cours de la petite enfance (0–4 ans). Cette analyse faite en utilisant la méthodologie GRADE (« Grading of Recommendations Assessment, Development, and Evaluation ») se propose de présenter les meilleures données probantes concernant le seuil de comportement sédentaire associé à des mesures de l'adiposité-santé, de la santé des os, du développement des habiletés motrices, de la santé psychosociale, du développement cognitif et des facteurs de risque de maladie cardiométabolique chez les nourrissons, les tout-petits et les enfants d'âge préscolaire. La recherche a été effectuée dans les bases de données en ligne, les bibliothèques personnelles et les documents gouvernementaux afin d'en ressortir les études pertinentes. Les études présentant une intervention auprès d'un groupe (expérimental) ou une analyse prospective sont incluses dans l'analyse documentaire. Vingt-et-une études distinctes couvrant 23 articles et comptant 22 417 participants répondent aux critères d'inclusion; sept études s'adressent à des nourrissons, treize à des tout-petits et dix, à des enfants d'âge préscolaire. Parmi ces études, onze présentent des observations sur l'adiposité, six, des observations sur la santé psychosociale et huit, des observations sur le développement cognitif. Aucune parmi les études incluses ne traite de développement des habiletés

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motrices, de santé des os et des indicateurs de santé cardiométabolique. En conclusion et selon cette analyse documentaire, la qualité des données probantes est de faible à modérée pour suggérer que consacrer plus de temps à regarder la télévision est associée à des mesures désavantageuses de l'adiposité et à de plus faibles valeurs des mesures de santé psychosociale et de développement cognitif. Il n'y a pas de données probantes suggérant que le fait de regarder la télévision est bénéfique pour l'augmentation de la santé psychosociale et du développement cognitif. Dans plusieurs cas, on observe une relation dose-réponse entre l'augmentation du temps consacré à regarder la télévision et la diminution de la santé psychosociale ou du développement cognitif. Cette analyse peut servir de base à l'élaboration des directives en matière de santé publique. (PROSPERO numéro d'enregistrement : CRD4011001280.)

Mots-clés : nourrissons, tout-petits, enfants d'âge préscolaire, inactivité, assis, télévision, adiposité, santé psychosociale, développement cognitif, développement des habiletés motrices, santé des os et du squelette, indicateurs de santé cardiométabolique.

[Traduit par la Rédaction]

Introduction

Sedentary behaviour is an important area of study in health research. It is defined as any waking behaviour associated with an energy expenditure ≤1.5 METs and a sitting or reclining posture, and is considered separate and distinct from a lack of moderate- to vigorous-intensity physical activity (i.e., not meeting specified physical activity guidelines) (Sedentary Behaviour Research Network 2012; Tremblay et al. 2010). Canadian research on school-age children (aged 5–18 years) indicates that on average they spend 8.6 h per day, or 62% of their waking hours, engaging in sedentary behaviour (Colley et al. 2011). These sedentary activities, especially those that are screen-based, are associated with increased risk for obesity, and decreased fitness, self-esteem, pro-social behaviour, and academic achievement (Tremblay et al. 2011*c*).

Accumulating evidence indicates sedentary lifestyles are also occurring in the early years (defined in this paper as aged 0–4 years; i.e., birth to 4.99 years). For example, several sources report that children in the early years spend 73%–84% of their waking hours being sedentary (Reilly et al. 2004; Vale et al. 2010). Furthermore, most children in the early years engage in more than 1 h per day of screen time (Carson et al. 2010) and are being exposed to screen-based activities before the age of 2 years (Zimmerman et al. 2007). Consequently, there is an increased interest in the health implications of excessive sedentary behaviour during this critical period of growth and development. Evidence suggests that compared with school-aged children, screen time may be associated with additional negative health outcomes in the early years (Christakis et al. 2009; Lillard and Peterson 2011). Furthermore, sedentary behaviour habits formed during the early years may track over time (Janz et al. 2005). As a result, there may be several immediate and long-term health benefits by encouraging appropriate sedentary behaviour habits in this age group (United Nations General Assembly 2001; World Health Organization 2010).

Information related to sedentary behaviour for young children was recently released as part of new physical activity guidelines in Australia (Australian Government Department of Health and Ageing 2010) and the United Kingdom (Start Active Stay Active 2011). Though the United Kingdom identified no specific cut-point for sedentary behaviour time, guidelines from Australia state that screen time is not appropriate for those <2 years of age, and should be limited to <1 h per day for those aged 2–5 years (Australian Government Department of Health and Ageing 2010). Further, guidelines from Australia and the United Kingdom recommend limiting time spent being restrained for long periods of time. Similarly, the American Academy of Pediatrics discourages media use in children <2 years of age and that it should be limited to <2 h of quality educational screen time per day for children older than 2 years (American Academy of Pediatrics, Council on Communications and Media 2011*a*, 2011*b*). Finally, recommendations from the Canadian Pediatric Society state that television viewing should be limited to 1 to 2 h per day for children of all ages (Ford-Jones and Nieman 2003). However, to date, recommendations on appropriate levels of sedentary behaviour have not been informed by a systematic review that focuses specifically on sedentary behaviour.

Therefore, the purpose of this paper is to present evidence examining the relationship between sedentary behaviour and health indicators in the early years (aged 0–4 years). Specifically, this systematic review aims to synthesize the best available evidence on the optimal dose (i.e., frequency, interruptions, time, and type) of sedentary behaviour, as measured by direct and indirect methods, associated with improved health indicators in infants (1 month – 1.0 year), toddlers (1.1–3.0 years), and preschoolers (3.1–4.99 years). The evidence presented in this review can serve to inform the development of evidence-based sedentary behaviour guidelines for this age group.

Methods

This review is registered with the international prospective register of systematic reviews PROSPERO network (registration no. CRD4011001280). More information on PROSPERO is available at http://www.crd.york.ac.uk/prospero/.

Quality assessment

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework was used to guide our evaluation of the evidence from this systematic review, including a priori ranking of health indicators and risks of harm for decreasing sedentary behaviours and quality assessment of the evidence. In brief, GRADE is an internationally endorsed framework that provides a systematic and transparent methodology for clarifying research questions,

determining outcomes of interest, summarizing relevant evidence, and presenting recommendations based on the quality of available evidence. For this review, included studies were divided by age group and then by health indicator. Quality of evidence for each health indicator was assessed based on study design, risk of bias, consistency of results, directness of the intervention, precision of results, and possible dose–response gradient during data extraction. Randomized control trials begin at the highest quality evidence but may be decreased due to study limitations, inconsistency of results, indirectness of evidence, imprecision, or reporting bias. Observational studies begin at the lowest quality evidence but may be increased if the magnitude of treatment effect is large, if there is a reported dose–response relationship, or if all plausible biases would decreased the magnitude of effect. Details on data extraction are presented in the following sections. Details on GRADE methodology can be found elsewhere (Balshem et al. 2011; Guyatt et al. 2011*a*, 2011*b*, 2011*c*, 2011*d*, 2011*e*, 2011*f*, 2011*g*, 2011*h*).

Study inclusion criteria

The review sought to identify studies that examined the relationship between sedentary behaviour time and a specified health indicator in the early years (infants: 1 month – 1.0 years; toddlers: 1.1–3.0 years; preschoolers: 3.1–4.99 years). Studies were included only if there was a specific measure of sedentary behaviour time obtained via direct (e.g., measurements of sitting, sedentary behaviour through accelerometery, or direct observation) or self-reported (e.g., television viewing, video gaming, and "screen time" — defined as composite measures of television, computers, video games) methods. Sedentary behaviour time may also have been measured as a composite of total time engaged in sedentary behaviours. Health indicators were chosen a priori by an expert panel that convened in March 2011 as part of the Canadian sedentary guidelines for the early years development process (Tremblay et al. 2012). Health indicators were chosen based on expert consensus and to harmonize with research from Australia and the United Kingdom. Priority of relevant health indicators was determined by consensus a priori (see Table 1). The 6 eligible health indicators were

1. Adiposity (e.g., body mass index (BMI), waist circumference, skinfolds, bio-impedance analysis (BIA), dual-energy X-ray absorptiometry (DXA or DEXA);
2. Bone and skeletal health (e.g., bone mineral density (BMD), bone mass (i.e., bone mineral content (BMC));
3. Motor skill development (e.g., motor proficiency, gross motor skills, locomotor and object control);
4. Psychosocial health (e.g., self-concept, self-esteem, emotions, happiness, social–peer interaction, acceptance, aggression, temperament);
5. Cognitive development (e.g., language development, attention);
6. Cardiometabolic health indicators (e.g., plasma lipids, lipoprotein concentrations (e.g., high-density lipoprotein cholesterol, triglycerides), hypertension, fasting glucose, insulin resistance, inflammatory markers (e.g., C-reactive protein).

Studies were included if they were published and peer reviewed, and employed one of the following designs: randomized controlled trial, quasi-experimental, intervention, prospective cohort, or any study that has either a comparison group or a follow-up period (Dishman et al. 2004; Haynes et al. 1990). Longitudinal studies were included if the data presented in the article were consistent with established age limits (i.e., the study was required to have at least 1 measurement from the 0- to 4-year-old period). Details on included study designs and relevant definitions can be found in Appendix A. Inclusion criteria included limits on study design so that only the highest quality evidence was included, to minimize risk of bias, and to ensure our search identified a manageable number of possible studies. No language or date limits were imposed in the search; however, because of issues of feasibility, potential papers published in languages other than English or French ($n = 7$) were excluded.

Study exclusion criteria

Studies examining "active gaming" (e.g., Nintendo Wii, Microsoft Kinect, Sony's Playstation Move, video arcades, etc.) and those that defined sedentary behaviour as "failing to meet physical activity guidelines" were excluded.

Search strategy

A comprehensive strategy was used to identify relevant studies in the following electronic bibliographic databases: Ovid MEDLINE(R) (1948 to 11 May 2011), Ovid EMBASE (1947 to 11 May 2011), and Ovid psycINFO (1806 to week 2 of May 2011), EBSCO SPORTDiscus (1985 to 11 May 2011), and Cochrane Central Database (up to May 2011). The search strategy (see Appendix B) was created by A.G.L., with the help of an expert in library and information services, and run by A.G.L. Database searches were limited to studies involving "infant", "toddler", or "preschool" children (exact age limitations varied by database). References were extracted as text files from the OVID, EBSCO, and Cochrane interfaces and imported in to Reference Manager Software (version 11; Thompson Reuters, San Francisco, Calif., USA). Duplicate articles were first removed using Reference Manager Software; remaining duplicates were removed manually. All articles were assigned a unique reference identification number in the database.

Titles and abstracts of potentially relevant articles were screened by 2 independent reviewers (V.C. and A.G.L.) and full text copies were obtained for articles meeting initial screening criteria. The same reviewers independently examined all full text articles for inclusion in the review; any discrepancies were discussed by the reviewers. If they were unable to reach consensus, a third reviewer was asked to examine the article, and in some cases, the questionable articles were presented to the entire guideline development panel and consensus on inclusion was achieved.

In addition to our search, 6 key content experts were contacted and asked to identify the most influential papers from their personal libraries examining sedentary behaviour and health in the early years. Two of these experts were involved in the development of preschool guidelines in Australia and the United Kingdom. Content experts were also consulted to help identify key health indicators and guide decisions on search terms. To further help identify studies and to guide the review process, government documents from Canada (Canadian Pediatrics Society), Australia (Australian Government Department of Health and Ageing 2010), and the

Table 1. A priori consensus rankings assigned by the Guideline Development and Research Committee for each health indicator by age group.

Health indicator	Infant (<1 y)	Toddler (1–2 y)	Preschool (3–4 y)
Adiposity (e.g., overweight, obesity, BMI)	Critical	Critical	Critical
Bone (e.g., bone and skeletal health)	Unimportant	Unimportant	Critical
Motor development (e.g., gross motor skills, locomotor–object control)	Critical	Critical	Critical
Psychosocial health (e.g., self-efficacy, self-esteem, pro-social behaviour, temperament, aggression, social functioning)	Unimportant	Critical	Critical
Cognitive development (e.g., language development, attention)	Important	Important	Critical
Cardiometabolic health (e.g., blood pressure, insulin resistance, blood lipids)	Unimportant	Unimportant	Important
Risks (injury)	NA	NA	NA

Note: Health indicators were ranked based on whether they were critical for decision-making, important but not critical, or of low importance for decision-making. The focus when searching and summarizing the evidence was on indicators that were important or critical. Rankings were based on the GRADE framework (Guyatt et al. 2011*a*). NA, not applicable.

United Kingdon (Start Active Stay Active 2011) were used for reference.

Data extraction

Standardized data extraction tables were created through consultation with methodological experts and input from the guideline development panel; data extraction was completed by 1 reviewer and checked by another for accuracy (one of V.C., S.C.G., M.E.K., or A.G.L.). Information was extracted regarding study characteristics (year, study design, country, number of participants, age), type of sedentary behaviour, measure of sedentary behaviour, and health indicator. Within each age group, at least 2 reviewers (V.C., S.C.G., M.E.K., A.G.L.) independently assessed the quality of evidence for all studies (Guyatt et al. 2011*a*, 2011*b*, 2011*c*, 2011*d*, 2011*e*, 2011*f*, 2011*g*). If there was a discrepancy, the reviewers discussed their assessment until consensus was achieved. Based on these assessments, the impact of the risk of bias assessments on our overall confidence in the effect size across studies was examined, within and across each outcome (e.g., adiposity) and age group (e.g., infants). Reviewers were not blinded to the authors or journals when extracting data.

Analysis

By age group (i.e., infants, toddlers, or preschoolers), we identified all studies contributing to each health indicator. By health indicator, meta-analysis was planned for data that were sufficiently homogeneous in terms of statistical, clinical, and methodological characteristics using Review Manager Software 5.0 (The Cochrane Collaboration, Copenhagen, Denmark). Otherwise, qualitative synthesis was conducted for remaining studies. A priori comparisons for subgroup analysis were planned as follows: by direct or indirect measurement; by dose of sedentary behaviour (i.e., frequency, interruptions, time, or type); finally, by study quality (if sufficient homogeneity existed, through risk of bias assessment).

Harms of decreased sedentary behaviour

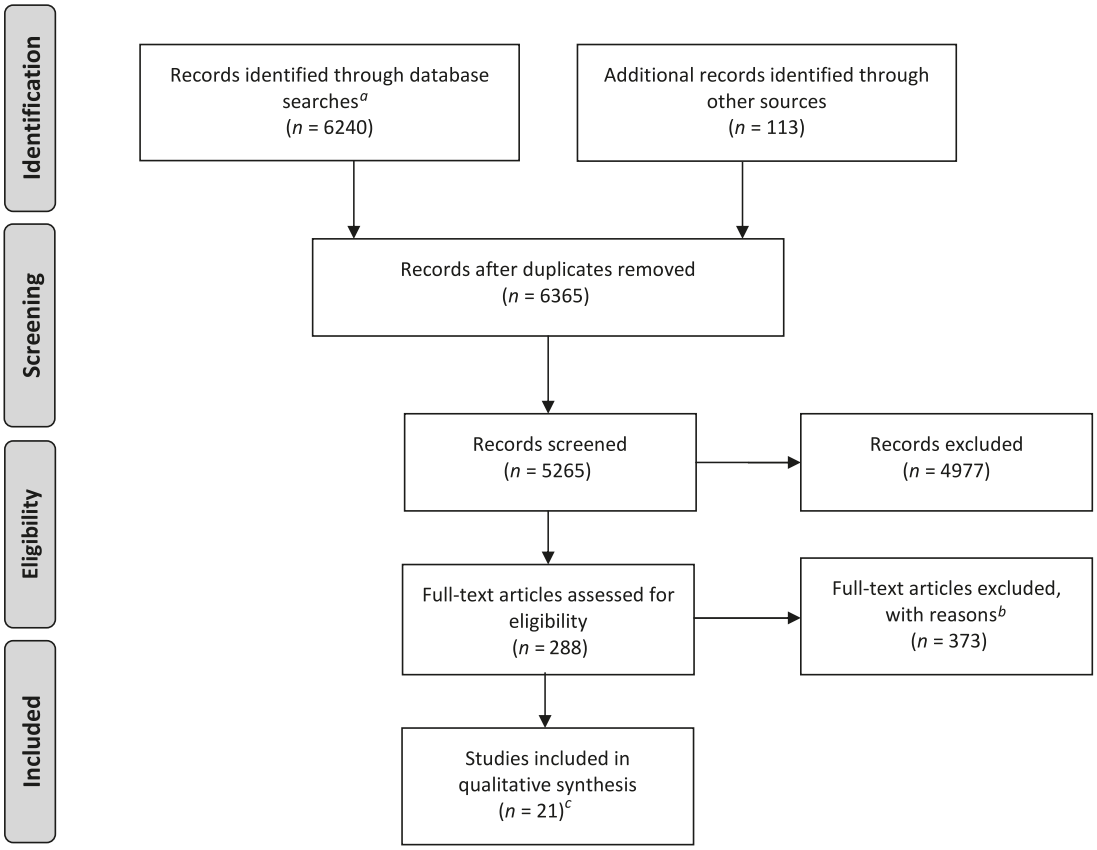
To ensure that both benefits and harms of interventions to decrease sedentary time were considered, potential harms associated with decreased sedentary time were discussed. Similar to discussions regarding importance of health indicators mentioned above, potential harms associated with decreased sedentary time were ranked by priority (unimportant, important, or critical) a priori by 4 reviewers (S.C.G., M.E.K., A.G.L., M.S.T.). A search was conducted on risks ranked as "important" or "critical". Musculoskeletal injury was the only risk ranked as critical and an Ovid MEDLINE search was performed to assess the evidence. To maximize the search, all study designs were included (see search strategy in Appendix B).

Results

The preliminary search of electronic databases identified 6240 potentially relevant articles (Fig. 1). Of these, 2041 were identified in MEDLINE, 2411 in EMBASE, 601 in psycINFO, 640 through SportDiscus, 547 through Cochrane Central Database, and 113 through key informants, government documents, and bibliographies. After de-duplication, 5265 relevant articles remained. A preliminary review of titles and abstracts resulted in 288 articles being included for detailed assessment of the full text. Of these, 21 unique studies represented in 23 papers met the criteria for study inclusion. Individual study characteristics can be seen in Table 2. Reasons for excluding studies included ineligible age (n = 107), ineligible exposure (e.g., diet, not meeting physical activity guidelines) (n = 64), ineligible outcome (n = 29), ineligible analysis or study design (e.g., review, cross-sectional analysis) (n = 173); many studies were excluded for multiple reasons. No studies were excluded because of active gaming.

Table 2 provides a summary of all studies included in the review. In total, data from 22 417 participants were included. Study sample size ranged from 19 (Gupta et al. 1994) to 5493 (Reilly et al. 2005) participants. Articles were published over a 17-year period from 1994 (DuRant et al. 1994; Gupta et al. 1994) to 2010 (Cheng et al. 2010; Foster and Watkins 2010; Pagani et al. 2010; Zimmerman and Bell 2010). Included studies involved participants from 8 countries. Almost all (21 of 23) included papers presented data from prospec-

Fig. 1. Prisma flow diagram of included studies. a, Databases included the following: Medline (n = 2041), Embase (n = 2411), PsycINFO (n = 601), SportDiscus (n = 640), Cochrane central database (n = 547); b, some full text articles were excluded for multiple reasons; c, 21 unique studies represented in 23 papers.



tive cohort studies with follow-up periods between 1 month and 8 years.

Quality of evidence by age group and across outcomes can be found in Tables 3–5. Nine unique studies examined the relationship between sedentary behaviour and health in infants, 12 in toddlers, and 10 in preschoolers. The outcomes of interest represented in the included studies were adiposity (n = 11), cognitive development (n = 8), and psychosocial health (n = 6). No included studies examined the relationship between sedentary behaviour and bone skeletal health, motor development, or cardiometabolic health in the early years (aged 0–4 years). Some studies included results for more than 1 age category and were presented accordingly. All studies used parent, caregiver, or teacher reports to quantify the time children spent watching television. Because of the heterogeneity of measurements (for both sedentary exposure and health indicator), meta-analysis was not possible for any outcomes. Subgroup analysis was not possible for measurement type, dose, or study quality.

Data synthesis

Overall, in infants, there was moderate-quality evidence to suggest television viewing elicited no benefits and may be harmful to cognitive development; and low-quality evidence to suggest increased television viewing was associated with unfavourable adiposity. In toddlers, there was moderate evidence suggesting television viewing has a negative impact on adiposity, moderate evidence to suggest it negatively affected psychosocial health, and low-quality evidence to suggest it has a negative impact on cognitive development. In preschoolers, there was low- to high-quality evidence on television's negative impact on adiposity, moderate-quality evidence between increased television and decreased scores on measures of psychosocial health, and low-quality evidence on the inverse relationship between television viewing and cognitive development.

Adiposity

Eleven studies examined the relationship between sedentary behaviour and measures of adiposity; none in infants, 4 in toddlers, and 6 in preschoolers; 1 study included data from those aged 0–6 years. All included studies had parent-reported television viewing as the main exposure. Adiposity was measured through BMI (Dennison et al. 2004; DuRant et al. 1994; Pagani et al. 2010; Reilly et al. 2005), BMI z scores (Zimmerman and Bell 2010), change in body fat (Blair et al. 2007), and mean sum of skinfolds (DuRant et al. 1994; Proctor et al. 2003). One prospective cohort (Zimmerman and Bell 2010) reported on the relationship between television viewing and BMI z scores across young children (defined as ages 0–6 years). They reported that increased television viewing was associated with increased adiposity; however, when commercialized television viewing was controlled for, this relationship disappeared. No studies examined this relationship specifically in infants.

In toddlers, 4 prospective studies were included. Three of

Table 2. Descriptive characteristics of included studies.

Reference	Country	Study design	Population (*n*)	Age group	Exposure and measure	Outcome
Alston and James-Roberts 2005	UK	Prospective cohort	38	Infant mean = 9.4–10.0 mo	Parent report TV (min·d^{-1}); direct observation of home environment	Cognitive development (babbling)
Blair et al. 2007	New Zealand	Prospective cohort	871	Baseline = 1 y; follow-up = 3.5 y	Parent report TV (h·d^{-1}); accelerometer	Adiposity (percent body fat)
Brown et al. 2010	Australia	Prospective cohort	4983	Baseline = 3–5 y; follow-up = 6–7 y	Parent report TV (h·d^{-1})	Adiposity (weight status)
Cheng et al. 2010	Japan	Prospective cohort	302	Baseline = 18 mo; follow-up = 30 mo	Parent report TV (h·d^{-1})	Psychosocial (hyperactivity–inattention, pro-social behaviour)
Chonchaiya and Pruksananonda 2008	Thailand	Case–control	Case = 56; control = 110	Toddler mean = 2.1 y[a]	Parent report TV (h·d^{-1})	Cognitive development (delayed language development)
Christakis et al. 2009	USA	Prospective cohort	329	Toddler mean = 18.6 mo	Parent report TV (h·d^{-1}); digital audio recorder	Cognitive development (vocalization)
Christakis and Zimmerman 2007[b]	USA	Prospective cohort	376	Toddler–preschool baseline = 2–5 y	Parent report violent TV, nonviolent TV, educational TV (h·d^{-1})	Psychosocial health (behavioural problems)
Dennison et al. 2004	USA	Randomized trial	Intervention = 90; control = 73	Preschool mean = 3.9 y	Education program to decrease TV viewing (h·d^{-1})	Adiposity (BMI, BMI *z* scores, triceps skinfold)
DuRant et al. 2004	USA	Prospective cohort	191	Preschool mean = 3–4 y	Direct observation TV (h·d^{-1}) and stationary time	Adiposity (change in BMI, sum of skinfolds, waist-to-hip ratio)
Foster and Watkins 2010[b]	USA	Prospective cohort	1159	Baseline = 1–3 y; follow-up = 7 y	Parental report TV (h·d^{-1})	Cognitive development (attention)
Guptka et al. 1994	India	Prospective cohort	19	Preschool mean = 3–5 y	Parent report TV (h·d^{-1})	Adiposity (weight status)
Jago et al. 2005	USA	Prospective cohort	149	Preschool mean = 4.4 y	Direct observation TV (h·d^{-1})	Adiposity (BMI)
Lumeng et al. 2006	USA	Prospective cohort	946	Baseline = 36 mo; follow-up = 54 mo	Parent report TV (h·d^{-1})	Adiposity (prevalence of overweight)
Mistry et al. 2007	USA	Prospective cohort	3165	Baseline = 30–33 mo; follow-up = 5.5 y	Parent report TV (h·d^{-1})	Psychosocial health (cooperation, assertion, self-control, responsibility, social skills)
Pagani et al. 2010	Canada	Prospective cohort	1314	Baseline = 29 mo.; follow-up = 10 y	Parent report TV (h·wk^{-1})	Psychosocial health (engagement, victimization); cognitive development (math scores); adiposity
Proctor et al. 2003	USA	Prospective cohort	103	Preschool mean = 4.0 y	Parent report TV (h·d^{-1})	Adiposity (BMI, sum of skinfolds, triceps skinfolds)
Reilly et al. 2005	UK	Prospective cohort	5493	Toddler baseline = 3 y; follow-up = 7 y	Parent report TV (h·d^{-1})	Adiposity (prevalence >95%ile)
Schmidt et al. 2009	USA	Prospective cohort	872	Baseline = 0–2 y; follow-up = 3 y	Parent report TV (h·d^{-1})	Cognitive development (visual motor ability, vocabulary)
Tomopoulous et al. 2007	USA	Prospective cohort	75	Baseline = 21 mo.; follow-up = 33 mo.	Caregiver–teacher report TV (h·d^{-1})	Psychosocial behaviour (aggressive behaviour, attention, oppositional defiant behaviour, externalization)
Tomopoulous et al. 2010	USA	Prospective cohort	253	Baseline = 6 mo; follow-up = 12 mo	Parent report TV (min·d^{-1})	Cognitive development (communication and language development)
Zimmerman et al. 2005	USA	Prospective cohort	1266	Baseline = 4 y; follow-up = 9.2 y	Parent report TV at age 4 (h·d^{-1})	Psychosocial health (bullying at age 6)
Zimmerman and Christakis 2007[b]	USA	Prospective cohort	560	Baseline = 0–3 and 4–5 y; follow-up = 5–8 and 9–10 y	Parental report educational TV, violent TV, nonviolent TV (h·d^{-1})	Cognitive development (attention)
Zimmerman and Bell 2010[b]	USA	Prospective cohort	1118	Baseline = 0–6 y; baseline = 5–11 y	Parent report TV (h·d^{-1})	Adiposity (BMI)

Note: BMI, body mass index; TV, television.

[a]Analysis was in part retrospective and examined age at which children first started watching television (7.2 months for those with a language delay, 11.9 months for those without a language delay); therefore, information was included with other studies focused on infants.

[b]Christakis and Zimmerman (2007) and Zimmerman and Christakis (2007) both used data from the Panel Study of Income Dynamics; Foster and Watkins (2010) and Zimmerman and Bell (2010) both used data from the National Longitudinal Study of Children and Youth.

Table 3. Is sedentary behaviour associated with poor health outcomes in infants (<12 months)?

Quality assessment										
No. of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	No. of participants	Absolute effect (confidence interval, SE)	Quality	Importance
Adiposity (infants, follow-up 5 y; intervention is TV viewing at ages 0–6 y; outcome is BMI										
1	Observational study[a]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	915	B = 0.1(0, 0.2)[b]	⊕⊕◯◯ LOW	CRITICAL
Cognitive development (infants, follow-up between 8 mo and 6 y; intervention is TV and other media exposure (games, videos) at 0–48 mo; outcomes are receptive vocabulary, visual motor skills, cognitive, language development, attention, memory, reading and math scores										
7[c]	Observational studies[d]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	Dose response gradient[e]	2162[f]	OR = 2.2 (1.2–4.1) (violent TV)[g] OR = 1.7 (1, 2.9) (nonviolent TV)[g] OR = 5.70(1.9,17.6)[h] B = –0.3(–0.3, –0.2)[i] B = 0.5(0.2, 0.9)[j] B = –1.5(–2.7, –0.3) to –1.2 (–2, –0.4)[k,l]	⊕⊕⊕◯ MODERATE	IMPORTANT

Note: Bibliography: Adiposity, Zimmerman and Bell (2010); cognitive, Schmidt et al. (2009), Alston and James-Roberts (2005), Zimmerman and Christakis (2007), Foster and Watkins (2010), Tomopoulos et al. (2010), Chonchaiya and Pruksananonda (2008), Christakis et al. (2009), Zimmerman et al. (2005). TV, television; BMI, body mass index; OR, odds ratio.

[a]Includes 1 prospective cohort study (Zimmerman and Bell 2010).

[b]Each additional hour of commercial television (with advertisements) associated with an increase of 0.11 BMI z scores, no effect seen for noncommercial television, therefore authors conclude it is the content of the television (advertising) and not the sedentary behaviour that is the cause of the increase in BMI (Zimmerman and Bell 2010).

[c]Data from Alston and James-Roberts (2005) not presented because the analysis did not investigate the relationship between television exposure and cognitive development.

[d]Includes 1 case control study (Chonchaiya and Pruksananonda 2008) and 6 prospective cohort studies (Christakis et al. 2009; Foster and Watkins 2010; Schmidt et al. 2009; Tomopoulos et al. 2010; Zimmerman et al. 2005; Zimmerman and Christakis 2007).

[e]Dose–response relationship was seen for increased exposure and poorer cognitive performance in 3 studies (Chonchaiya and Pruksananonda 2008; Tomopoulos et al. 2010; Zimmerman and Christakis 2007).

[f]Case control study (Chonchaiya and Pruksananonda 2008): n = 56 (case), n = 110 (control).

[g]Each additional hour of violent or nonviolent programming associated with increased attention problems (Zimmerman and Christakis 2007).

[h]Adjusted odds of onset of television viewing before 12 months and exposure to 2+ hours a day for increased risk of language delay (Chonchaiya and Pruksananonda 2008).

[i]Each additional hour of exposure associated with a decrease in child's vocalization count (Christakis et al. 2009).

[j]Each hour of television viewing associated with increases on reading recognition and comprehension and memory scores respectively; no significant effect on math scores (Zimmerman et al. 2005).

[k]Adjusted log transformed coefficients for effects of media exposure at 6 months with cognitive and language development at 14 months, respectively (Tomopoulos et al. 2010).

[l]No effect of television viewing at 1 year of age and attention at 7 years of age when covariates are controlled (Foster and Watkins 2010); no effect of television exposure at 6–24 months on language and visual motor skills at 3 years (Schmidt et al. 2009).

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Table 4. Is sedentary behaviour associated with poor health outcomes in toddlers (aged 1.1–3.0 years)?

Quality assessment										
No. of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	No. of participants	Absolute estimate (confidence intervals, SE)	Quality	Importance
Adiposity: (observational) follow-up 8 mo to 7.7 y; intervention is TV exposure and sedentary time at 29–36 mo; outcomes are BMI and % body fat										
4	Observational studies[a]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	Dose–response gradient[b]	7310[c]	B = 0.1(0, 0.2)4[d]; OR = 1.4(1.0–1.8), 1.6(1.1, 2.1)[e], 0.8(0.2, 1.4)[f]; B = 2.5(0.7, 4.2), 5.2(1.2, 9.1)[g]; B = .05(0.02)[h,i]	⊕⊕⊕○ MODERATE	CRITICAL
Psychosocial health (toddlers, follow-up 1 to 8 y; intervention is TV exposure at 18–48 mo; outcomes are pro-social scores, victimization, emotional reactivity, antisocial behaviour, aggressive and externalizing problems)										
5	Observational studies[j]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	Dose–response gradient[k]	4707	Mean = 5.8(4.9, 6.7) to 4.7(4.2, 5.3)[l]; OR 2.0 (1.1, 3.8), 1.7(1–2.7)[m]; B = 0.10(SE 0.01)[n]; B = –0.4(–0.7, –0.2), 1.4(0.8, 2), 1.7(1, 2.5)[o]; OR = 4.1(2.19, 8.0)[p]	⊕⊕⊕○ MODERATE	CRITICAL
Cognitive development (toddlers) (follow-up 1 mo to 6 y; intervention is TV exposure and audible TV exposure at 0–48 mo; outcomes are attention, vocalization, math achievement, reading recognition and comprehension, memory)										
6	Observational studies[q]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	6866	B = 0.4(0.2–0.5)[r]; B = –0.3(–0.3, –0.2)[s]; B = –0.07(0.0), –0.06(0.0)5[t]; OR = 2.2(1.2–4.1) (violent TV); OR = 1.7 (1, 2.9) (nonviolent TV)[u,v]	⊕⊕○○ LOW	IMPORTANT

Note: Bibliography: Adiposity, Lumeng et al. 2006, Reilly et al. 2005, Blair et al. 2007, Pagani et al. 2010; psychosocial, Cheng et al. 2010, Christakis and Zimmerman 2007, Tomopoulos et al. 2007, Mistry et al. 2007, Pagani et al. 2010; cognitive, Pagani et al. 2010, Mistry et al. 2007, Foster and Watkins 2010, Christakis et al. 2009, Zimmerman et al. 2005, Zimmerman and Christakis 2007, Schmidt et al. 2009, Christakis and Zimmerman 2007. BMI, body mass index; OR, odds ratio; TV, television.

[a]Includes 4 prospective cohort studies (Blair et al. 2007; Lumeng et al. 2006; Pagani et al. 2010; Reilly et al. 2005).

[b]Dose–response between increased television viewing and BMI (Reilly et al. 2005); hours of television watched per day and % body fat (Blair et al. 2007); hours of television and BMI (Pagani et al. 2010); Lumeng 2006 looked at television as dichotomous variable and did not have a dose–response relationship.

[c]Sample size totals based on adjusted analyses.

[d]Each additional hour of commercial television (with advertisements) associated with an increase of 0.11 BMI z scores, no effect seen for noncommercial television; therefore, authors conclude it is the content of the television (advertising) and not the sedentary behaviour that is the cause of the increase in BMI (Zimmerman and Bell 2010).

[e]Odds ratio for watching 4.1–8 h and 8+ hours per week respectively.

[f]Odds ratio for each additional hour of sedentary time (outcome is BMI) (Reilly et al. 2005).

[g]Odds ratio for 1–3 h of television viewing and 3+ hours (compared with <1 h of television per day) (outcome is change in body fat) (Blair et al. 2007).

[h]Standardized beta for each additional hour of television (outcome is BMI (Pagani et al. 2010).

[i]No association between ≥2 h per day of television viewing and adiposity (Lumeng et al. 2006).

[j]Includes 5 prospective cohort studies (Cheng et al. 2010; Christakis and Zimmerman 2007; Mistry et al. 2007; Pagani et al. 2010; Tomopoulos et al. 2010).

[k]Two of the included studies showed evidence for a dose–response relationship between increased television viewing and poor measures of psychosocial health (Christakis and Zimmerman 2007, Pagani et al. 2010, Zimmerman et al. 2005).

[l]Mean scores on pro-social scale for 1 h of television to >4 h; dose–response relationship (Cheng et al. 2010).

[m]Odds ratios for aggressive behaviour and externalizing problems on Child Behavior Checklist for a 1-h increase in television viewing; no effect seen for oppositional defiant problems; effects are stronger when programming was noneducational (Tomopoulos et al. 2007).

[n]For each additional hour of television viewing victimization score increases by 10% (Pagani et al. 2010).

[o]Significant effects for early exposure only for emotional reactivity, significant effects of early and sustained exposure on aggressive and externalizing behaviours, respectively, no effects seen on anxious–depressed scale (Mistry et al. 2007).

[p]Increased odds of antisocial behaviour at 7–9 years for each additional hour of violent programming that boys watched at 2–4 years; no effect seen for nonviolent and educational programming (Christakis and Zimmerman 2007).

[q]Includes 6 prospective cohort studies (Christakis and Zimmerman 2007; Foster and Watkins 2010; Mistry et al. 2007; Pagani et al. 2010; Schmidt et al. 2009; Zimmerman et al. 2005).

[r]Effects of sustained exposure (30–33 months and 5.5 years) on attention scores (Mistry et al. 2007)

[s]Each additional hour of exposure associated with a decrease in child's vocalization count (Christakis et al. 2009).

[t]Each hour of television viewing associated with a 7% decrease in classroom engagement and 6% decrease in math achievement (Pagani et al. 2010)

[u]Each additional hour of violent or nonviolent programming associated with increased attention problems (Zimmerman and Christakis 2007)

[v]No effect on attention, Foster and Watkins (2010); no effect of television exposure at 6–24 months on language and visual motor skills at 3 years (Schmidt et al. 2009).

Table 5. Is sedentary behaviour associated with poor health outcomes in preschool children (aged 3.0–4.9 years)?

Quality assessment										
No. of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	No. of participants	Absolute estimate (confidence intervals, SE)	Quality	Importance
Adiposity preschool: (RCT) follow-up 7 wk; intervention is 7-session (weekly for 20 min) program to reduce TV viewing for children aged 2.5 to 5.5 y; outcomes are amount of viewing time and BMI)										
Adiposity: (observational studies) follow-up 2–7 y; intervention is sedentary behaviour, TV, and video exposure at ages 4–5 y, 3–4 y, 0–6 y, 4 y, and 3–11 y; outcomes are BMI, waist/hip ratio, and skinfolds										
1	RCT	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	Intervention n = 90; control n = 73	Mean difference = –21.5(–42.5, –0.5)[a]	⊕⊕⊕⊕ HIGH	CRITICAL
5	Observational studies[b]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None[c]	3743	B = 0.1(0, 0.2)[d]	⊕⊕◯◯ LOW	CRITICAL
								Mean BMI = 20.8(0.7)3+h; 18.7(0.6)<1.8h[e]		
								Mean skinfolds = 104.7(8.1) 3+h; 77.9(7.2)<1.8h[e]		
								B = –0.041(0.017) (year 2); B = –0.044(0.017) (year 3)[f,g]		
Psychosocial health (preschool, follow-up 2–7.5 y; intervention is TV viewing at 2–4.5 y; outcomes are victimization, bullying, and antisocial behaviour)										
3	Observational studies[h]	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	Dose–response gradient	2909	OR = 4.1(2.19, 8.0)[i]	⊕⊕⊕◯ MODERATE	CRITICAL
								OR = 1.1(1.0, 1.1)[j]		
								B = 0.06(0.01)[k]		
Cognitive development: (preschool, follow-up 1–5 y intervention TV viewing at 3–5 y; outcome is attention problems, reading, math, and memory scores)										
1[l]	Observational studies	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	672	No effect[m]	⊕⊕◯◯ LOW	CRITICAL

Note: Bibliography: Adiposity, Dennison et al. 2004, DuRant et al. 1994, Zimmerman and Bell and 2010, Jago et al. 2005, Proctor et al. 2003, Brown et al. 2010; psychosocial, Pagani 2010, Christakis and Zimmerman 2007, Zimmerman et al. 2005; cognitive, Zimmerman and Christakis 2007. RCT, randomized clinical trial; TV, television; BMI, body mass index.

[a]Mean difference in television viewing ≥2 h per day in intervention group, BMI also decreased in intervention group, but difference was nonsignificant (Dennison et al. 2004).

[b]Includes 5 prospective cohort studies (DuRant et al. 1994; Jago et al. 2005; Proctor et al. 2003; Zimmerman and Bell 2010); Brown et al. (2010) was a prospective study but only presented cross-sectional analysis for the variables in question and was therefore excluded from further analysis.

[c]Dose–response gradient was reported in 1 study (Proctor et al. 2003) but was insufficient to warrant upgrading quality.

[d]Each additional hour of commercial television (with advertisements) associated with an increase of 0.11 BMI z scores, no effect seen for noncommercial television; therefore, authors conclude it is the content of the television (advertising) and not the sedentary behaviour that is the cause of the increase in BMI (Zimmerman and Bell 2010).

[e]Mean BMI for 3+ hours of television compared with <1.8 h television and video viewing over the 7 years of the study; mean sum of skinfolds (mm) for 3+ hours compared with <1.8 h over the 7 years of the study; model controlled for age, sex, baseline anthropometry, and physical activity levels (Proctor et al. 2003).

[f]Increased BMI across 3 years associated with increased television viewing (hours per day) (Jago et al. 2005).

[g]Television viewing was not correlated with skinfolds, BMI, or waist-hip ratio, although data were collected over 1 year and the data were collapsed so while the study design was longitudinal, the analysis was only quasi longitudinal (DuRant et al. 1994).

[h]Includes 3 prospective cohort studies (Christakis et al. 2009; Pagani et al. 2010; Zimmerman et al. 2005).

[i]Increased odds of antisocial behaviour at 7–9 years for each additional hour of violent programming boys watched at 2–4 years; no effect seen for nonviolent and educational programming (Christakis and Zimmerman 2007).

[j]Increased odds of bullying at 6–11 years for each additional hour of television watched at age 4 (Zimmerman et al. 2005)

[k]For each hour of increased television viewing between 29 and 53 months there is a 6% increase in victimization (Pagani et al. 2010).

[l]Includes 1 prospective cohort study (Zimmerman and Christakis 2007).

[m]No effect of television viewing at age 4–5 on attention problems at age 9–10 years (Zimmerman and Christakis 2007).

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these studies reported a dose–response relationship between hours of television viewing and increased BMI (Pagani et al. 2010; Reilly et al. 2005) and percent body fat (Blair at al. 2007). The remaining study dichotomized groups by those who watched more (or less) than 2 h of television per day, making it impossible to discern any dose–response relationship. We upgraded the quality of evidence from low to moderate because of the dose–response relationship, which means that as the number of hours of television exposure increased so did the level of adiposity (Table 4); we identified no serious risk of bias, inconsistency, indirectness, or imprecision.

In preschoolers, 1 randomized trial (Dennison et al. 2004) and 5 prospective studies were included (Brown et al. 2010; DuRant et al. 1994; Jago et al. 2005; Proctor et al. 2003; Zimmerman and Bell 2010). The purpose of the randomized trial was to decrease television viewing through a preschool educational program. Although the program was successful in decreasing the time preschoolers watched television, this was not associated with any significant changes in BMI. Of the 5 prospective studies, 1 reported a dose–response relationship with those in the highest tertile of television and video viewing ($\geq$3 h·day^{-1}) having greater increases in body fat (measured through BMI, sum of skinfolds and triceps skinfolds) in early adolescents (mean age = 11.1 years) than those in the lowest tertile of television and video viewing ($\geq$1.75 h·day^{-1}). This finding remained after controlling for level of physical activity and was worse for those who had the highest overall levels of sedentary behaviour (Proctor et al. 2003). Two of the 5 studies reported that those who watched more television during the preschool period had higher skinfold measurements (Proctor et al. 2003) and BMI (Jago et al. 2005) later in life (at age 11 years and 6 years, respectively). The studies had low- to high-quality evidence and no serious risk of bias, inconsistency, indirectness, or imprecision (Table 5).

Psychosocial health

Six studies examined the relationship between sedentary behaviour and measures of psychosocial health (e.g., hyperactivity, self-control, engagement); none of the included studies reported on infants, 5 reported on toddlers and 3 reported on preschoolers.

In toddlers, 5 prospective studies reported that higher levels of television viewing were associated with lower scores on pro-social checklists (e.g., hyperactivity, pro-social behaviour) (Cheng et al. 2010), higher risk for aggressive behaviour and externalizing problems (Mistry et al. 2007; Tomopoulos et al. 2007) and increased risk for victimization (i.e., was called names, hit or pushed, or made fun of by other children) (Pagani et al. 2010). In preschoolers, 3 prospective cohort studies (Christakis and Zimmerman 2007; Pagani et al. 2010; Zimmerman et al. 2005) reported a dose–response relationship between increased television viewing and poor measures of psychosocial health. Each additional hour of television viewing was associated with increased odds for antisocial behaviour (Christakis and Zimmerman 2007), victimization (Pagani et al. 2010), and maternal reported bullying (Zimmerman et al. 2005). In both toddlers and preschoolers, a stronger association between screen time and poor measures of psychosocial health was observed when the content of the screen time was either violent or noneducational in nature (Christakis and Zimmerman 2007; Tomopoulos et al. 2007). Overall, the studies had moderate-quality evidence and no serious risk of bias, inconsistency, indirectness, or imprecision; evidence of a dose–response relationship existed for toddlers and preschoolers (Tables 4 and 5).

Cognitive development

Eight studies examined the relationship between sedentary behaviour and cognitive development; 7 of these were in infants, 5 were in toddlers, and 1 was in preschoolers. Three of these studies examined cognitive development across the early years and the data were therefore included for more than a single age group (Foster and Watkins 2010; Zimmerman et al. 2005; Zimmerman and Christakis 2007). The studies had low- to moderate-quality evidence and no serious risk of bias, inconsistency, indirectness, or imprecision (Tables 3–5); evidence of a dose–response relationship existed for infants. Indicators and measurements of cognitive development varied across age group and study.

One case-control study (Chonchaiya and Pruksananonda 2008) and 6 prospective cohort studies (Christakis et al. 2009; Foster and Watkins 2010; Schmidt et al. 2009; Tomopoulos et al. 2010; Zimmerman et al. 2005; Zimmerman and Christakis 2007) examined this relationship in infants. Of these, 2 studies (Foster and Watkins 2010; Schmidt et al. 2009) reported no relationship between early television viewing and measures of attention, language, or visual motor skills. Three studies (Chonchaiya and Pruksananonda 2008; Tomopoulos et al. 2010; Zimmerman and Christakis 2007) reported a dose–response relationship between increased exposure to television and decreased cognitive performance; attention; vocalization count and language delays; and reading recognition, comprehension, and memory scores. We upgraded the quality of evidence from low to moderate because of the dose–response relationship between increased television exposure and decreased cognitive outcomes (Table 3).

Five prospective cohort studies (Christakis and Zimmerman 2007; Foster and Watkins 2010; Mistry et al. 2007; Pagani et al. 2010; Zimmerman et al. 2005) examined the relationship between television viewing and cognitive development in toddlers. Of these, 2 studies (Foster and Watkins 2010; Schmidt et al. 2009) reported no significant relationship. The remaining 3 studies (Christakis et al. 2009; Mistry et al. 2007; Pagani et al. 2010) reported a dose–response relationship with each additional hour of television exposure related to decreased vocalization, classroom engagement, and math scores. One low-quality prospective cohort study (Zimmerman and Christakis 2007) reported on the relationship between television viewing and cognitive development in preschoolers. The studies examining cognitive outcomes for toddlers and preschoolers were low quality (Tables 3 and 4).

Risk of decreased sedentary behaviour

A total of 57 articles were found through a search of Ovid MEDLINE and by scanning reference lists. None of these studies met the inclusion criteria. Most reported on the danger of furniture falling on young children and were not related to one of our health indicators of interest.

Discussion

This review aimed to use the best quality evidence to report on the relationship between sedentary behaviour time and health indicators during the early years. Current evidence supports the idea that increased television viewing is associated with unfavourable measures of adiposity, psychosocial health, and cognitive development. Further, no evidence exists to suggest television viewing is beneficial for improved psychosocial or cognitive development. In several instances, a dose–response relationship existed between increased time spent watching television and decreased psychosocial or cognitive development. This is consistent with evidence in older children (aged 5–17 years) that reported an association between increased screen time and unfavourable body composition, decreased fitness, lowered scores for self-esteem, and pro-social behaviour and decreased academic achievement (Tremblay et al. 2011*c*).

The results of this review do not provide specific information on the dose (i.e., frequencies, interruptions, times, or types) of sedentary behaviour necessary for good health, nor do they provide definitive information as to how this relationship differs between boys and girls. All studies reported on the relationship between television viewing and a health indicator (i.e., no other types of sedentary behaviour were explored). We would like to highlight that television viewing is only a crude measure of sedentary behaviour and it is likely that caregivers underestimate this time, meaning that our results may in fact be underestimating its overall impact of television viewing on poor health. Therefore, future work should focus on using direct measures (i.e., accelerometers, inclinometers) within large cohorts of children so that groups can be stratified by volume of sedentary behaviour, sex, and age group. Direct measurements would also allow researchers to better understand the sedentary patterns children engage in throughout the day. This information would help to identify specific times when parents, caregivers, and educators should promote reductions in sedentary behaviours.

Effort was made to determine possible risks associated with decreasing children's sedentary time. However, no studies that specifically examined the association between decreased sedentary time and increased health risk could be identified. The lack of evidence may be indicative of the lack of potential harms associated with decreasing sedentary time. It is possible that parents may feel their children are "missing out" if they abstain from watching television, as there is a misconception amongst the general public that television provides unique learning (Active Healthy Kids Canada 2009, 2010; Zimmerman et al. 2007) and socializing (Holt et al. 2008) opportunities. Though there is evidence to show that violent television is more harmful than educational programming (Christakis and Zimmerman 2007; Zimmerman and Christakis 2007), evidence supporting the idea that children learn better through electronic stimulation is lacking. In fact, the opposite appears to be true (i.e., children learn better by engaging with parents and caregivers than with a television) (Barr and Wyss 2008; Barr et al. 2007; Nielsen et al. 2008; Zack et al. 2009). The authors do wish to acknowledge the safety benefits of restraining children (i.e., in a stroller, car seat) and encourage parents and caregivers to put safety first, but to try and limit this time. For example, on a long car ride, breaking up sedentary time with activity breaks may be beneficial for young children.

The authors would like to acknowledge some specific strengths and limitations to this review. This review followed the rigorous methodological standards that have been established for systematic reviews. Furthermore, this review used the GRADE framework to guide the review process and assess the evidence. In accordance with GRADE, as many decisions as possible were made a priori, which helps to limit potential bias throughout the review. Furthermore, all steps of the review (i.e., inclusion criteria, exclusion criteria, data extraction, GRADE tables) were done in duplicate to minimize error. However, using such a rigorous methodology also creates limitations. For example, it is possible this review would have benefited from including studies that used a lower quality design (i.e., cross-sectional). Further, all included studies used parental report measures of television viewing as a proxy measure of sedentary time. Future work should focus on using both direct and reported (parent, caregiver) measures to assess total daily sedentary behaviour, and its subcomponents beyond television viewing, in this age group. Ideally this would include multiple follow-up measurements so the longitudinal effects of high levels of sedentarism at a young age can be better understood. It is also important that future work aims to harmonize methods for data collection and analysis so that meta-analysis can be performed.

Conclusion

To our knowledge, this is the first published systematic review aimed specifically at clarifying the relationship between sedentary behaviour time and health indicators in the early years (aged 0–4 years). This review has found evidence that increased television viewing is associated with unfavourable measures of adiposity and decreased scores on measures of psychosocial health and motor skill development. In many cases, risks associated with television viewing increased in a dose–response manner. No benefits of increased television viewing were found. This work may be used as evidence to inform public health guidelines.

Conflict of interest

No competing interests were disclosed by authors. M.E.K. is funded by a Fellowship Award and Bisby Prize from the Canadian Institute of Health Research (CIHR). I.J. holds Tier 2 Canada Research Chair positions at Queen's University. J.A.S. is supported by a Social Sciences and Humanities Research Council – Joseph-Armand Bombardier CGS Master's Scholarship. B.W.T. holds a CIHR New Investigator Award. V.C. is supported by a CIHR – Frederick Banting and Charles Best Doctoral Award.

Authors' contributions

A.G.L. and M.S.T. were responsible for the initiation, conceptualization, and design of the systematic review; oversaw the data collection and extraction, GRADE analysis, and interpretation of data; and were responsible for revising the manuscript critically for important intellectual content. A.G.L. was the primary author of the manuscript. M.E.K. and S.C.G. were responsible for the design and methodology of the

review, GRADE assessment, and revising the manuscript critically for important intellectual content. A.G.L. and V.C. were responsible for data collection and extraction, risk of bias assessment, and were responsible for revising the manuscript critically for important intellectual content. C.D., I.J., J.C.S., J.A.S., and B.W.T. oversaw the data collection and extraction, analysis, and interpretation of data, and were responsible for revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript. M.S.T. is the guarantor of the paper.

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Appendix A

Glossary of terms and relevant study designs (Sedentary Behaviour Research Network 2012; Tremblay et al. 2010; http://www.csep.ca/CMFiles/Guidelines/PAGuidelinesGlossary_E.pdf).

Glossary of terms:

Sedentarism: Extended engagement in behaviours characterized by minimal movement, low energy expenditure, and rest.

Sedentary: A distinct class of behaviours characterized by low energy expenditure (school work, reading, TV, computer, video games) that is characterized by little physical movement and low energy expenditure ($\leq$1.5 METs).

Physically active: Meeting established guidelines for physical activity (see Canadian guidelines at www.csep.ca/guidelines).

Physical inactivity: The absence of physical activity, usually reflected as the proportion of time not engaged in physical activity of a predetermined intensity

Active video gaming: Video games that are designed to promote movement and interaction from the participant(s). Some examples include Nintendo Wii, Microsoft Kinect, Sony's Playstation Move, and video arcades that require movement.

Recreational screen time: Television watching, video game playing, using the computer, or use of other screens during discretionary time (i.e., nonschool- or work-based use) that are practiced while sedentary.

Frequency: The number of times an exercise or activity is performed. Frequency is generally expressed in sessions, episodes, or bouts per day or week.

Interruptions: Interruptions refer to the number of times sedentary behaviour is interrupted by physical activity thus decreasing the amount of prolonged sedentary behaviour.

Time: The length of time in which a sedentary behaviour is performed. Duration is generally expressed in minutes.

Type: The type of activity that the individual is engaging in. As sedentary physiology is a fairly new field and technology is constantly providing new types of sedentary behaviours, this may be in constant flux.

Experimental studies

Randomization, random allocation, random sample: A sample derived by selecting sampling units (such as patients) such that each unit has an independent (and generally equal) chance of being selected. Selection is determined by chance, often with the aid of a table of randomly ordered numbers.

Randomized trial (randomized control(led) trial, randomized clinical trial, RCT): Experiment in which individuals are randomly allocated to receive or not receive an experimental preventative, therapeutic, or diagnostic procedure and then followed to determine the effect of the intervention.

Nonrandomized control trial (or quasi experimental): Experiment in which assignment of patients to the intervention groups is at the convenience of the investigator or according to a preset plan that does not conform to the definition of random.

Before–after trial: Investigation of therapeutic alternatives in which individuals of 1 period and under 1 treatment are compared with individuals at a subsequent time, treated in a different fashion. If the disorder is not fatal and the "before" treatment is not curative, the same individuals may be studied in the before and after periods, strengthening the design through increased group comparability for the 2 periods.

Crossover trial: A method of comparing 2 or more treatments or interventions in which subjects or patients, on completion of the course of 1 treatment, are switched to another. Typically, allocation to the first treatment is by random performance in 1 period is used to judge their performance in others, usually reducing variability.

Community based clinical trial: Designed to be administered directly through primary health care physicians, community health care centres, and outpatient facilities.

Observational studies

Cohort: A group of persons with a common characteristic or set of characteristics. Typically, the group is followed for a specified period to determine the incidence of a disorder or complications of an established disorder (that is, prognosis), as in cohort study.

Cohort analytic study: Prospective investigation of the factors that might cause a disorder in which a cohort of individuals who do not have evidence of an outcome of interest but who are exposed to the putative cause are compared with a concurrent cohort who are also free of the outcome but not exposed to the putative cause. Both cohorts are then followed to compare the incidence of the outcome of interest.

Prospective cohort study: A group of individuals is selected at random from a defined population. After the cohort is selected, baseline information on potential risk factors is collected, and individuals are followed over time to track the incidence of disease between those people subsequently exposed or not exposed to the risk factor of interest.

Case-control study: Study generally used to test possible causes of a disease or disorder, in which individuals who have a designated disorder are compared with individuals who do not have the disorder with respect to previous current exposure to a putative causal factor. For example, persons with cancer (cases) are compared with persons without cancer (controls) and history of hepatitis is determined for the 2 groups. Often referred to as a retrospective study because the logic of the design leads from effect to cause. In essence,

this type of study is an attempt to look backward in time to identify the characteristics that may have contributed to the development of the disease.

Panel study: Study used prospectively to measure participants at multiple time points in an effort to determine the cause–effect relationship between and exposure and an outcome.

Appendix B: Search strategies

Table B1. MEDLINE.

No.	Searches	Results
1	exp obesity/	108 359
2	(obesit* or obese).tw.	124 960
3	exp overweight/	108 924
4	(overweight or over-weight).tw.	25 457
5	exp body fat distribution/	3 386
6	exp body composition/	29 155
7	waist circumference/	1 765
8	skinfold thickness/ or (skin fold* or skinfold*).tw.	10 083
9	(body composition* or BMI or body mass index).tw.	101 193
10	exp "body weights and measures"/	364 803
11	(bio-impedance analysis or BIA).tw.	1 451
12	absorptiometry, photon/	13 882
13	(absorptiometery or densitometry or photodensitometry or DXA or DEXA).tw.	14 714
14	exp bone/	426 975
15	bone tissue.tw.	8 146
16	Bone density/	33 356
17	Bone development/	10 846
18	Osteogenesis/	15 524
19	insulin resistance/	29 282
20	(metabolic cardiovascular syndrome or metabolic syndrome or syndrome x).tw.	18 927
21	((cardiovascular or heart or vascular) adj2 risk$).tw.	50 862
22	exp hypertension/	188 648
23	exp blood pressure determination/ or exp blood pressure monitoring, ambulatory/ or exp blood/	869 989
24	exp blood pressure/	225 909
25	exp blood glucose/ or exp diabetes mellitus, type 2/	161 720
26	exp glucose intolerance/ or glucose tolerance test/	28 896
27	Motor activity/	62 440
28	Psychomotor performance/	39 590
29	Child development/	29 819
30	gross motor skill*.tw.	231
31	cognitive development.tw.	2 610
32	"growth and development"/	592
33	Attention/	49 095
34	Self efficacy/	8 709
35	Self concept/	39 299
36	Child behavior disorder/	16 729
37	(pro-social behav* or prosocial behav* or pro social behav*).tw.	621
38	exp social behavior/	131 753
39	Aggression/	23 466
40	Temperament/	3 431
41	Social adjustment/	19 400
42	sedentar*.tw.	13 068
43	sedentary lifestyle/	561
44	((chair or sitting or car or automobile or auto or bus of indoor or in-door or screen or computer) adj time).tw.	665
45	low energy expenditure.tw.	81

Table B1 (*concluded*).

No.	Searches	Results
46	(computer game* or video game* or ((television adj watch*) or tv watch*)).tw.	1 638
47	television/	10 267
48	computer/	47 199
49	"video games"/	1 140
50	(screen based entertainment of screen-based entertainment or screen time).tw.	176
51	physical inactivit*.tw.	2 728
52	sitting.tw.	12 103
53	or/1–13	473 403
54	or/13–18	463 899
55	or/19–26	1 415 972
56	or/27–30	127 983
57	or/31–33	52 179
58	or/34–41	186 640
59	or/42–52	86 430
60	or/52–58	2 537 973
61	59 and 60	27 623
62	Limit 61 to ("infant (1 to 23 months)" or "preschool child (2 to 5 years)")	1 632
63	(infant* or preschool* or child* or pediatric* or paediatric*).tw.	1 095 855
64	61 and 63	3 534
65	62 or 64	3 901
66	cohort studies/ or comparative studies/ or follow-up studies/ or prospective studies/ or risk factors/ or cohort.mp. or compared.mp. or groups.mp. or multivariate.mp.	4 363 964
67	Limit 65 to randomized controlled trial	200
68	65 and 66	1 990
69	67 or 68	2 041

Table B2. EMBASE.

No.	Searches	Results
1	sedentar*.tw.	15 777
2	((chair or sitting or car or automobile or auto or bus of indoor or in-door or screen or computer) adj time).tw.	767
3	low energy expenditure.tw.	113
4	(computer game* or video game*).tw.	1 579
5	((television adj watch*) or tv watch*).tw.	387
6	(screen based entertainment of screen-based entertainment or screen time).tw.	188
7	television viewing/ or computer/ or recreation/	75 882
8	sitting.tw.	16 870
9	bed rest.mp.	8 763
10	physical inactivit*.tw.	3 272
11	exp obesity/	200 669
12	(obesit* or obese).tw.	160 951
13	exp overweight/	200 669
14	(overweight or over-weight).tw.	32 825
15	exp body fat distribution/	2 386
16	exp body composition/	49 106
17	waist circumference/	10 513
18	skinfold thickness/ or (skin fold* or skinfold*).tw.	12 753
19	(body composition* or BMI or body mass index).tw.	128 737
20	exp "body weights and measures"/	80 448
21	(bio-impedance analysis or BIA).tw.	1 873
22	absorptiometry, photon/	2 299
23	(absorptiometery or densitometry or photodensitometry or DXA or DEXA).tw.	19 353
24	exp bone/	573 698

Table B2 (*concluded*).

No.	Searches	Results
25	bone tissue.tw.	10 930
26	Bone density/	42 908
27	Bone development/	23 309
28	Osteogenesis/	23 309
29	insulin resistance/	53 088
30	(metabolic cardiovascular syndrome or metabolic syndrome or syndrome x).tw.	25 900
31	((cardiovascular or heart or vascular) adj2 risk$).tw.	65 751
32	exp hypertension/	404 947
33	exp blood pressure determination/ or exp blood pressure monitoring, ambulatory/ or exp blood/	1 759 587
34	exp blood pressure/	354 453
35	exp blood glucose/ or exp diabetes mellitus, type 2/	209 678
36	exp glucose intolerance/ or glucose tolerance test/	29 889
37	Motor activity/	34 369
38	Psychomotor performance/	13 923
39	Child development/	33 323
40	gross motor skill*.tw.	316
41	cognitive development.tw.	3 174
42	"growth and development"/	149 125
43	Attention/	43 954
44	Self efficacy/	47 142
45	Self concept/	47 142
46	Child behavior disorder/	37 318
47	(pro-social behav* or prosocial behav* or pro social behav*).tw.	734
48	exp social behavior/	907 085
49	Aggression/	36 353
50	Temperament/	4 791
51	Social adjustment/	17 564
52	or/1–10	120 734
53	or/11–23	426 167
54	or/23–28	623 033
55	or/29–36	2 535 536
56	or/37–40	80 442
57	or/41–43	196 037
58	or/44–51	983 554
59	or/53–58	4 512 051
60	52 and 59	34 203
61	(infant* or preschool* or child* or pediatric* or paediatric*).tw.	1 467 934
62	Limit 60 to preschool child<1 to 6 years>	1 517
63	randomly.ab.	195 183
64	trial.ti.	122 282
65	randomized.ab.	269 996
66	63 or 64 or 65	515 782
67	cohort studies/ or comparative studies/ or follow-up studies/ or prospective studies/ or risk factors/ or cohort.mp. or compared.mp. or groups.mp. or multivariate.mp.	4 519 589
68	66 or 67	4 714 508
69	Limit 62 to (clinical trial or randomized controlled trial or controlled clinical trial)	78
70	62 and 68	583
71	69 or 70	601

Table B3. Searches.

No.	Searches	Results	Search type
1	sedentar*.tw.	2 501	Advanced
2	((chair or sitting or car or automobile or auto or bus of indoor or in-door or screen or computer) adj time).tw.	173	Advanced
3	(computer game* or video game*).tw.	2 555	Advanced
4	((television adj watch*) or tv watch*).tw.	317	Advanced
5	(screen based entertainment of screen-based entertainment or screen time).tw.	83	Advanced
6	television viewing/ or computer/ or computer games/	5 173	Advanced
7	physical inactivit*.tw.	651	Advanced
8	bed rest.tw.	213	Advanced
9	sitting.tw.	2 682	Advanced
10	low energy expenditure.tw.	8	Advanced
11	exp obesity/	11 022	Advanced
12	(obesit* or obese).tw.	15 967	Advanced
13	exp overweight/	11 501	Advanced
14	(overweight or over-weight).tw.	6 087	Advanced
15	body fat/	232	Advanced
16	body weight/	8 828	Advanced
17	waist circumference.tw.	707	Advanced
18	skinfold/	0	Advanced
19	(body composition* or BMI or body mass index).tw.	9 956	Advanced
20	(bio-impedance analysis or BIA).tw.	110	Advanced
21	(absorptiometery or densitometry or photodensitometry or DXA or DEXA).tw.	291	Advanced
22	bones/	824	Advanced
23	bone tissue.tw.	26	Advanced
24	bone disorders/	276	Advanced
25	insulin resistance/	632	Advanced
26	(metabolic cardiovascular syndrome or metabolic syndrome or syndrome x).tw.	1 081	Advanced
27	((cardiovascular or heart or vascular) adj3 risk$).tw.	4 471	Advanced
28	exp hypertension/	4 368	Advanced
29	exp blood pressure determination/ or exp blood pressure monitoring, ambulatory/ or exp blood/	10 763	Advanced
30	exp blood pressure/	5 083	Advanced
31	diabetes mellitus/ or glucose/	4 868	Advanced
32	exp motor development/	6 464	Advanced
33	exp motor performance/	11 496	Advanced
34	Motor skills/ or Gross motor skill learning/	2 954	Advanced
35	exp attention/	40 650	Advanced
36	Self efficacy/	11 311	Advanced
37	Self concept/	32 664	Advanced
38	social behavior/	12 223	Advanced
39	aggressive behavior/ or child attitudes/	22 811	Advanced
40	personality/	21 089	Advanced
41	Social adjustment/	8 280	Advanced
42	language development/	18 521	Advanced
43	or/1–10	12 206	Advanced
44	or/11–21	29 555	Advanced
45	or/21–24	1 308	Advanced
46	or/25–31	28 034	Advanced
47	or/32–34	19 941	Advanced
48	or/36–41	105 011	Advanced
49	(infant* or preschool* or child* or pediatric* or paediatric*).tw.	499 808	Advanced
50	childhood play development/	996	Advanced
51	behavior problems/	20 432	Advanced
52	35 or 42 or 50 or 51	79 791	Advanced
53	44 or 45 or 46 or 47 or 48 or 52	252 956	Advanced

Table B3 (*concluded*).

No.	Searches	Results	Search type
54	44 and 53	29 555	Advanced
55	49 and 54	5 563	Advanced
56	Limit 54 to (140 infancy<age 2 to 23 mo>or 160 preschool age<age 2 to 5 years>)	1 056	Advanced
57	55 or 56	5 640	Advanced
58	cohort studies/ or comparative studies/ or follow-up studies/ or prospective studies/ or risk factors/ or cohort.mp. or compared. mp. or groups.mp. or multivariate.mp.	568 901	Advanced
59	Limit 57 to ("0430 followup study" or "0450 longitudinal study" or "2000 treatment outcome/randomized clinical trial")	742	Advanced
60	57 and 58	2 101	Advanced
61	59 or 60	2 411	Advanced

Table B4. SPORTDiscus.

No.	Query
S12	S9 and S10 and S11
S11	Sedentary or sitting or low energy expenditure or computer games or television or physical inactivity
S10	(S2 or S3 or S4 or S5 or S6 or S7)
S9	Case control study or cohort analysis or compared or multivariate or randomized controlled trial or longitudinal or follow up
S8	Children or preschool or infant or pediatric or peadiatric
S7	Self efficacy or self esteem or self concept or pro social behaviour or aggression or temperament or social adjustment
S6	Cognitive development or attention or language development
S5	Motor activity or gross motor skill or motor development or object control or child development or (growth and development)
S4	Insulin resistance or metabolic syndrome or hypertension or blood pressure or blood glucose or glucose intolerance
S3	Bone or bone density or bone development or osteogenesis
S2	Obesity or obese or overweight or body fat or waist circumference or skinfold or (DXA or DEXA)
S1	Motor activity or physical activity or exercise or play

Table B5. Preschool SB_May10: HALO.

ID no.	Search	Hits
1	(sedentar*)	547
2	((chair OR sitting OR car OR automobile OR auto OR bus OR indoor OR in-door OR screen OR computer) ADJ time)	1 023
3	(television OR tv)	1 377
4	(computer games OR video games)	294
5	(physical inactivit* OR bed rest OR sitting)	4 074
6	(no. 1 OR no. 2 OR no. 3 OR no. 4 OR no. 5)	7 964
7	(obesit* OR obese OR overweight OR over-weight OR body composition OR body fat OR waist circumference OR bio-impedance analysis OR BIA OR absorptiometry OR DXA OR DEXA OR body mass index OR BMI OR skin folds OR skin-folds OR skin-fold OR skin-folds)	22 758
8	((cardiovascular disease* OR heart disease* OR vascular disease*) ADJ risk*)	521
9	(self-esteem OR self concept OR motor development OR child development)	12 080
10	(cognition development OR behavioural conduct OR behavioral conduct OR pro-social behaviour OR pro-social behavior OR prosocial behaviour OR prosocial behavior)	4 263
11	(no. 7 OR no. 8 OR no. 9 OR no. 10)	36 724
12	(no. 6 AND no. 11)	2 220
13	(child* OR infant* OR preschool* OR pediatric OR paediatric)	86 544
14	(no. 12 AND no. 13)	873
15	(no. 14)	547

Table B6. Risk and harms of decreased sedentary behaviour. Database(s): Ovid MEDLINE(R) 1948 to week 3 of November, 2011. Search strategy.

No.	Searches	Results
1	sedentar*.tw.	13 369
2	sedentary lifestyle/	908
3	((chair or sitting or car or automobile or bus or indoor or in-door or screen or computer) adj time).tw.	627
4	low energy expenditure.tw.	85
5	(computer* or video game* or ((television adj watch*) or tv watch)).tw.	193 762
6	television/	10 730
7	computer/	48 010
8	"video games"/	1 347
9	(screen based entertainment or screen-based entertainment or screen time).tw.	189
10	physical inactivit*.tw.	2 793
11	sitting.tw.	12 105
12	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11	257 143
13	Musculoskeletal Physiological Processes/	34
14	"Wounds and Injuries"/ep, pc [Epidemiology, Prevention & Control]	12 728
15	12 and 14	248
16	Limit 15 to ("infant (1 to 23 months)" or "preschool child (2 to 5 years)")	57