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Review Article

The effects of standing desks within the school classroom: A systematic review

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ABSTRACT

Background. The school classroom environment often dictates that pupils sit for prolonged periods which may be detrimental for children's health. Replacing traditional school desks with standing desks may reduce sitting time and provide other benefits. The aim of this systematic review was to assess the impact of standing desks within the school classroom.

Method. Studies published in English up to and including June 2015 were located from online databases and manual searches. Studies implementing standing desks within the school classroom, including children and/or adolescents (aged 5–18 years) which assessed the impact of the intervention using a comparison group or pre–post design were included.

Results. Eleven studies were eligible for inclusion; all were set in primary/elementary schools, and most were conducted in the USA (n = 6). Most were non-randomised controlled trials (n = 7), with durations ranging from a single time point to five months. Energy expenditure (measured over 2 h during school day mornings) was the only outcome that consistently demonstrated positive results (three out of three studies). Evidence for the impact of standing desks on sitting, standing, and step counts was mixed. Evidence suggested that implementing standing desks in the classroom environment appears to be feasible, and not detrimental to learning.

Conclusions. Interventions utilising standing desks in classrooms demonstrate positive effects in some key outcomes but the evidence lacks sufficient quality and depth to make strong conclusions. Future studies using randomised control trial designs with larger samples, longer durations, with sitting, standing time and academic achievement as primary outcomes, are warranted.

Contents

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1. Introduction

Due to advances in technology and environmental changes over the last few decades, particularly in more developed countries, many people spend the majority of their waking day sedentary (Ng & Popkin, 2012). Sedentary behaviour has been defined as "any waking behaviour characterised by an energy expenditure ≤1.5 METs while in a sitting or reclining posture" (Sedentary Behaviour Research Network., 2013). Adverse associations between high levels of sedentary behaviour and cardio-metabolic health risk markers (for example: obesity, blood pressure, cholesterol, insulin, and reduced cardiorespiratory fitness) have been reported in children (Marshall et al., 2004; Mitchell & Byun, 2014; Tremblay et al., 2011). Furthermore, high levels of sedentary time have also been associated with reduced self-esteem and academic performance (Tremblay et al., 2011). These effects are largely independent of moderate-to-vigorous-physical activity (Mitchell & Byun, 2014).

While children are the most active age group, sedentary behaviour is increasingly prevalent in this population; data suggest that Canadian and US children spend around 60% (6–8 h) of waking hours sedentary, while studies suggest that UK children spend more than 65% of waking hours sedentary (Colley et al., 2011; Steele et al., 2009; Whitt-Glover et al., 2009). Sedentary behaviour has been found to track from childhood into adolescence and adulthood (Biddle et al., 2010). Therefore, the development of effective strategies to reduce sedentary behaviour is imperative for the current and future health of young people.

While children function in multiple environments including the home, community and school, evidence suggests that children sit for longer during school hours compared to non-school hours (Abbott et al., 2013). School pupils typically spend the majority of their school day in a classroom where the environment dictates prolonged periods of sitting. The classroom is therefore an important and opportune environment for the implementation of interventions aiming to reduce sitting (Salmon, 2010).

Environmental changes in the workplace such as the implementation of adjustable sit-to-stand desks, which enable the user to alternate between sitting and standing, have led to significant reductions in sitting time (Alkhajah et al., 2012; Pronk et al., 2012) and increases in energy expenditure (Cox et al., 2011; Reiff et al., 2012) in adults. In these studies, sit-to-stand desk use was associated with a number of health benefits, including reductions in blood pressure (Cox et al., 2011), back and neck pain (Pronk et al., 2012), increases in HDL cholesterol (Alkhajah et al., 2012), and improved mood states (Pronk et al., 2012). As employed within the workplace, making environmental changes to the classroom could be an effective way of reducing children's sitting time. Such interventions could provide the opportunity to reduce total sedentary time, as well as the ability to break up prolonged bouts of sitting, both of which have been shown to be beneficial to health in children (Saunders et al., 2013; Tremblay et al., 2011). Classroom-based interventions may also help target health inequalities by being accessible to all children. The question of whether standing desks are beneficial in the classroom is an important public health topic; however a review of the current evidence has not been conducted to date. The term 'standing desk' is used differentially across studies and can encompass sit-to-stand desks, standing workstations, stand-sit workstations, stand-biased desks and adjustable furniture. For simplicity the term standing desk is used herein to incorporate all of these terms. The purpose of this systematic review was to examine the effects of interventions that have implemented standing desks within the school classroom.

2. Method

2.1. Search strategy

Search strategies were built around four groups of keywords: Standing desk (sit-to-stand desk, standing desk, standing workstation, stand-sit workstation, stand-biased desks, adjustable furniture); school classroom (elementary, school, classroom, high school, classroom environment, secondary, primary, middle, academic); study type (intervention, trial, controlled trial, randomised controlled trial (RCT), quasi-intervention, feasibility, pilot); and sample type (young people, children, adolescents, girls, boys, youth). Science Direct, PubMed, Web of Science, Cochrane Library, Cochrane Library central register of controlled trials, APA Psych NET and EPPI Centre databases were searched using the key terms. In addition, manual searches of personal files were conducted along with screening of reference lists of relevant articles.

2.2. Inclusion criteria

For inclusion, studies were required to (1) be an intervention with either a comparison (control) measure or pre and post intervention measures; (2) include a standing desk as the experiment/treatment within a school classroom setting with its impact independently measured; (3) include children aged 5–11 years, and/or adolescents aged 12–18 years (or a mean within these ranges) as study participants. Studies that did not state the mean age of participants were classified as pre-school children, school-aged children or adolescents depending on the ages of the majority of the sample; (4) be published in a peer-reviewed journal in the English language; and (5) be published up to and including June 2015.

2.3. Identification of relevant articles

Potentially relevant articles were selected by the authors who (1) screened the titles (AS); (2) screened the abstracts (AS); and (3) if abstracts were not available or did not provide sufficient information, retrieved the full article and screened using a standardised in/out form developed for this study to determine whether it met the inclusion criteria (AS). At each stage a selection of papers were cross-checked by NP and SC. Where there was uncertainty or disagreement regarding inclusion, a discussion was held between the authors to reach a decision.

2.4. Data extraction and coding

Detailed information was extracted from each article by AS using a standardised data extraction form developed for this systematic review. Data extraction was cross checked by NP and SC. Information extracted from each article included: study setting, sample characteristics, study design, intervention design and implementation, length of intervention, standing desk characteristics, outcome measures and assessments, and study quality criteria. In addition, information about the study outcomes (e.g. intervention effects) were extracted (Table 1). The impact of the standing desk intervention on each outcome measure was coded as: + = significant positive effect; − = significant negative effect; 0 = no significant effect; * = no statistical test performed (Table 2).

2.5. Study quality

Quality of included studies was assessed by AS and NP using the Delphi list (Verhagen et al., 1998) as used in previous systematic reviews of behavioural interventions with children (Brown et al., 2013; Haapala, 2012; Van Stralen et al., 2011). AS assessed the quality of the entire sample and NP assessed the quality of a subsample (>30%). Where there was disagreement (n = 1 paper) discussions were held to reach a consensus.

The Delphi list includes 8 assessment items: randomisation methods, treatment allocation, comparisons of main outcomes at baseline, eligibility criteria, blinding of assessor, blinding of participants, provision of point estimates and measures of variability, and if intention-to-treat analysis was used. Item 6 ('were the participants blinded?') was excluded from the list as it was deemed inappropriate

Table 1
Overview of studies.

Study	Location	School	Design	Intervention duration	Sample (n)	Age, years. Mean (SD)	Total study groups	Intervention groups	Control groups	Standing desk	Extra equipment	Adjusted for user?	Standing desk per participant?	Main outcome	Secondary outcomes	Study quality
Benden et al. (2011)	Texas, USA	E	RCT pilot	5 months	58	6–7	5	2 (+1 WGC)	2 (+1 WGC)	Artco-bell, Temple, TX	Stool	Y	Y	EE	ST, FSD, CB	Low
Benden et al. (2012)	Texas, USA	E	WST	5 months	9	6–8	1	1	1	Archetype, Artco-bell, Temple, TX	Stool	NS	Y	EE	S	Low
Benden et al. (2014)	Texas, USA	E	CT	5 months	326	8.5 7–10	8	4	4	Stand2Learn LLC college station, TX, USA	stool	NS	NS	EE	S	Low
Benden et al. (2013)	Texas, USA	E	RCT	Single time point	42	7–9	4	2	2	Archetype, Artco-bell, Temple, TX	Stool	Y	Y	P	C	Low
Hinckson et al. (2013)	Auckland, NZ	E	CT	4 weeks	30	10 (1)	3	2	1	Work station (Ghanghao Furniture Factory, China)	Exercise balls and mats	Y	N	ST, SG, S, SSC	PN, F, FSD	Low
Koepp et al. (2012)	Idaho, USA	E	RMT, pilot	5 months	8	11.3 (0.5) 11–12	1	1	0	VisualEd Tech, Wharton, NJ	Stool	Y	Y	S	CB, C	Low
Lanningham-Foster (2008)	Minnesota, USA	E	WST	12 weeks	40	10 (1) 9–11	1	1	1	NS	Anti-fatigue mats	Y	N	PA	–	Low
Clemes et al. (2015)	Bradford, UK/Victoria, AUZ	E	CT/RCT	9/10 weeks	40/44	9–10 10 (0.3)/11–12 11.6 (0.5)	2/2	1/1	1/1	Ergotron WorkFit-PD	NS	NS	N/Y	SG	ST, S, SPT	Low/medium
Aminian et al. (2015)	Auckland, NZ	E	CT	5 months	26	9–11	2	1	1	Work station (Ghanghao Furniture Factory, China)	Exercise balls and mats	Y	Y	ST, SG	S, SSC, SPT, CB, PN, ADHD	Low
Dornhecker et al. (2015)	NS	E	CT	5 months	282	7–10	NS	NS	NS. $n = 124$	NS	Stools	Y	NS	CB	-	Low

E = elementary; RCT = randomised control trial; WST = within-subject control trial; CT = control trial; RMT = repeated measures trial; NS = not stated; WGC = within group comparison; EE = energy expenditure; ST = standing time; FSD = feasibility of standing desks; CB = classroom behaviour; S = steps; P = posture; C = comfort; SG = sitting; SSC = sit-to-stand counts; PN = pain; F = fatigue; PA = physical activity; SPT = stepping time; ADHD = attention deficit hyperactivity disorder.

Table 2
Overview of standing desk implementation.

Study	Standing desk	Extra equipment	Standing desk implementation details	Desk adjusted for user?	Study purpose explained to pupils, teachers or parents	Standing desk training provided	Methods to increase standing time promoted
Benden et al. (2011)	Artco-bell, Temple, TX	Stool	All traditional desks replaced with sit-to-stand desks within the two intervention classrooms. One sit-to-stand desk per child, whether participating in the study or not. Not reported if pupils could adjust the desk freely.	Not reported	Sit-to-stand desks explained to pupils during the consent and assent process. No further details reported in the study.	Not reported	Participants were allowed to sit or stand at their discretion
Benden et al. (2012)	Archetype, Artco-bell, Temple, TX	Stool	The entire class was switched to stand-biased desks. No details reported on the number of children per desk or if the desks were adjustable by the pupil freely.	Not reported	Not reported	Not reported	Participants were allowed to sit or stand at their discretion
Benden et al. (2014)	Stand2Learn LLC college station, TX, USA	Stool	Every study participant received a stand-biased desk. No details reported regarding those who did not participate in the study, whether they received a stand-biased desk or if these desks were freely adjustable by the pupil.	Not reported	Teachers informed of the study purpose, protocol and financial incentive if they chose to take part. Parents informed of the study purpose in a meeting with researchers	Not reported	Not reported
Benden et al. (2013)	Archetype, Artco-bell, Temple, TX	Stool	One stand-biased desk per intervention class participant. No details reported regarding desk allocation of pupils not participating in the study or traditional desk availability within the intervention class. Desks not adjustable by pupils freely.	Set at or slightly below standing elbow height	Not reported	Not reported	Not reported
Hinckson et al. (2013)	Work station (Ghanghao Furniture Factory, China)	Exercise balls and mats	Eight standing workstations across two classes (five and three). Each class included a central circle workstation and semi-circle workstations placed around the room. No details of desk allocation for pupils not taking part in the study. Desks not adjustable by pupil freely.	Children in groups of fours and fives of similar height were assigned the same workstations (three different height settings)	Standing desks discussed with teachers and pupils. One of the two teachers was 'highly motivated' to trial the standing desks. The other teacher was 'less motivated.'	Not reported	Not reported
Koepp et al. (2012)	VisualEd Tech, Wharton, NJ	Stool	A standing desk was allocated to each study participant. This included every pupil in the class. Desk not adjustable by pupils freely.	Desk height set at each participant elbow height	Not reported	Not reported	Not reported
Lanningham-Foster (2008)	Not reported	Anti-fatigue mats to sit on the floor and stability balls to sit.	All traditional desks were replaced with standing desks but the number of pupils per desk was not disclosed. These desks were not adjustable by pupils. 4–5 traditional tables and chairs were retained as an alternative option for participants.	Not reported	Pupils and parents were invited to attend preliminary information meetings about the study	Not reported	Not reported
Clemes et al. (2015)	Ergotron WorkFit-PD	Stools	UK: Three standard desks replaced with six adjustable sit-to-stand desks, used by six pupils who could adjust the desks freely. The entire class was rotated between these six desks and traditional desks every day. AUZ: All standard desks in the classroom replaced with sit-to-stand desks, one per pupil, which pupils could adjust freely.	Not reported	Not reported	Intervention class teachers within both the UK and AUZ study received training on desk adjustment	Intervention teachers from both countries received training in sedentary behaviour reduction strategies. Pupils initially encouraged to increase standing by 30 min a day and to gradually increase this time during the intervention period.
Aminian et al. (2015)	Work station (Ghanghao Furniture Factory, China)	Exercise balls, beanbags, benches and mat spaces available for sitting.	All traditional desks replaced with five standing workstations: one circular desk in the centre of the class, three semi-circular desks and one for computers. Semi-circular desks shared by 4–5 children. These desks were not adjustable by pupils freely.	Pupils of similar floor to elbow height were grouped together to share the desks.	Not reported	Not reported	Not reported
Dornhecker et al. (2015)	Stand biased desk (model not reported)	Stools	Stand-biased desks were installed in the intervention class. One desk per pupil. Desk allocation for pupils not taking part in the study and presence of standard desks in the classroom not reported. Desks could not be adjusted by pupils freely.	Adjusted to each student's height although the details of this procedure were not reported.	Parents were sent letters detailing the purpose of the study.	Not reported	Not reported

for assessing the quality of standing desk interventions. Consequently the final assessment list consisted of seven items. Studies were given a 0 or 1 fulfilment score for each item, resulting in a final score out of 7, and then categorised as either low (0–2), medium (3–5) or high (6–7) quality. This categorisation system is based on a system used in previous research (Bhui et al., 2015).

3. Results

The literature searches yielded 2131 titles of potentially relevant articles and 11 papers were eligible for inclusion (see Fig. 1). Two papers reported different outcomes for the same study (Benden et al., 2011; Blake et al., 2012) while another paper reported the findings of two independent pilot studies (Clemes et al., 2015). Therefore the findings from 11 studies with 11 independent samples are reported herein.

All studies were conducted within elementary schools, predominantly in the US (Benden et al., 2011; Benden et al., 2012; Benden et al., 2013; Benden et al., 2014; Koepp et al., 2012; Lanningham-Foster et al., 2008), with ages ranging from 6 to 12 years (see Table 1). Sample sizes varied from 8 to 326, and intervention durations ranged from a single time point to five months. Two studies were RCTs (Benden et al., 2011; Benden et al., 2013), six studies were non-randomised controlled trials (Aminian et al., 2015; Benden et al., 2012; Benden et al., 2014; Dornhecker et al., 2015; Hinckson et al., 2013; Lanningham-Foster et al., 2008), one study had a pre–post design without a control group (Koepp et al., 2012), one paper described two independent studies (Clemes et al., 2015), within which, one used a non-randomised control design and one used a RCT design. Ten studies were scored low quality (Aminian et al., 2015; Benden et al., 2011; Benden et al., 2012; Benden et al., 2013; Benden et al., 2014; Clemes et al., 2015 (UK study); Dornhecker et al., 2015; Hinckson et al., 2013; Koepp et al., 2012; Lanningham-Foster et al., 2008) and one scored medium quality (Clemes et al., 2015 (Australian study)); scores ranged from 1 to 3 out of 7.

3.1. Standing desk implementation

Methods of standing desk implementation varied across studies (Table 2). Six provided a standing desk per participant (Benden et al., 2011; Benden et al., 2013; Benden et al., 2014; Clemes et al., 2015 (Australian study); Dornhecker et al., 2015; Koepp et al., 2012). In two studies pupils of a similar height shared a workstation (Aminian et al., 2015; Hinckson et al., 2013), one study reported rotating children in a class between sit-to-stand desks and traditional seated desks (Clemes et al., 2015 (UK study)) and two studies did not report how pupils were allocated to a standing desk (Benden et al., 2012; Lanningham-Foster et al., 2008). Seven studies reported exposing all children in the class (Aminian et al., 2015; Benden et al., 2011; Benden et al., 2012; Clemes et al., 2015 (UK and Australian studies); Koepp et al., 2012; Lanningham-Foster et al., 2008) to the standing desk intervention (with

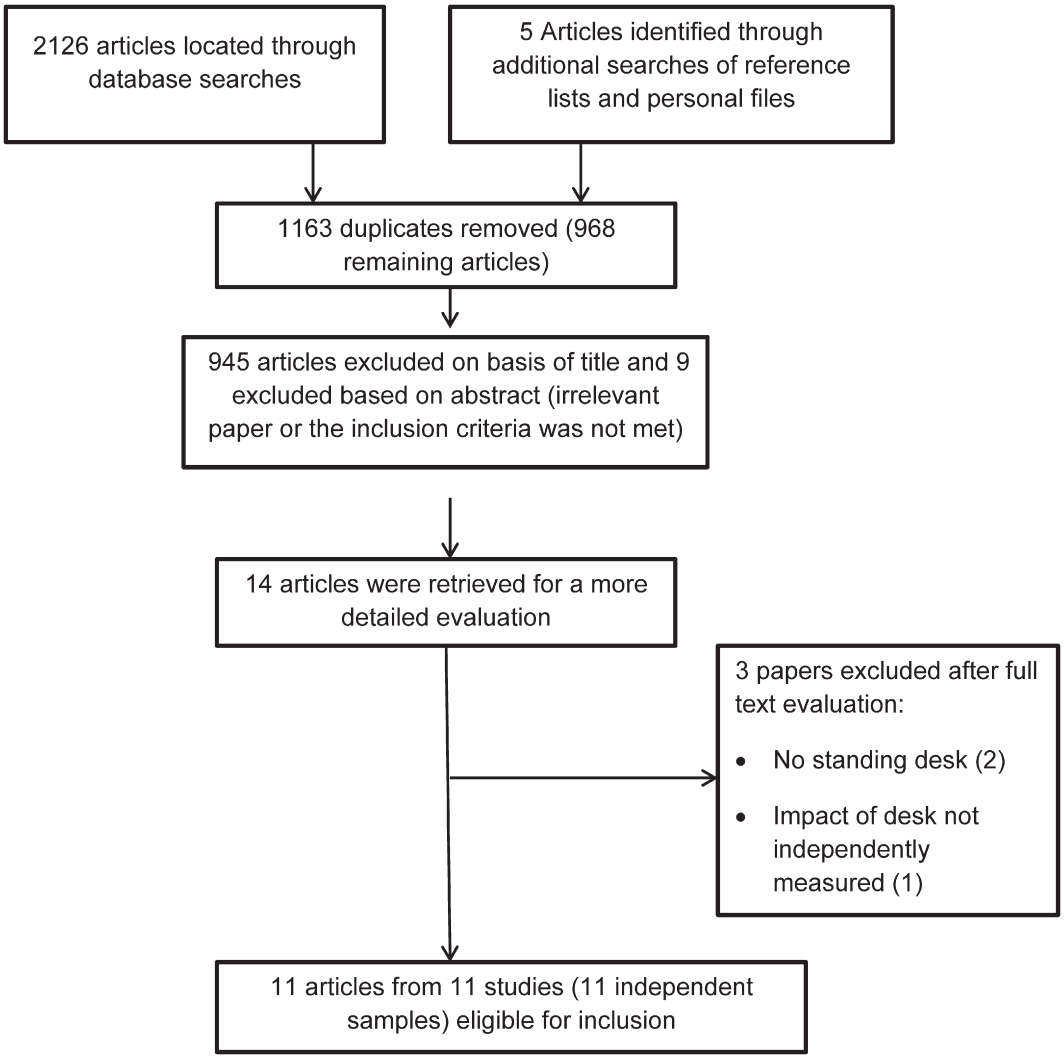

Fig. 1. Flow chart describing the study-identification process.

Table 3
Overview of outcome measures across studies. Data presented as mean ± SD unless otherwise stated.

Outcome	Study	Measure	Intervention duration and number of measurement time points	Occasions and duration of measure	Findings	Compared to a control group	A controlled study but without a comparison made to a control	No control group in study
Steps	Benden et al. (2012)	Body Bug Armband	5 months; 2	2 h per day (8.30–10.30 am) over a 5 day period in fall and spring semesters	17.6% (836) step increase at follow-up in IG compared to CG.	+[a]		
	Benden et al. (2014)	Sensewear ® activity monitor	5 months; 2	2 h per day (9-11 am) over a 5 day period in fall and spring semesters	Fall: IG 1.61 step/min (P = 0.0002) greater than CG. Spring: IG group 0.12 step/min (P = 0.8193) greater than CG.	+/0		
	Hinckson et al. (2013)	Accelerometer (ActivPAL)	4 weeks; 2	Week 1 and 4, 0500–2400 h	IG v CG = 0.01 effect size (90% CL = 0.94) — unclear magnitude of effect.	0		
	Koepp et al. (2012)	Pedometer (W4L Classic)	5 months; daily	Only 'class time' stated	363 more steps at follow-up in IG but not significant (P = 0.1127).			0
	Clemes et al. (2015)	ActivPAL3	UK — 9 weeks; 2	UK — weeks 1 and 9. Seven days, 24 h	UK — class time: increase in IG and CG groups (IG +1370, P = 0.013; CG +1163, no statistic reported) at follow-up. Total time: IG and CG increased at follow-up (IG +81 ± 4223; CG +1321 ± 4712)		+/+[a]	
			AUZ — 10 weeks; 2	AUZ — weeks 1 and 10. Seven days, waking hours	AUZ — class time: IG and CG decreased (−143, NS; −109, NS) at follow-up. Total time: Both IG and CG decreased in steps at follow-up (IG −1908 ± 3268, P < 0.01; CG −2165 ± 4238 P < 0.03)		−[a]/−	
	Aminian et al. (2015)	ActivPAL	5 months; 3	Baseline, week 4 and week 8; 7 days	School time: 675 greater steps over 8 weeks in IG. CL too wide for effect, values not reported. Total time: 1859 greater steps over 8 weeks in IG. CL too wide for effect, values not reported.	0/0		
Stepping time	Hinckson et al. (2013)	Accelerometer (ActivPAL)	4 weeks; 2	Weeks 1 and 4, 0500–2400 h	IG v CG = 0.29 effect size (90% CL = 0.82) — unclear magnitude of change.	0		
	Clemes et al. (2015)	ActivPAL3	UK — 9 weeks; 2	UK — weeks 1 and 9. Seven days, 24 h	UK — class time: No difference in IG v CG at follow-up (P > 0.05). Total time: No change in IG and CG in B v follow-up (P > 0.05).	0	0	
			AUZ — 10 weeks; 2	AUZ — weeks 1 and 10. Seven days, waking hours	AUZ — class time: No difference in IG and CG in B v follow-up (no statistic reported). Total time: IG and CG reduced at follow-up (IG −20.9 ± 40.2 min, no statistic reported; CG −24.2 ± 50.3; no statistic reported)		0[a]/0[a]	
	Aminian et al. (2015)	ActivPAL	5 months; 3	Baseline, week 4 and week 8; 7 days	School time: 11 min/day greater stepping time IG v CG over 8 weeks. CL too wide for effect, values not reported. Total time: 26 min/day greater stepping time in IG v CG over 8 weeks. CL too wide for effect, values not reported.	0/0		
Standing time	Hinckson et al. (2013)	Accelerometer (ActivPAL)	4 weeks; 2	Weeks 1 and 4, 0500–2400 h	IG v CG = 0.71 effect size (90% CL = 0.48); very likely large increase in standing time in IG.	+		
	Clemes et al. (2015)	ActivPAL3	UK — 9 weeks; 2	UK — weeks 1 and 9. Seven days, 24 h	UK — class time: No difference of IG v CG at B or follow-up (P > 0.05). Total time: No difference of IG and CG at B v follow-up (P > 0.05).	0	0	
			AUZ — 10 weeks; 2	AUZ — weeks 1 and 10. Seven days, waking hours	AUZ — class time: IG had greater standing time v CG (P < 0.01) at follow-up. Both IG and CG increased at follow-up v B (P < 0.001). Total time: IG increased at follow-up (+13 ± 53.1; P < 0.01). No change in CG at follow-up.	+	+	
	Aminian et al. (2015)	ActivPAL	5 months; 3	Baseline, week 4 and week 8; 7 days	School time: 24 min/day increase in IG v CG over 8 weeks. CL too wide for effect, values not reported. Total time: 55 min/day increase in IG v CG over 8 weeks. CL too wide for effect (±129).	0/0		
Sitting time	Hinckson et al. (2013)	Accelerometer (ActivPAL)	4 weeks; 2	Weeks 1 and 4, 0500–2400 h	IG v CG = −0.49 effect size (90% CL = 0.64) — very likely large decrease in sitting.	+		

(continued on next page)

Table 3 (*continued*)

Outcome	Study	Measure	Intervention duration and number of measurement time points	Occasions and duration of measure	Findings	Compared to a control group	A controlled study but without a comparison made to a control	No control group in study
	Clemes et al. (2015)	ActivPAL3	UK — 9 weeks; 2	UK — weeks 1 and 9. Seven days, 24 h	UK — class time: no difference of IG v CG at follow-up ($P > 0.05$). Decrease in IG at follow-up (-52.4 ± 66.6 min; $P = 0.03$). Total time: No difference of IG or CG for B v follow-up ($P > 0.05$).	0	0	
			AUZ — 10 weeks; 2	AUZ — weeks 1 and 10. Seven days, waking hours	AUZ — class time: IG had less sitting time v CG ($P = 0.03$) at follow-up. Both IG and CG increased at follow-up v B (IG $-9.8 \pm 16.5\%$, $P = <0.001$; CG $-5.9 \pm 11.6\%$, $P = 0.004$). Total time: No difference of IG and CG for B v follow-up ($P > 0.05$).	+	0	
	Aminian et al. (2015)	ActivPAL	5 months; 3	Baseline, week 4 and week 8; 7 days	During school: −24 min/day in IG v CG over 8 weeks. CL too wide for effect, values not reported. Total time: 45 min/day decrease in IG v CG over 8 weeks. CL too wide for effect (± 122).	0/0		
Energy expenditure	Benden et al. (2011)	Body Bug Armband	5 months; 4	2 h per day (8–10 am) over 5 consecutive school days.	IG 0.18 kcal·min ($P = 0.022$, 17%) greater EE than CG group at follow-up	+		
	Benden et al. (2012)	Body Bug Armband	5 months; 2	2 h per day (8.30–10.30 am) over a 5 day period in fall and spring semesters	IG 25.7% increase in mean EE at follow-up. Mean EE 0.29 kcal·min higher v CG ($P < 0.0001$) after adjusting for covariates.	+		
	Benden et al. (2014)	Sensewear ® activity monitor	5 months; 2	2 h per day (9-11 am) over a 5 day period in fall and spring semesters	Fall: IG 0.16 kcal·min ($P < 0.0001$) greater than CG group. Spring: 0.08 kcal·min ($P = 0.0092$) greater than CG group	+		
Sit-to-stand counts	Hinckson et al. (2013)	Accelerometer (ActivPAL)	4 weeks; 2	Weeks 1 and 4, 0500–2400 h	IG v CG = −0.96 effect size (90% CL = 0.54) — very likely large decrease in sit-to-stand counts.	−		
	Aminian et al. (2015)	ActivPAL	5 months; 3	Baseline, week 4 and week 8; 7 days	School time: −6 transitions in IG v CG over 8 weeks. CL too wide for effect, values not reported. Total time: IG −34 transitions at 8 weeks v B (−28.8%). CG −38 transitions at 8 weeks v B (−34.0%).	0	0[a]	
Comfort	Benden et al. (2013)	Discomfort survey developed by the researchers	1	Baseline self-assessment	Greater comfort in neck, arms, and legs in IG. Greater comfort in the back, wrists, hands, ankles and feet in CG. CG reported greater discomfort in all areas of the body when combining data, except for arms. No statistical tests performed.	0[a]		
	Koepp et al. (2012)	Teacher observations — discomfort/fatigue	5 months; daily	"Class periods" but total observation time not stated	No significant difference at follow-up in IG ($P = 0.6$; z test) v B.			0
Classroom behaviour	Koepp et al. (2012)	Teacher observations — pupil behaviour that is disruptive to the class	5 months; daily	Class periods — total observation time not stated	No significant difference at follow-up in IG of disruptive behaviour ($P < 0.5$, z test).			0
	Dornhecker et al. (2015)	Academic engagement (AE) — behaviour observations of students in schools (BOSS) tool	5 months; 2	Fall and spring; 12 minute observations in 15 second epochs, once per child	Fall: IG greater AE than CG (+4.21 score, $P = 0.003$). Spring: IG had small increase (0.72 AE) but no change from CG ($P > 0.05$)	+/0		
Physical activity	Lanningham-–Foster et al. (2008)	Triaxial accelerometer Biaxial inclinometer	12 weeks; 4	Weeks 1, 2, 3, and 12 — full school days over 4, 1, 2–3 and 4 days respectively.	No difference between CG (71 ± 0.4 m/s^2) and standing desk IG (71 ± 0.7 m/s^2) in average movement (P value not reported).	0		
Pain and fatigue	Aminian et al. (2015)	Nordic musculoskeletal questionnaire	5 months; 3	Baseline, week 5 and week 9	Little or no pain reported and similar values reported from baseline to follow-up across body parts in IG. No CG data reported.		0[a]	
Posture	Benden et al. (2013)	Portable Ergonomic Observations — time in different postures	1	3 × 10 min observations.	A greater proportion of the standing students portrayed more time in preferred postures and less time in non-preferred postures overall.		+[a]	
Concentration	Koepp et al. (2012)	Teacher observations	5 months; daily	Class periods but total time not stated	No significant difference at follow-up in IG ($P = 0.81$, z test) v B.			0
ADHD	Aminian	Strengths and	5 months; 3	Baseline, week 5 and week 9	No significant difference between IG and CG at final measure	0		

only those with consent participating in the evaluation), while four studies did not describe whether the whole class or participants only were exposed to the standing desks (Benden et al., 2013; Benden et al., 2014; Dornhecker et al., 2015; Hinckson et al., 2013).

Seven studies reported adjusting the height of each desk to each user's requirements (Aminian et al., 2015; Benden et al., 2011; Benden et al., 2013; Dornhecker et al., 2015; Hinckson et al., 2013; Koepp et al., 2012; Lanningham-Foster et al., 2008), while desk adjustment was not mentioned in four studies (Benden et al., 2012; Benden et al., 2014; Clemes et al., 2015 (UK and Australian studies)). Three studies provided sit-to-stand desks where the user could adjust between sitting and standing freely (Benden et al., 2011; Clemes et al., 2015 (UK and Australian studies)) whereas the remaining eight studies used standing desks or workstations that were not adjustable (Aminian et al., 2015; Benden et al., 2012; Benden et al., 2013; Benden et al., 2014; Dornhecker et al., 2015; Hinckson et al., 2013; Koepp et al., 2012; Lanningham-Foster et al., 2008). Two studies reported the provision of training for pupils on standing desk use and the same two studies were the only ones to report the use of sedentary behaviour reduction strategies provided to teachers (Clemes et al., 2015 (UK and Australian study)).

3.2. Impact of standing desks

An overview of outcome measures can be seen in Table 3. From the 11 studies, the most common outcome measures were step counts (n = 7), sitting time, standing time, stepping time (all n = 4) and energy expenditure (n = 3). Most outcome measures were quantitative (n = 30 out of a possible 37 outcome measures) with qualitative assessments consisting of interviews with teachers (n = 4), principals (n = 1), parents (n = 1) or pupils (n = 1) and focus groups with students and parents (n = 2).

3.2.1. Steps

The impact of standing desks on step counts was reported in seven studies with mixed results. The time periods used to measure step counts varied between studies, ranging from 2 h to total daily waking hours (Table 3). Four studies compared step counts between intervention and control groups; two of these reported no effect (Aminian et al., 2015; Hinckson et al., 2013), one showed a positive effect at mid-intervention but no effect at post-intervention (Benden et al., 2014) and the other reported an increase in steps without using statistical tests (Benden et al., 2012). In the remaining three studies, one paper reporting two independent studies (located in the UK and Australia) had control groups within each setting but did not compare step counts between control and intervention groups (Clemes et al., 2015). Using pre–post analyses, a significant increase in step counts during class time was seen in the UK intervention group, while no changes were seen in the Australian intervention group (Clemes et al., 2015). The remaining study, which used a pre–post design, showed no effect on step counts during class time over the intervention period (Koepp et al., 2012). In terms of stepping time, four studies found no change in intervention groups compared to control groups (Aminian et al., 2015; Clemes et al., 2015 (UK and Australian studies); Hinckson et al., 2013).

3.2.2. Standing

Four studies measured standing time with mixed results. All four compared intervention group data with control group data (Aminian et al., 2015; Clemes et al., 2015 (UK and Australian studies); Hinckson et al., 2013). One study reported an increase in standing time (Hinckson et al., 2013) and another found no effect on standing during school time or across the whole day (Aminian et al., 2015). One paper reported significant increases in the proportion of time spent standing during class time in the Australian study, while no changes in the proportion of time spent standing were observed in the UK study (Clemes et al., 2015).

3.2.3. Sitting

Four studies measured sitting time and all compared intervention group data with control group data. One study reported a decrease in total daily sitting time among the intervention group (Hinckson et al., 2013), and another reported no effect on sitting time (Aminian et al., 2015). One paper reporting two studies found a decrease in time spent sitting during class time in the Australian intervention group, relative to the control group, while no significant differences in sitting time during class time were observed between the UK intervention and control groups (Clemes et al., 2015).

3.2.4. Energy expenditure

Three studies found an increase in energy expenditure in intervention groups using standing desks compared to controls (Benden et al., 2011; Benden et al., 2012; Benden et al., 2014).

3.2.5. Other outcome measures

One study reported a significant reduction in the number of transitions recorded between sitting and standing relative to a control group (Aminian et al., 2015), while another study reported no significant differences in postural transitions relative to controls (Hinckson et al., 2013). Two studies measured comfort and neither found a change. One compared the intervention group to controls without using statistical tests (Benden et al., 2013) while the second used a pre–post analysis (Koepp et al., 2012). Two studies measured classroom behaviour. One found an improvement in child behaviour through academic engagement (measured by the teacher using the Behaviour Observations of Students in Schools (BOSS) tool (Shapiro, 2010)) at an intervention mid-point but no effect thereafter compared to the control group (Dornhecker et al., 2015). Another study, without a comparison group, found no change in classroom behaviour (based on teacher observations of disruptive behaviour) over the intervention period (Koepp et al., 2012). One study reported no change in pain in an intervention group compared to baseline measures without using statistical tests or a comparison group (Aminian et al., 2015). One study reported no change in physical activity (measured using speed of movement (expressed as metres per second) with an accelerometer) in an intervention group compared to a control group without using any statistical tests (Lanningham-Foster et al., 2008). One study reported an improvement in posture in an intervention group compared to a control group, also without using statistical tests (Benden et al., 2013). One study, without a control group, found no effect of standing desks on concentration compared to baseline (Koepp et al., 2012) and another found no effect in attention deficit hyperactivity disorder (ADHD) scores when compared to a control group (Aminian et al., 2015).

4. Discussion

The purpose of this review was to assess the impact of standing desks within the school classroom setting. While this area of research is very much in its infancy, the studies included in this review addressed diverse outcomes. Furthermore, this area of research is rapidly evolving and new studies are emerging at a fast pace. This review is therefore very timely as it provides a summary of the current evidence and enables the identification of future research directions for standing desk interventions conducted within the school environment. The current evidence base is relatively small (11 primary studies) and consists of mostly pilot studies that lack a robust study design. Furthermore, most studies had small samples which lacked the statistical power required to detect differences between control and intervention groups. Consequently, it is difficult to make strong conclusions on the effectiveness of standing desks in schools at present.

From the findings so far, standing desk interventions in the school classroom consistently showed positive effects on energy expenditure, but in only three studies. Evidence for an effect on step counts, standing time, sitting time, and stepping appears to be mixed which could be due to the diverse assessments and measurements and low statistical power within most studies.

Energy expenditure, measured with body monitors, increased in the intervention groups relative to controls in all three studies over a five month period. This suggests that standing desks are beneficial for energy balance in children. However, measurements only took place for 2 h within each study and so it is unknown if the standing desk intervention maintained this energy increase throughout the entire school day or waking day. If the increases in energy expenditure, all found within measures only conducted during school mornings, were consistent across an entire primary/elementary school day (e.g. 5 h of class time) it would equate to an approximate elevation of 24–87 cal, which are modest improvements during school hours. However, it is unknown how much additional standing time, if any, influenced these changes as this behaviour was not measured.

Step count was the most commonly assessed outcome. Across the 11 studies within this review, a variety of devices were used (e.g. the activPAL, ActiGraph, Pedometers, Sensewear armband) for various outcome measures. A common feature of these tools is a step count function which would suggest why this was the most common outcome measure. Although not a primary outcome in any study, an increase in steps would suggest the participant is standing more and being more active. Consequently this data is meaningful for determining the effectiveness of standing desks. The current evidence demonstrated mixed results across seven studies; only three studies reported any increase in steps with just one demonstrating a significant increase compared to a control group for the full intervention duration. Consequently, based on these findings, it is unclear whether standing desks increase steps in children. It should be noted that the differences in measurement durations implemented between studies (from 2 h per day, to class time only, to waking hours) do make comparisons of the findings between studies difficult. For example, increased steps during school hours may be compensated for by reductions during evenings or children may be more active during morning periods at school compared to afternoons. Consequently, these variations somewhat limit the generalizability of the evidence.

Studies that did report an increase in steps did not measure standing or sitting time. Furthermore, studies that demonstrated an increase in standing time also reported reductions in sitting time but no change in step counts or stepping time. Consequently, there was not a clear relationship between stepping and standing or sitting behaviour. All studies that measured standing and sitting time did report improvements in all mean intervention group values at follow-up but only around half reported significant increases compared to control groups. On the balance of this evidence, and because of the lack of quality, it is inconclusive whether standing desks increase standing and reduce sitting during classroom time.

It is important that standing desks are practical within the classroom and are not detrimental to classroom behaviour or learning if they are to become a permanent infrastructure within schools. Most of the positive findings reported for the variables of feasibility, classroom behaviour and learning came from qualitative interviews and focus group data not reported in the results of this review (including an additional paper (Blake et al., 2012) based on a study in this review (Benden et al., 2011)), where teachers, parents and pupils reported mostly positive opinions of the desks. Across all quantitative and qualitative evidence no negative results were found in any feasibility or learning related outcome including feasibility of standing desks, pain and fatigue, comfort, posture, concentration, ADHD, or classroom behaviour, except from an interview with one teacher (the desks were described as a distraction for the class as only some students took part in the study and had standing desks) (Hinckson et al., 2013). On the whole these findings suggest that standing desks within the classroom are practical and not detrimental to a child's ability to learn, with the balance of qualitative data suggesting that they are facilitative. However, it is very important that academic achievement is captured as an outcome measure in further standing desk research to provide direct evidence on the impact of learning. It would not be viable for these desks to be part of school infrastructure if they are detrimental to academic performance, even if there are gains in other key outcomes.

4.1. Limitations and future directions

Standing desks are a novel intervention, particularly within the school classroom environment. While a diverse set of outcomes have been measured, there is a distinct lack of depth of evidence for most, further compounded by insufficient and inconsistent statistical comparisons to control groups. Consequently, conclusions for several outcomes are not possible due to a lack of evidence. As standing desks first and foremost are designed to increase standing and reduce sitting, more studies are needed to assess these key behavioural components. If these behaviours are not measured, there is no direct evidence to link improvements in standing or sitting time to positive changes in other outcome measures such as steps, energy expenditure, markers of health or classroom behaviour. Furthermore, it would be beneficial to determine whether these desks influence reductions in total daily sedentary time and their effectiveness in promoting regular breaks in prolonged sitting and how these changes influence other outcomes. Encouragingly, the more recent papers in this review used posture monitors, such as the activPAL, as the outcome measure and it is likely that as the field progresses we will see more papers with sitting and standing time as primary outcomes.

The standing desk interventions within this review were implemented in several different ways (e.g. full class allocation versus participant only desk allocation, freely adjustable versus fixed standing desks, one desk per participant versus shared standing workstations). It is difficult to decipher the most effective design as positive changes were found across differently implemented interventions (e.g. increased standing time with multi-user workstations (Hinckson et al., 2013) and with freely adjustable sit-to-stand desks, one per pupil) (Clemes et al., 2015; Australian study). Some papers lacked key details regarding intervention implementation, thus limiting the ability to compare findings across studies. Future research should seek to directly compare different interventions to determine the most successful or cost effective standing desk implementation strategy for reducing sedentary behaviour and impacting other key outcomes.

Finally, standing desks have a potential risk of having a novelty effect due to their innovative design, which has been found in a workplace standing desk intervention (Mansoubi et al., 2016). Within our sample of studies, no study reported the presence or absence of any novelty effects in children therefore no conclusion can be made at this stage. Future research should aim to explore differences between short term (i.e. 2–4 weeks) mid-point and long term (i.e. 6–9 months) measures to fully examine the sustainability of this intervention.

There are some strengths within the current evidence. The intervention setting of a primary/elementary school classroom provided very similar characteristics between studies, such as demographics (i.e. class size, ages) and learning conditions (e.g. class duration, number of classes a pupil has per day), despite being across four countries (USA, UK, New Zealand and Australia). This is beneficial as it allows for more direct comparisons of the findings and for more conclusions of the impact of standing desks in schools to be made. However, it would be beneficial to diversify the country setting in future studies as the majority were conducted in the US. All studies that measured sedentary behaviour and physical activity used objective measures over five to seven days which provided more valid and reliable habitual data as well as further facilitation of study comparisons. However, data measured over the entire day, instead of just class time, should have

been reported in more studies to reflect any changes in behaviour over the full day and determine any compensatory effects (Mansoubi et al., 2016).

Almost all studies within this review implemented standing desks as a single component intervention design. It may be beneficial for more studies to include further supplementary methods to enhance the impact of the desks, such as sedentary behaviour reduction strategies utilised in two studies (Clemes et al., 2015 (UK and Australian studies)). A study that did not meet the inclusion criteria (Cardon et al., 2004), described a multi-component intervention including educational and practical components such as information on health and posture, the creation of a classroom that encouraged movement, along with a standing workstation area. Future research should consider multifaceted intervention 'packages' such as these to potentially engage a wider set of needs and interests within the school classroom.

In conclusion, standing desk interventions in the classroom setting, have, to date, showed some positive effects. A positive impact on energy expenditure was the only consistent outcome reported from the limited evidence. The effect of standing desks in the classroom on standing, sitting and stepping time is unclear and future studies are needed to examine the impact of standing desks on these fundamental outcomes. Standing desk interventions would appear to be practical and do not demonstrate a detrimental effect on classroom behaviour or learning from the current evidence. Further research should seek to implement standing desks with larger samples, over a full academic year and within schools of lower socio-economic status as this is a key demographic for improving health inequalities and academic achievement. All studies within this review implemented standing desks within the primary/elementary school setting and therefore further intervention studies should assess this intervention in secondary/high schools. Although logistically this may be more challenging, due to pupils moving to different classrooms throughout the day compared to a single classroom in primary/elementary schools. However, it will be important to determine the impact of these interventions within the next phase of the education system, as reducing sedentary behaviour is needed throughout the life course.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Transparency document

The Transparency document associated with this article can be found, in online version.

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