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Review

Effectiveness of interventions aiming at reducing sedentary behaviour in a non-surgical population with overweight or obesity: A systematic review and meta-analysis

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ABSTRACT

Aim: This systematic review and meta-analyses of randomised controlled trials (RCTs) investigated the effectiveness of interventions to reduce sedentary behaviour amongst people with overweight or obesity. Secondarily, it aimed to investigate the effectiveness of these interventions on body mass index (BMI), time spent in moderate-to-vigorous physical activity (MVPA) and health-related quality of life (HRQoL).
Methods: A search of six databases (CENTRAL, PubMed, Embase, PEDro, CINAHL and PsycINFO) was conducted from inception to July 2018. RCTs in which sedentary behaviour was measured by accelerometry or inclinometry, with participants of any age with overweight or obesity were included. Subgroup analyses were undertaken comparing studies that included adults versus children and studies with an active component (e.g., treadmill desk, physically active breaks) versus no active component to their intervention.
Results: Nine studies (n = 1859) were included. Compared to the control group, the interventions significantly reduced time spent in sedentary behaviour (standardised mean difference [95% confidence interval] −0.33 [−0.59 to −0.08] overall; −0.53 [−0.95 to −0.11] in adults). Subgroup analyses demonstrated that only interventions that included active components reduced time spent in sedentary behaviour (−0.54 [−0.88 to −0.20]) and increased time spent in MVPA (1.29 [0.02 to 2.56]). Subgroup analyses demonstrated that interventions only reduced BMI in studies of children (−0.09 [−0.18 to −0.00]) and in those with no active component (−0.09 [−0.18 to −0.01]). There were insufficient data to investigate the effectiveness of these interventions on HRQoL.
Conclusions: This novel systematic review and meta-analyses suggests interventions aiming to effectively reduce objectively-measured sedentary behaviour need to specifically include an active component.

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Introduction

According to the World Health Organization, the prevalence of obesity worldwide has tripled since 1975 [1]. Of note, more than 1.9 billion adults were classified as overweight in 2016, of which, 650 million were obese [1]. In 2014–2015, 63.4% of Australian adults were overweight, with 27.9% of these classified as obese [2]. The main causes of obesity include increased time in sedentary behaviour and increased intake of energy-dense, micronutrient-poor food [3]. People with overweight or obesity are at increased risk of chronic health conditions, including cardiovascular disease and type 2 diabetes mellitus [4]. Overweight or obesity are also associated with significant economic costs. For example, the obesity cost of overweight and obesity to Australia in 2011–2012 was estimated to be $8.6 billion (in 2014–15 dollars) [5]. Given the detrimental health effects and economic costs associated with overweight and obesity, as well as the association between obesity and sedentary behaviour, there has been increased interest on the effects of interventions aimed at reducing sedentary behaviour in this population.

Sedentary behaviour is defined as any waking behaviour involving an energy expenditure of equal to or less than 1.5 metabolic equivalents (METs) when in a sitting or reclining posture (e.g., sitting, television viewing, computer use) [6,7]. With modern lifestyles and advances in technology, people are spending more time in sedentary behaviour [8]. Previous research found that, on average, Australian adults spend more than 50% of waking time in sedentary behaviour [9] and more than 40% of Australian's occupations involve mostly sitting [10]. An overview of 27 systematic reviews concluded that there is strong evidence supporting a positive association between sedentary behaviour and chronic health conditions and all-cause mortality in the general population [11]. Detrimental health effects may be even higher in people with overweight or obesity, since they were found to spend more time in sedentary behaviour, when compared to those with normal-weight [12–14].

It is important to differentiate between sedentary behaviour and physical inactivity. Physical inactivity is characterised by inadequate amounts of moderate-to-vigorous intensity physical activity (MVPA) (i.e., physical activity characterised by an energy expenditure >3 METs) [15]. Even if people accumulate recommended amounts of MVPA [16], and are considered physically active, they may also accrue large amounts of sedentary behaviour [7], which can have a negative impact on their health [12,17]. A systematic review and meta-analysis examining the effectiveness of interventions aimed at reducing time in sedentary behaviour amongst adults found that increasing time spent in physical activity alone does not necessarily equate to a clinically meaningful reduction in time spent in sedentary behaviour [18]. Sedentary behaviour is associated with obesity and other chronic health conditions, independent of physical activity [9,10,12,19,20]. This highlights the importance of targeting time spent in sedentary behaviour, as well as physical activity, when aiming to reduce sedentary behaviour.

Different types of interventions have been used to reduce time in sedentary behaviour; a previous systematic review suggested interventions targeting sedentary behaviour and lifestyle interventions could reduce sedentary time in the general adult population [21]. Meta-analysis of 34 studies showed an overall reduction of 22 min/day in sedentary time favouring the intervention group (95% confidence interval [CI] −35.8 to −8.9 min/day, $p = 0.001$, $I^2 = 71\%$, $n = 5868$). Previous systematic reviews investigating the effectiveness of physical activity and sedentary behaviour interventions suggest that those that include education regarding the negative health consequences associated with sedentary behaviour, self-monitoring behaviour (via the use of activity monitors) and environmental modification (such as standing desks) appear to be the most effective [18,22]. Considering the association between sedentary behaviour, obesity and other health conditions, independent of physical activity [11], interventions that aim to reduce sedentary behaviour in people with overweight or obesity appear highly relevant. As yet, there has not been a systematic review of the effects of interventions aimed at reducing sedentary behaviour in people with overweight or obesity.

Therefore, the primary aim of this systematic review and meta-analysis is to assess the effectiveness of interventions aimed at reducing objectively-measured sedentary behaviour (i.e., measured by accelerometry or inclinometry) amongst people with overweight or obesity. The secondary aim is to investigate the effects of these interventions on body mass index (BMI), time spent in MVPA and health-related quality of life (HRQoL).

Methods

Types of studies

Randomised controlled trials (RCTs) investigating the effectiveness of interventions aimed at reducing objectively-measured sedentary behaviour in people with overweight or obesity were included. This systematic review was registered at PROSPERO (https://www.crd.york.ac.uk/prospero/display_record.asp?ID=CRD42017069373).

Types of participants

This review included RCTs in which participants of any age are overweight or obese as defined by their BMI (in adults) or by BMI

cross-referenced with the World Health Organisation Growth Reference median (in children) [23]. Eligible studies with any sample size were included in this review. In studies with mixed cohorts of participants with normal-weight and overweight or obesity, the authors were contacted for data relevant to participants with overweight or obesity. If the data requested were provided, the study was also included in the review. Studies that investigated participants who underwent bariatric surgery, were pregnant or diagnosed with diabetes, cancer or other known medical conditions were excluded.

Types of intervention

Any intervention (or combination of interventions) aimed at reducing sedentary behaviour in people with overweight or obesity were included. These included, but were not limited to, education regarding the negative health consequences associated with sitting, self-monitoring behaviour (via the use of activity monitors) and environmental modification (such as standing desks) [22]. Interventions of any length were included. Due to the variety of interventions, all characteristics of the interventions including type, time frame, intensity, frequency, duration and attrition were recorded. Control groups received usual care in the form of standard curriculum or education regarding the negative health consequences associated with sitting or were waitlisted.

Types of outcome measures

The primary outcome measure of this review was time spent in sedentary behaviour as measured by accelerometry or inclinometry. Studies using scales or questionnaires to measure sedentary behaviour were excluded. Secondary outcome measures included BMI, time spent in MVPA (measured using accelerometer or inclinometer) and HRQoL [15]. The decision to only include studies that measured sedentary behaviour using accelerometers or inclinometers was made because these devices can objectively differentiate between sedentary behaviour and physical activity [9,24], and self-reported sedentary behaviour may not be an accurate reflection of overall sedentary time [25].

Search methods for identification of studies

Studies were identified by searching six electronic databases, published from each database inception until July 2018: CENTRAL (the Cochrane registry of controlled trials), PubMed, Embase (via Ovid), PEDro, CINAHL and PsycINFO. The search terms and strategy used were: #1 – overweight OR obes* OR high body mass OR high body mass index OR high BMI; #2 – sedentary behavi* OR sedentar* OR sitting OR underactiv* OR physical inactiv* OR inactiv*; #3 – #1 AND #2; #4 – acceleromet* OR, inclinomet* OR, actigraph* OR, activity monitor* OR GPS; #5 – #3 AND #4. A search of the reference lists of accepted studies, review articles and registered RCTs was completed. Duplicates were identified and removed using EndNote (EndNote X7.7.1). The EndNote library was then uploaded to Covidence (http//www.covidence.org). Two review authors (SM, KK) independently reviewed the titles and abstracts of all studies identified, with any disagreement being resolved by a third review author (VC). Two review authors (SM, RC) then independently reviewed the full text of all included studies and determined the inclusion of acceptable studies. Any disagreement was resolved by a third review author (VC). Abstracts from conference presentations and study protocols were excluded. Where necessary, authors of potentially eligible studies were contacted regarding missing or unpublished data of participants with overweight or obesity.

Data extraction and quality assessment

Three review authors (RC, KK, SM) extracted data using a standardised form and data was assessed for accuracy by the other four review authors (MH, VC, LN, JZ). Then, meta-analyses were conducted by four review authors (RC, KK, VC, JZ) for primary and secondary outcomes using Review Manager (RevMan version 5.3. Copenhagen: the Nordic Cochrane Centre, The Cochrane Collaboration 2014).

The Cochrane collaboration's 'seven evidence based domains' table was used to assess the risk of bias within the included studies [26]. Risk of bias was assessed by three review authors (RC, SM, KK) and cross-checked by four review authors (MH, VC, LN, JZ). A review of protocols of RCTs published in clinical trials registries (ANZCTR.gov.au and ClinicalTrials.gov) was conducted to identify reporting bias.

Data synthesis and analysis

Standardised mean difference (SMD) and 95% CI were calculated for continuous outcomes to account for the variance in reporting for outcomes. Where the standard deviation (SD) of the within-group difference from baseline to post-intervention was not reported in the included studies, it was calculated (in RevMan) based on 95% CIs. For those studies that did not report within-group difference from baseline to post-intervention, post-intervention data were used in the meta-analysis, as long as no significant difference between the control group and intervention group was reported at baseline.

Clinical heterogeneity within all included trials was examined and reported. Heterogeneity was investigated by visual assessment of forest plots and calculation of the I^2 statistic. The I^2 provided an estimate of the percentage of variability due to heterogeneity rather than to chance alone. Heterogeneity was considered to be substantial if $I^2 > 50\%$ [26]. In the case of substantial heterogeneity, sensitivity analysis was undertaken to investigate if clinical or methodological heterogeneity were the potential causes.

Meta-analyses were conducted using the inverse variance DerSimonian and Laird method [27]. A random-effect model was utilised in order to calculate summary estimates. If the studies were shown to be homogeneous, a fixed-effect model was used. Subgroup analysis was conducted to investigate possible differences in findings of RCTs that included (i) adults vs children and (ii) interventions with an active component vs no active component.

Results

Flow of studies through the review

The initial search identified 1391 records from all databases and no additional records were found through hand search of reference lists of included studies. Nine RCTs were included in this systematic review [28–36]. The study flow diagram is presented in Fig. 1.

Characteristics of studies

Characteristics of included studies are presented in Table 1. All nine studies included participants with overweight or obesity. The total number of participants across the nine RCTs was 2884, ranging between 10 and 2221 [28–36]. However, only data from the participants with overweight or obesity were included in the analyses, with a total number of 1859 participants, ranging between 10 and 1252 in individual studies. Five studies included adults aged between 18 and 65 years [28–32] and the other four studies included children aged between 6 and 12 years [33–36].

Table 1
Characteristics of included studies (data for participants with overweight or obesity only).

Author	Participants	BMI *Mean* (*SD*)	Age *n*	Sex M/F *n*	Intervention	Control	Duration of study	Accelerometry/ inclinometry protocol	Analysis type and Attrition *n*(%)	Outcome Measures	Time point for data extraction
Biddle et al. [28]	n = 187 adults with overweight or obesity with one or more risk factor for T2DM	I: 34.9 (4.9) C: 34.5 (5.0)	I: 32.4 (5.45) C: 33.3 (5.8)	I: 28/66 C: 31/62	n = 94 Group-based education workshop (single 3-h session), self-monitoring device to aid behaviour change 'Gruve' MUVE 4, motivational phone call	n = 93 Information leaflet focusing on education about T2DM, importance of PA and reducing SB, negative health benefits associated with sitting	12 months	Actigraph GT3X accelerometer worn for 10 consecutive days during waking hours including bathing activities	ITT analysis I: 94, C: 93 Attrition I: 30/94 (32%) C: 25/93 (27%) 25% non-attendance at education workshop	ST (hours/day) BMI (kg/m^2) MVPA (min/day) HRQoL (EQ-5D)	12 months
Carr et al. [29]	n = 49 adults with overweight, working in full time sedentary desk dependent occupations	I: 31.7 (4.9) C: 33.2 (4.5)	I: 42.6 (8.9) C: 47.6 (9.9)	I: 3/20 C: 1/16	n = 25 Portable pedal machine, pedometer (Omron HJ-150), web-based motivation (Walker Tracker), no specific guidelines for use of pedal machine	n = 24 Wait-list, maintained behaviours for 12 weeks at which time they were given the option to receive the intervention	12 weeks	StepWatch activity monitor worn for 7 consecutive days during waking hours	Per-protocol analysis I: 23, C: 17 Attrition I: 2/25 (8%) C: 7/24 (29%)	ST (min/day) BMI (kg/m^2) Light intensity PA (min/day) Moderate intensity PA (min/day) Vigorous intensity PA (min/day)	12 weeks
Carr et al. [30]	n = 60 adults with overweight or obesity, physically inactive, working in full time sedentary jobs	I: 34.5 (6.8) C: 33.0 (5.6)	I: 45.2 (10.90) C: 45.0 (10.70)	I: 8/19 C: 8/19	n = 30 Portable seated under-desk, elliptical machine (activeLife Trainer), iPod Touch tracker, pedalling goal sheet (progressed from 30 min/day to 80 min/day at week 16)	n = 30 Equivalent protocol to what the intervention group received (ergonomic workstation optimization intervention, emails prompting rest breaks and posture variation) but no active work station	16 weeks	GENEActiv original, worn for 5 continuous working days during all non-bathing hours	Per-protocol analysis I: 27, C: 27 Attrition I: 3/30 (10%) C: 3/30 (10%)	ST (% occupational work day) Light intensity PA (% work day) Moderate intensity PA (% work day) Vigorous intensity PA (% work day)	16 weeks

Schuna et al. [31]	n = 41 adults with overweight or obesity office workers, whose job descriptions required continuous desk work	I: 36.1 (8.7) C: 35.6 (8.2)	I: 40.0 (9.5) C: 40.3 (10.9)	I: 0/21 C: 1/19	n = 21 Shared-treadmill desk intervention, 90 min/day (2 × 45 min sessions), automated reminder for participants 10 min prior to their scheduled session	n = 20 No formal intervention (usual working conditions)	3 months	ActiGraph GT3X+ accelerometer worn for at least 4 working days (weekdays) for 24 h	Per-protocol analysis I: 15, C: 16 Attrition I: 6/21 (29%) C: 4/20 (20%)	ST (min/h) BMI (kg/m^2) MVPA (min/h)	3 months
Judice et al. [32]	n = 10 adults with overweight or obesity, employed in a full-time academic or administrative role that involved greater than 7 h/day computer-based work	Cross-over design: 32.6 (5.5)	Cross-over design: 50.4 (11.5)	Cross-over design: 5/5	n = 10 Workplace intervention to reduce sitting time. A software program (Workrave, GitHub) gave hourly alerts to break-up sitting-time for approximately 7 min through taking part in walking. Step goal-setting was also used.	n = 10 Participants were told to maintain their habitual physical activity levels and sedentary patterns in both working and non-working hours	2 weeks (1 week intervention and 1 week control)	ActivPAL Professional worn 24 h per day for 7 days	Paired analysis (as it was a cross-over RCT) Attrition All participants completed the study	Sitting time (hours/day) Standing-time (hours/day) Stepping time (hours/day)	Post I (7 days)
Grydeland et al. [33][a]	n = 96 11-year-old adolescents	I: 23.6 (1.8) C: 23.0 (2.1)	I: 11.2 (0.3) C: 11.2 (0.3)	I: 6/20 C: 31/36	n = 28 School-based intervention (HEIA study) consisting of class components (pedometer, 10-min PA break weekly), parent education, activity box	n = 68 Normal curriculum, wore accelerometers	20 months	Actigraph 7164/GT1M worn for 5 consecutive days during all non-bathing waking hours (data from the first day not included)	Per-protocol analysis I: 26, C: 67 Attrition Reports high dropout and not enough valid accelerometry data across the full cohort of participants	ST (min/day) BMI (kg/m^2)	Post I (20 months)

Table 1 (*Continued*)

Author	Participants	BMI	Age	Sex	Intervention	Control	Duration of study	Accelerometry/ inclinometry protocol	Analysis type and Attrition	Outcome Measures	Time point for data extraction
		Mean (*SD*)	*n*	M/F *n*					*n*(%)		
Kipping et al. [34][a]	n = 2221 8–9 year-old children in year 4	Not provided by authors	I: 9.5 (0.3)	I: 544/520	n = 1064	n = 1157	Not reported in detail – delivered during school year 5	Actigraph GT3X+ accelerometer worn for 5 days (3 week day, 2 weekend) during all non-bathing hours	ITT analysis	ST (min/day)	Post I (end of year 5)
			C: 9.5 (0.3)	C: 549/608	School-based intervention (active for Life Year 5) including 16 lessons, 10 parent–child interactive homework activities	Normal curriculum			ST I: 603, C:649 BMI I: 880, C:953	BMI (z-score) MVPA (min/day)	
Serra-Paya et al. [35]	n = 113 6–12 year-old children with overweight or obesity engaged in low levels of activity (<2 h/week of outside of school hours)	I: 25.22 (3.35)	I: 10.1 (1.98)	Not provided by authors	n = 54	n = 59	8 months	ActiGraph GT3X+ accelerometer worn for 8 consecutive days during waking hours	ITT analysis I: 54, C: 59	ST (% awake time)	8 months
		C: 24.65 (3.18)	C: 9.73 (1.97)		Family-based multi-component behavioural intervention (Nereu Program), including 90 1-h PA sessions (3 per week) and 60 min counselling sessions (one per week for 60 min)	Usual advice from Pediatrician on healthy eating and PA			Attrition I: 10/54 (19%) C: 14/59 (24%)	BMI (sd) MVPA (% awake time)	

Wafa et al. [36]	n = 107 7–11 year-old children with obesity, with at least one parent who perceived their child's weight as a problem	I: 27.6 (3.4)	I: 9.7 (1.4)	I: 28/24	n = 52	n = 55	26 weeks	CSA/MTI GT1 M accelerometer worn for 5 days during waking hours	Per-protocol analysis I: 34, C: 45	ST (% monitored daytime)	6 months
		C: 28.0 (7.0)	C: 9.9 (1.6)	C: 26/29	Group-based intervention aiming to change child's SB, PA and diet. Largely lead by a dietician, including 8 sessions, total of 8 contact hours	Wait-list, did not receive treatment until at least 6 months had elapsed after the study had ended			Attrition I: 18/52 (35%) C: 9/55 (16%)	BMI (z-score) MVPA (% monitored daytime) HRQoL (Peds QL)	

BMI, body mass index; BMI (sd), BMI standard deviation according to lambda-mu-sigma (LMS) method for constructing normalised growth standards; C, control group; ED 5Q, EuroQol 5 Dimensions; HEIA, health in adolescents study; HRQoL, health-related quality of life; I, intervention group; ITT, intention to treat; MVPA, moderate-to-vigorous intensity physical activity; n, number of participants; PA, physical activity; Peds QL, Pediatric Quality of Life Inventory; SB, sedentary behaviour; SD, standard deviation; ST, sedentary time; T2DM, type 2 diabetes mellitus.

[a] Data provided by authors.

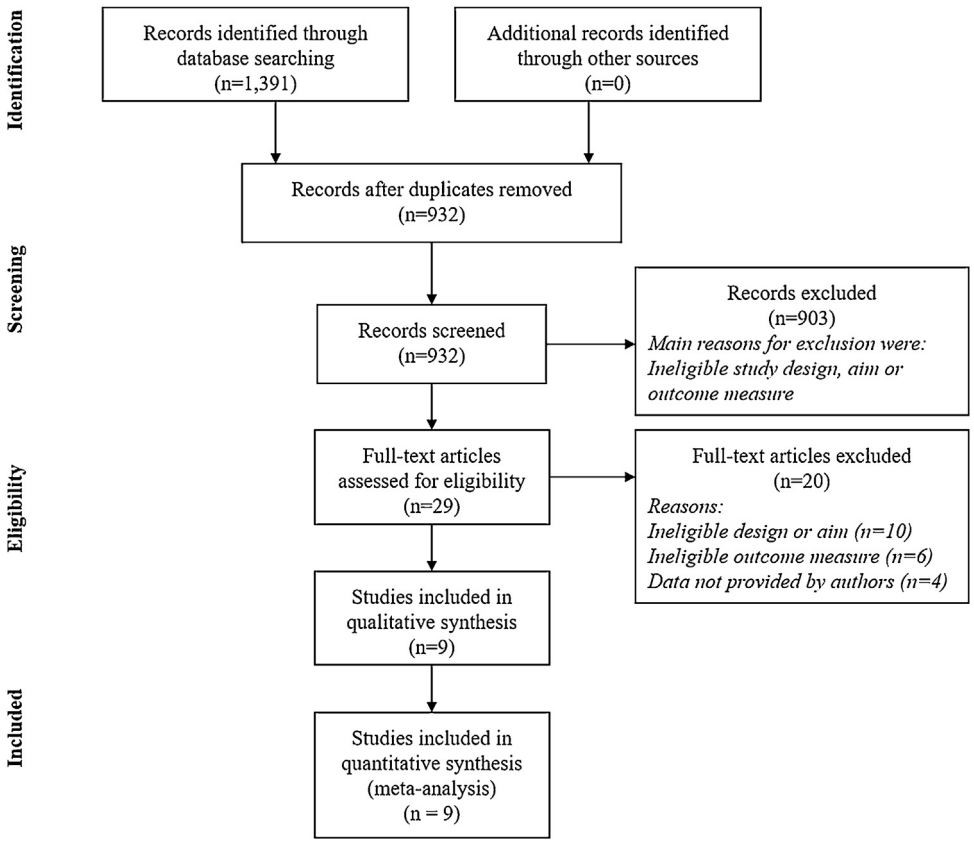

Fig. 1. Study flow diagram.

The interventions varied across the nine studies included in this review. Intervention groups were provided with active components such as a treadmill desk [31], portable pedal machine [29], seated under desk elliptical machine [30], physical activity sessions [35], physical activity break/activity box [32,33], whereas three studies focused on an educational intervention and encouragement to decrease time spent in sedentary behaviour (without including an active component to the intervention) [28,34,36]. Control groups received no formal intervention (i.e., maintained their normal behaviours for the duration of the intervention [31,32], received normal curriculum [33,34], wait-list control [29,36], equivalent protocol to what the intervention group received except for active component [30]), usual advice from pediatrician on healthy eating and physical activity [35] or information leaflet regarding the negative health benefits associated with sitting [28]. The duration of interventions varied between 2 weeks and 12 months, and total dosages of intervention between a single 3-h group session to 90 one-hour sessions.

Risk of bias in included studies

A summary of the risk of bias across the included studies is shown in Fig. 2. Eight studies were assessed as having low risk of selection bias (randomisation) [28–30,32–36]. Five studies reported adequate allocation concealment (low risk of selection bias) [29,32,34–36]. The other four studies did not explicitly state the method of the allocation concealment (unclear risk on allocation concealment) [28,30,31,33]. All included studies were assessed as having a high risk of performance bias (no blinding of participants and personnel).

In five studies outcome assessors were blinded to group allocation (low risk of performance bias) [29,30,34–36]. Two studies described the outcome assessors were not blinded (high risk of performance bias) [28,33], and two studies did not report sufficient information on blinding outcome assessors (unclear risk of performance bias) [31,32]. Six studies were assessed as having low risk of attrition bias [29–32,34,35], whereas three studies were assessed as having high risk of attrition bias, due to (i) high dropout rates [28]; (ii) no intention to treat analysis, without clear description of missing data [33]; and (iii) having the primary outcome measured in 34/52 (65%) in the experimental group and 46/55 (84%) in the control group, which was not balanced between groups, and the lack of intention to treat analysis [36].

Four studies were assessed as having low risk of selective reporting bias [29,30,32,34] whereas two studies were assessed as having high risk of reporting bias [28,35]. Three studies were not able to be assessed because of insufficient information provided regarding reporting bias [31,33,36]. Five studies revealed a high risk of other bias that included a control group starting six months later due to (i) being on a waiting list (could have been affected by a waiting list effect) [36]; (ii) poor adherence to the intervention (51% of adherence) [35]; and (iii) attention bias towards the treatment group [28,29,31]. The remaining four studies were evaluated as either having a low risk of other bias [30,32,34] or having an unclear risk since insufficient information was provided [33].

Effect of interventions

Outcome: time spent in sedentary behaviour

Based on pooled data from the nine included studies, overall, time spent in sedentary behaviour was significantly reduced in the intervention group when compared to the control group (SMD [95% CI] −0.33 [−0.59 to −0.08]) (Fig. 3).

Adults vs children. Pooled data of the five studies that investigated time spent in sedentary behaviour in adults who are overweight

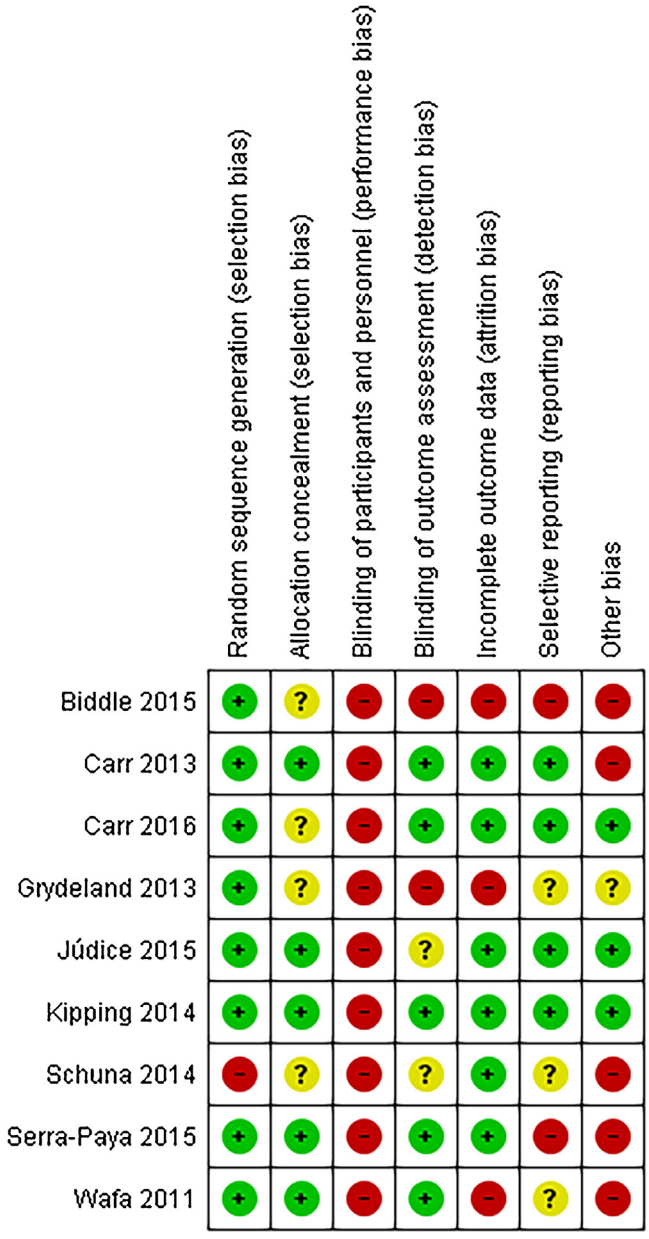

Fig. 2. Risk of bias summary: review authors' judgement about each risk of bias item for each included study.

or obese [28–32] demonstrated that, on completion of intervention, time spent in sedentary behaviour was significantly reduced in the intervention group when compared to the control group (SMD [95% CI] −0.53 [−0.95 to −0.11], I^2 62%) (Fig. 3A). Substantial heterogeneity was observed in the subgroup of studies that included adults (I^2 = 62%). Sensitivity analysis was therefore undertaken excluding the study by Biddle et al. [28] which was the only study in adults in which the intervention did not include an active component. Further, 24% of participants allocated to the intervention group did not attend the structured education workshop and a high attrition rate at 12 months was reported (32% attrition in the intervention group). The exclusion of the study by Biddle et al. [28] yielded a more favourable point estimate for the reduction in time spent in sedentary behaviour in adults that received interventions (SMD [95% CI] −0.71 [−1.05 to −0.37]), without substantial heterogeneity (I^2 = 0%), based on data from the remaining four studies [29–32].

Pooled data of the four studies that investigated time spent in sedentary behaviour in children who are overweight or obese [33–36] demonstrated that, on completion of intervention, there was no significant difference between the intervention and control groups (SMD [95% CI] −0.19 [−0.54 to 0.16]) with substantial heterogeneity (I^2 = 78%) (Fig. 3A). Due to significant methodological differences across the four studies, sensitivity analysis was not undertaken.

Active component vs no active component. Pooled data from the six studies that included interventions with an active component [29–33,35] demonstrated that, on completion of intervention, time spent in sedentary behaviour was significantly reduced in the intervention group when compared to the control group (SMD [95% CI] −0.54 [−0.88 to −0.20], I^2 = 52%) (Fig. 3B). Due to substantial heterogeneity in the subgroup of studies that included interventions with an active component, sensitivity analysis was undertaken excluding the study by Grydeland et al. [33], for which the intervention components predominantly targeted increasing overall MVPA to reduce sedentary behaviour. The exclusion of the study by Schuna et al. [31] resulted in a more favourable point estimate for the reduction in time spent in sedentary behaviour in the intervention group (SMD [95% CI] −0.69 [−0.94 to −0.43]), without substantial heterogeneity (I^2 = 0%), based on data from the remaining five studies [29–32,35]. Pooled data of the three studies that included interventions without an active component [28,34,36] demonstrated that, at completion of intervention, there was no significant difference between groups (SMD [95% CI] 0.00 [−0.11 to 0.12]) (Fig. 3B).

Outcome: body mass index

Based on pooled data from seven studies [28,29,31,33–36], overall, BMI was significantly reduced in the intervention group when compared to the control group (SMD [95% CI] −0.09 [−0.17 to −0.01], I^2 = 0%) (Fig. 4).

Adults vs children. Pooled data of the three studies that investigated BMI in adults who are overweight or obese [28,29,31] demonstrated that, on completion of intervention, there was no significant difference between the intervention and control groups (SMD [95% CI] −0.07 [−0.32 to 0.17], I^2 = 28%) (Fig. 4A). Pooled data of the four studies that investigated BMI in children who are overweight or obese [33–36] demonstrated that, on completion of intervention, there was a significant reduction in BMI in the group that received intervention, without substantial heterogeneity (SMD [95% CI] −0.09 [−0.18 to −0.00], I^2 = 0%) (Fig. 4A).

Active component vs no active component. Pooled data from the four studies that investigated BMI and included interventions with an active component [29,31,33,35], demonstrated that, on completion of intervention, there was no significant difference between the intervention and control groups (SMD [95% CI] −0.07 [−0.31 to 0.18], I^2 = 39%) (Fig. 4B). Pooled data of the three studies that investigated BMI and included interventions without an active component [28,34,36] demonstrated that, at completion of intervention, there was a significant reduction in BMI in the group that received intervention, without substantial heterogeneity (SMD [95% CI] −0.09 [−0.18 to −0.01], I^2 = 0%) (Fig. 4B).

Outcome: time spent in moderate-to-vigorous physical activity

Based on pooled data from five studies [28,31,32,35,36], overall, time spent in MVPA was not different between the intervention group and the control group (SMD [95% CI] 0.72 [−0.02 to 1.47], I^2 = 91%). This high heterogeneity may have occurred due to strong positive results of the studies by Judice et al. [32] and Serra-Paya

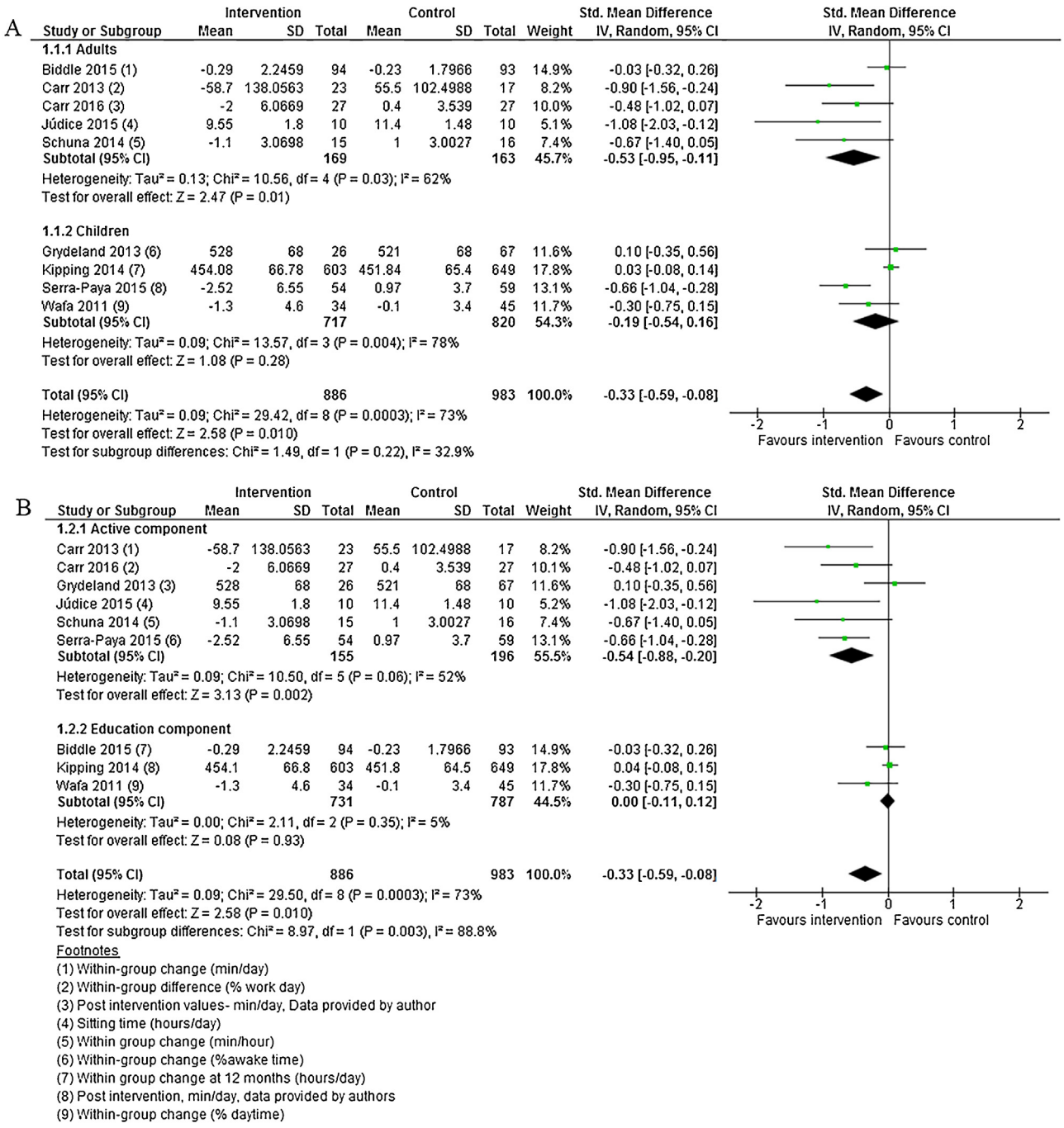

Fig. 3. Forest plot of comparison: effect of intervention on time spent in sedentary behaviour overall, for (A) adults vs children and (B) active component vs no active component.

et al. [35] (Supplementary material – Fig. S1) and clear methodological differences between these studies and the other three studies [28,31,36]. Subgroup analysis did not demonstrate differences between adults vs children (Supplementary material – Fig. S1). However, subgroup analysis of interventions with active vs no active component demonstrated that, on completion of intervention with active components, time spent in MVPA was significantly increased in the intervention group when compared to the control group (SMD [95% CI] 1.29 [0.02 to 2.56]) with substantial heterogeneity ($I^2 = 89\%$) (Supplementary material – Fig. S2). Sensitivity analyses were undertaken omitting one of the three studies at a time, with substantial heterogeneity ($86 \leq I^2 \leq 94$) maintained for all combinations of two studies.

Outcome: health-related quality of life

Meta-analysis was not undertaken for this outcome as only two studies reported HRQoL, using different questionnaires (the EuroQol 5 Dimensions [28] and the Pediatric Quality of Life Inventory [36]). One of these studies included adults [28] and the other included children [36]. There was no statistically significant difference in HRQoL between the intervention and control groups in any of the two studies (SMD [95% CI] −0.09 [−0.38 to 0.19] [28]; SMD [95% CI] 0.44 [−0.01 to 0.89] [36]).

Discussion

Nine RCTs have been included in this systematic review with a total of 1859 participants with overweight or obesity. The

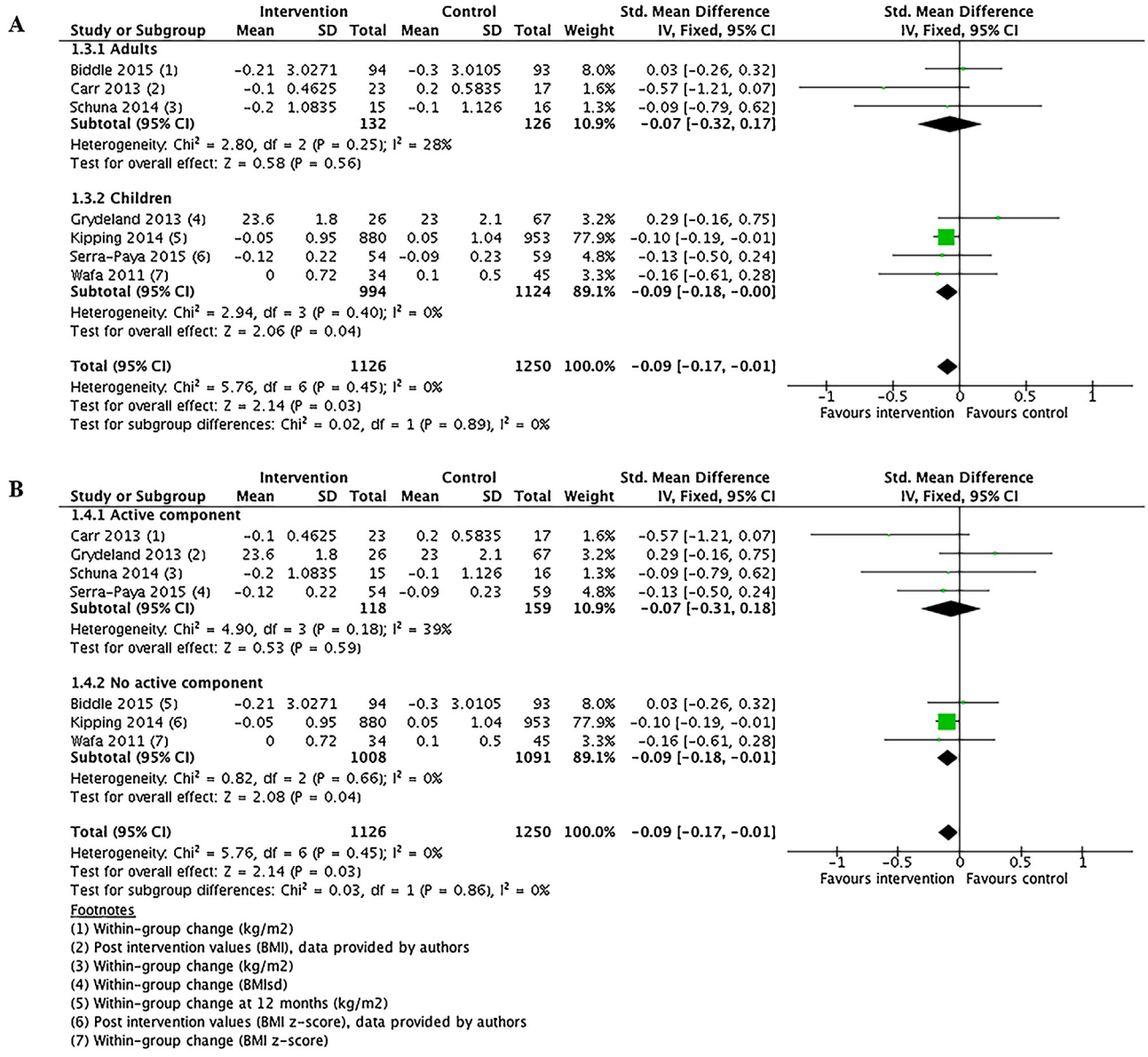

Fig. 4. Forest plot of comparison: effect of intervention on body-mass index overall, for (A) adults vs children and (B) active component vs no active component.

meta-analyses demonstrated that interventions aimed at reducing sedentary behaviour are, overall, effective at reducing time spent in sedentary behaviour (SMD [95% CI] −0.33 [−0.59 to −0.08]) and BMI (SMD [95% CI] = −0.09 [−0.17 to −0.01]) in people with overweight or obesity. Overall, there was no statistically significant difference between intervention and control groups in time spent in MVPA. There were insufficient data to investigate the effectiveness of these interventions on HRQoL.

Even though the types of intervention, duration of the intervention, and time points at which outcome measures were assessed varied amongst studies, pooled analyses demonstrated that interventions were effective at reducing objectively-measured sedentary behaviour. This finding is supported by previous systematic reviews that suggested sedentary behaviour interventions can be effective at reducing the amount of time adults spend sedentary [18,21,37]. However, these reviews did not focus on people with overweight or obesity, and included studies that used subjective measures of sedentary time, which can result in inaccurate estimates of time spent in sedentary behaviour [25]. However, subgroup and sensitivity analyses revealed that the effectiveness of such interventions rely on the inclusion of an active component. That is, analysis of the subgroup of studies that included an active component as part of their intervention (four studies in adults [29–32] and two studies in children [33,35]), demonstrated that participants that underwent interventions with an active component significantly reduced their time spent in sedentary behaviour compared to a control group. Conversely, participants that underwent interventions with no active component did not reduce their time spent in sedentary behaviour compared to a control group. These findings suggest that interventions based on education alone are not effective at changing sedentary behaviour. As proposed in one of the included RCTs [28], education alone as an intervention may not be sufficient to reduce time spent in sedentary behaviour, and an environmental modification may be required. Environmental modifications such as computer locking software, treadmill desk or under desk elliptical/pedal machine may maximise opportunity (prompt/make the behaviour possible) and influence motivation to limit or restrict sedentary behaviour [22]. Michie et al. [38] proposed that three essential conditions including capability, opportunity and motivation are required for

behaviour change interventions. Interventions with an active component (i.e., treadmill desk, pedal machine, physical activity breaks) not only provide the idea to move, but also make the activity accessible (opportunity) and visible (motivation), whereas educating participants about the importance of decreasing time spent in sedentary behaviour does not necessarily provide them with opportunity and motivation.

Heterogeneity for interventions that included an active component may be explained by the fact that the intervention components in the study by Grydeland et al. [33] predominantly targeted increasing overall physical activity to reduce sedentary behaviour (plus dietary advice). A systematic review and meta-analysis has shown that interventions focusing on physical activity or those including both a physical activity and sedentary behaviour component, resulted in smaller reductions in sedentary time in adults [18]. Another review found that interventions combining an increase of physical activity with a reduction in sedentary behaviour, when compared with studies just focussing on reducing time spent in sedentary behaviour did not reduce sedentary time in adults [21]. These findings highlight the importance of increasing knowledge regarding the difference between sedentary behaviour and physical inactivity and the detrimental health effects associated with increased time spent in sedentary behaviour [21]. Consistent with previous systematic reviews [18,21], the findings of this study suggest that strategies specifically focused on reducing sedentary behaviours should be used in order to effectively decrease time spent sedentary.

In addition to reducing sedentary time, interventions aimed at reducing sedentary behaviour were effective at reducing BMI in people with overweight or obesity. However, subgroup analysis demonstrated that this effect is mainly seen in children with overweight or obesity. This may be because studies that included children conducted multi-component behavioural interventions, focusing on not only decreasing sedentary time, but also changing their diet and encouraging them to increase their physical activity levels, while those studies including adults were focused on reducing time spent in sedentary behaviour. Azevedo et al. [39] conducted a systematic review and meta-analysis investigating the effectiveness of sedentary behaviour interventions for reducing body mass index amongst children and adolescents. Their findings indicated that multi-component interventions, which targeted sedentary behaviours and other behaviours (e.g., diet and physical activity) appear to favour BMI reduction. Additionally, studies that included children also employed involvement of children's family and teachers as a key strategy. Of note, children's diet and time spent in physical activity and sedentary behaviours is highly controlled by their parents or carers. Therefore, the fact that children may lose weight in response to such interventions is likely due to the high level of influence adults have on children's diet and activity levels, thereby leading to behaviour change [40]. Previous studies highlighted parent's influential role in supporting and managing children's behaviours, and the importance of having parents and carers as targets in interventions [41,42]. The finding that interventions with an active component did not significantly reduce BMI despite a reduction in sedentary behaviour and increase in MVPA was somewhat unexpected. A possible rationale could be that the reduction in sedentary behaviour and increase in MVPA may be associated with small changes in body composition (i.e., increase in lean body mass and decrease in fat mass) that are not reflected by significant change in body weight, and consequently no significant change in BMI [43,44].

There was no overall difference in time spent in MVPA between intervention and control groups. This finding may be explained by the fact that studies included in this systematic review were aimed at reducing sedentary behaviour. Previous work has shown that time spent in sedentary behaviour is mostly replaced by more time performing light-intensity physical activities (e.g., standing, walking slowly and doing light house chores), rather than MVPA [45,46]. Two studies [29,30] included portable under-desk pedal or elliptical machine as the active component in the interventions. Although pedalling activity may not be accurately measured due to accelerometer placement (e.g., accelerometer wore on the hip), these studies used ankle-worn devices with superior ability for detecting pedalling time when compare to hip-worn accelerometers. The effectiveness of numerous physical activity interventions to increase MVPA has been previously established [47,48]. Although substantial heterogeneity was found, the subgroup analysis of the current review, supports the previous studies findings by demonstrating that interventions with active components increased time spent in MVPA. Our findings also reinforce that increasing time spent in MVPA and reducing time spent in sedentary behaviour must be treated as separate, however, complementary aims of interventions.

Meta-analysis was not undertaken for HRQoL as only two studies reported HRQoL data, one in children [36] and one in adults [28]. There studies used different questionnaires to assess HRQoL and there was insufficient data to draw a conclusion. Health-related quality of life can be broadly divided into two main components, related to psychosocial and physical health aspects. The impact of prolonged time spent in sedentary behaviour on psychosocial health remains less clear than its impact on physical health outcomes [49]. Sedentary behaviour, defined as higher amounts of prolonged sitting for greater than 8 h/day, has been shown to be associated with poorer self-rated health in adults [50] and may negatively impact HRQoL, particularly the physical health aspects [51]. Further, an Australian study that included adolescents, found an inverse relationship between HRQoL and time spent using screen-based media [52]. These findings highlight the importance of further research into the impact of prolonged time spent in sedentary behaviour and interventions aimed at reducing time spent in sedentary behaviour on HRQoL.

Strengths and limitations

This is the first systematic review to assess the effectiveness of interventions aimed at reducing sedentary behaviour in people with overweight or obesity. Other key strengths of the current review are the use of a comprehensive search strategy across six databases [53] and the inclusion of RCTs only. Additionally, only studies that measured sedentary behaviour and MVPA using objective measures (i.e., accelerometry or inclinometry) were included in this review. Objective measures have been shown to be more accurate in estimating time spent in sedentary behaviour and MVPA when compared to subjective measures (e.g., scales and questionnaires) [25]. This is of particular importance amongst people with overweight or obesity, as adults with overweight appear to report significantly higher vigorous physical activity on self-reported measures when compared to accelerometry [54], and those with obesity have been found to incorrectly classify physical activity intensity [55].

Limitations of this review include the exclusion of four studies, despite meeting inclusion criteria, as either the authors did not have access to the missing data that they were requested or the authors did not reply to requests for data. Three studies included in this review that measured time spent in MVPA were not included in the meta-analysis of time spent in MVPA as the authors did not respond to requests for missing data. Additionally, risk of performance bias (i.e., blinding of participants and personnel) was rated as high in all nine included studies. This is due to the obvious nature of interventions aimed at reducing sedentary behaviour [55].

Conclusion

Interventions aimed at reducing sedentary behaviour in a non-surgical population with overweight or obesity are effective at reducing time spent in sedentary behaviour and BMI. The findings of this review suggest that interventions aimed at reducing sedentary behaviour need to specifically include an active component such as a treadmill desk, under desk elliptical/pedal machine or environmental modification such as sports equipment/altering school playground to stimulate activity, physical activity session/breaks during school or work hours, or active commuting. Education alone may not necessarily be adequate to reduce sedentary behaviour in this population. The findings of this review also suggest that interventions aimed at reducing sedentary behaviour are effective at significantly reducing BMI in children. Future research should examine the types of active components of interventions that are more effective at reducing time spent in sedentary behaviour of people with overweight or obesity, as well as investigate their impact on HRQoL.

Conflict of interest

The authors have no conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.orcp.2018.10.004.

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