Classroom Standing Desks and Sedentary Behavior: A Systematic Review

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abstract

CONTEXT: Reducing sedentary behaviors, or time spent sitting, is an important target for health promotion in children. Standing desks in schools may be a feasible, modifiable, and acceptable environmental strategy to this end.

OBJECTIVE: To examine the impact of school-based standing desk interventions on sedentary behavior and physical activity, health-related outcomes, and academic and behavioral outcomes in school-aged children.

DATA SOURCES: Ovid Embase, Medline, PsycINFO, Web of Science, Global Health, and CINAHL.

STUDY SELECTION: Full-text peer-reviewed journal publications written in English; samples of school-aged youth (5–18 years of age); study designs including the same participants at baseline and follow-up; and use of a standing desk as a component of the intervention.

DATA EXTRACTION: Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

RESULTS: Eight studies satisfied selection criteria and used quasi-experimental (n = 4), randomized controlled trial (n = 3), and pre–post, no control (n = 1) designs. When examined, time spent standing increased in all studies (effect sizes: 0.38–0.71), while sitting time decreased from a range of 59 to 64 minutes (effect sizes: 0.27–0.49). Some studies reported increased physical activity and energy expenditure and improved classroom behavior.

LIMITATIONS: One-half of the studies had nonrandomized designs, and most were pilot or feasibility studies.

CONCLUSIONS: This initial evidence supports integrating standing desks into the classroom environment; this strategy has the potential to reduce sitting time and increase standing time among elementary schoolchildren. Additional research is needed to determine the impact of standing desks on academic performance and precursors of chronic disease risk.

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To cite: Minges KE, Chao AM, Irwin ML, et al. Classroom Standing Desks and Sedentary Behavior: A Systematic Review. *Pediatrics.* 2016;137(2):e20153087

Reducing time in sedentary behaviors (ie, waking time spent sitting or reclining, with energy expenditure <1.5 metabolic equivalents[1]) is a target for health promotion and obesity prevention efforts in youth.[2] Recent evidence from a systematic review of cross-sectional and prospective studies has shown that children's leisure time sedentary behaviors are associated with unfavorable body composition and other metabolic and cardiovascular disease risk biomarkers, decreased fitness, and lower scores for self-esteem, as well as decreased academic achievement.[3] Studies have also shown that sedentary behaviors may be associated with health risks that are in addition to those attributable to not engaging in sufficient levels of physical activity[4–6]; some findings have been equivocal, however.[5]

Given the structured environment, the supervision provided by teachers and other school personnel, and the fact that youth spend >50% of the school day sitting, schools present an ideal setting in which to integrate health promotion interventions.[7–9] Many interventions have successfully targeted promoting physical activity in schools through physical education, recess, and during lunch breaks and before- and after-school activities.[10–13] An activity-permissive curriculum may also yield benefits for academic performance, cognitive functioning, time on task, and other important academic and behavioral outcomes.[14–17]

The incorporation of "standing desks" or "sit-to-stand desks" which can be raised or lowered in the classroom is a more recent strategy that is being explored to reduce the time children spend sitting in school. This option would be expected to encourage more time spent standing and in light ambulatory movement, improved postural control and function, and increased muscular activity and energy expenditure.[18,19]

The integration of classroom desks which reduce the time that students spend sitting is a promising target for children's health promotion initiatives. Indeed, an increasing number of interventions have been tested by using this approach, but the relevant evidence has yet to be synthesized.

In the present systematic review, the effects of school-based standing desk interventions on students' sedentary behavior and physical activity, health-related outcomes (eg, body composition, caloric expenditure), and academic-related outcomes (eg, academic achievement, classroom behavior) were examined.

METHODS

Literature Search

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement was used to identify and collate studies.[20] Our systematic review began with a search of the literature to locate articles that used quantitative methodology to assess the effects of standing desk interventions in school grades kindergarten through 12. Standing desk interventions were conceptualized as those which involved changes to the classroom physical environment that supported or encouraged reductions in sitting. Desk designs included both adjustable "sit-to-stand desks," which permitted use of a stool, and "standing desks," which did not have a stool.

The first and second authors identified (with the assistance of a medical librarian to ensure a balance of sensitivity and specificity) relevant sources through searches of the following electronic bibliographic databases: Ovid Embase, Ovid Medline, Ovid PsycINFO, Web of Science, Global Health, and CINAHL. The search included articles published from database inception to September 2014. An updated search was conducted in July 2015 with the use of PubMed and Google Scholar to obtain the most recently published articles. The results were limited to full-article peer-reviewed publications written in English. The search terms included the key words: "student OR pupil" AND "school OR education OR classroom" AND "standing desk OR furniture OR standing OR sitting OR seated OR desk OR sit-stand OR stand biased OR sedentary behavior" (Supplemental Table 3). To identify any articles that may have been missed during the literature search, reference lists of candidate articles were reviewed; this search yielded no additional articles.

Study Selection Criteria

The first and second authors independently reviewed the titles and abstracts of all citations identified by the literature search. Our selection criteria were specified in advance and included the following: (1) published in English in a peer-reviewed journal; (2) available in full text; (3) included youth in grades kindergarten through 12 (~5–18 years of age, excluding preschool-aged children); (4) intervention designs (ie, randomized controlled trial [RCT], quasi-experimental, pre–post design with no control condition); (5) studies that examined the effects of standing desks on the same students (ie, within-subjects design); and (6) studies that used standing desks as at least 1 component of the intervention. Observational, correlational, and descriptive studies were excluded, as were technical reports, reviews, editorials, unpublished manuscripts, and abstracts. If multiple articles were available from a single study, the most recently published article or the article containing the most comprehensive detail of study characteristics was selected for review and, where appropriate, included data from the other articles.

Article Review and Data Extraction

The PRISMA reporting guideline was adopted for the present article to improve transparency and completeness of reporting.[20] The first author conducted the data extraction by using structured summary tables to obtain reliable and consistent data from the primary studies. The fifth author checked data extraction independently, and discrepancies were resolved by discussion. Information was extracted pertaining to study characteristics: author; year; country; study aim; and descriptions of school, sample, study, and intervention.

A second data display matrix was created to extract data related to the study outcomes, including sedentary behavior–related or physical activity–related outcomes (eg, total sedentary, sitting or active time), health-related outcomes (eg, energy expenditure, BMI, musculoskeletal pain), and academic-related outcomes (eg, academic achievement, classroom behavior). Where reported, the results of statistical tests (95% confidence intervals or *P* values) and effect sizes were extracted. Effect sizes were interpreted as no effect (Cohen's $d \leq 0.1$), small effect (Cohen's $d = 0.2–0.4$), intermediate effect (Cohen's $d = 0.5–0.7$), and large effect (Cohen's $d \geq 0.8$).[21] If available, additional information was extracted pertaining to group characteristics, including the effects of standing desks according to gender, race/ethnicity, and grade level.

Data Synthesis

Studies were categorized based on their year of publication and geographical location. Where available, outcomes for each study were summarized and compared in terms of the net change in sedentary behavior, health, and academic characteristics. Due to significant variations in study design, participants, and treatment lengths, we were unable to conduct a meta-analysis. Furthermore, many studies did not report confidence intervals for the main outcomes; thus, we would have been unable to construct a forest plot. We did, however, calculate effect sizes for studies that reported sufficient information.

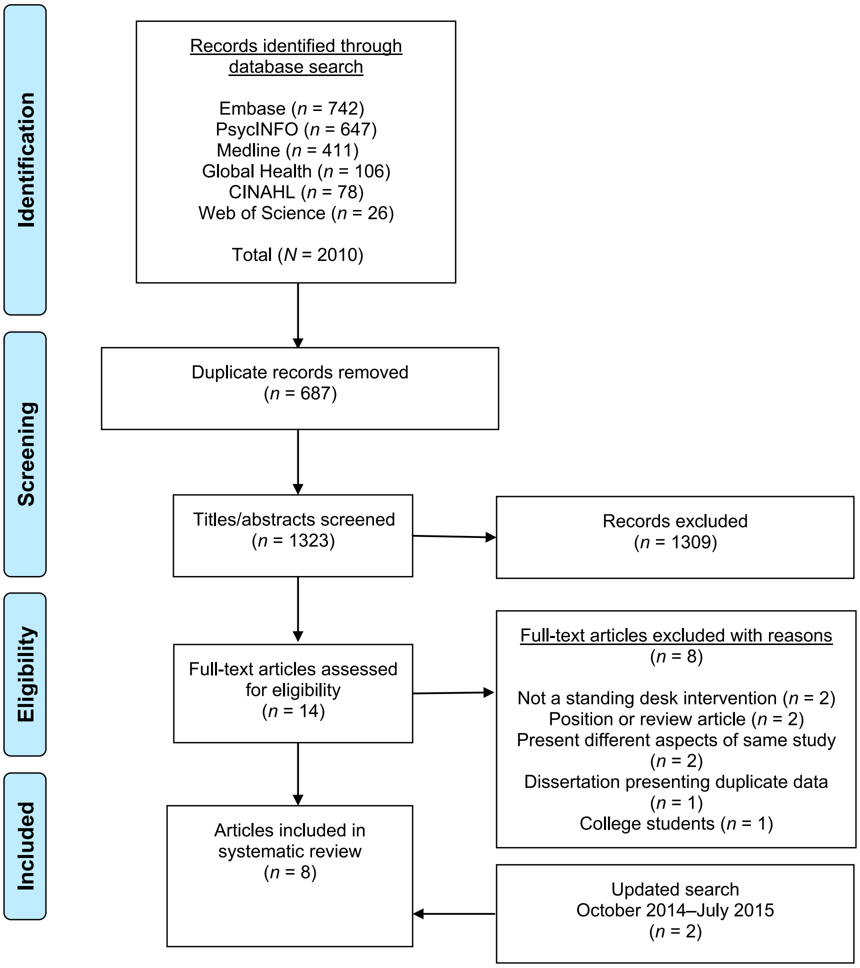

FIGURE 1
CONSORT flowchart of literature search.

Literature Search Results

The PRISMA flow diagram was used to document the literature search process (Fig 1). A total of 2010 articles were identified and imported into Endnote software. Duplicates were removed and any remaining duplicates were manually removed, leaving a total of 1323 articles. A thorough review of all article titles and abstracts was conducted to identify articles to review in full text (*n* = 14). The majority of articles excluded after review of their title or abstract were due to a cross-sectional design or because they were unrelated to a standing desk intervention. After full-text review, 8 of the 14 articles were excluded, most often due to not assessing a standing desk intervention or being a position paper or review article. The second search for articles published between October 2014 and July 2015 elicited 2 additional sources. Thus, a final sample of 8 articles was identified for the present review. Two publications that reported findings pertaining to the same intervention[22,23] were consolidated in the results of the primary study publication.[24]

RESULTS

Characteristics of the Relevant Studies Identified

Table 1 summarizes the characteristics of the studies included in our review. All studies examined the implementation of standing desks in school classrooms, and all study settings comprised elementary schools (range: first to sixth grade). No data were reported pertaining to the ownership of the schools (private or public) or the school characteristics other than geographical location and the socioeconomic status of the community. The study sample sizes ranged from 8 to 337 participants, and most were either a feasibility or pilot study, with the exception of 1 large RCT conducted in 3 elementary schools.[25] Participants' mean age varied across studies, from 8.0 to 11.6 years; the sample age was not reported in 1 study.[24] Gender was reported in all but 1 study, and the proportions of girls ranged from 37.5% to 58.3%. Race/ethnicity was reported in 3 studies and ranged from 23.0% to 70.3% white.[25–27] Anthropometric measurements (weight, height, and waist circumference) were reported in 6 studies. Based on Centers for Disease Control and Prevention BMI-for-age percentiles,[28] 3 samples had a normal mean BMI (BMI ≥5th and <85th percentiles).[25,26,29] Three other samples were overweight/obese (BMI ≥85th percentile),[27,30,31] and 2 additional studies did not report BMI or height and weight measures to derive BMI.[24,32] Geographically, 4 studies were conducted in the United States, 2 in New Zealand, 1 in Germany, and 1 article reported individual findings from Australia and England.

Varied study designs were used, including quasi-experimental (n = 4), RCT (n = 3), and pre–post no control (n = 1). Most studies used a convenience sampling recruitment method (n = 6). The standing desk interventions used 2 variations of standing desks. The first was an adjustable "standing desk" without the use of a stool; this design was used in 3 studies.[30–32] The other design was a "sit-to-stand" desk that incorporated both an adjustable standing desk and stool, and some desks included a swinging foot pendulum that permits extra movement and helps to correct posture.[24–27,29] There were no marked differences in outcomes between standing desk or sit-to-stand desk designs; henceforth, the term "standing desk" is used to represent both types of desks. Where applicable, the control condition for each study was a traditional seated desk.

In 5 studies, standing desks were configured into workstations as opposed to traditional rows of desks.[24,25,27,30,31] In addition to the standing desk intervention, 3 interventions included other nontraditional furniture to induce an activity-permissive and comfortable classroom.[27,31,32] In 1 of these studies, the effect of 3 classroom arrangements, including a traditional sitting desk, standing desk, and an activity-permissive classroom, were examined, and results were reported for each condition.[31] In the other study, the effects of attending school in a traditional classroom compared with an activity-permissive school environment were examined. In these studies, traditional desks were replaced with standing desks, but floor mats, exercise balls, and beanbags were also available for children to use if tired.[27,32] With the exception of 1 study,[32] all interventions were <1 year in duration (range: 1–15 months). Sedentary behavior and physical activity data were collected in each study by using at least 1 type of objective measurement (eg, accelerometers, pedometers).

Outcomes

All studies were designed to examine the impact of standing desks on at least 1 of the following outcomes: time spent standing, sitting, and stepping; frequency of step counts and sit-to-stand counts; time spent being physically active in the classroom, walking, dynamic sitting, and sitting on the floor; health (caloric expenditure, BMI, weight/height, and back and neck pain); and academic indicators. The outcomes of the interventions reviewed are displayed in Table 2. A summary of the observed changes in sedentary behavior and physical activity for the intervention group(s) after the integration of standing desks in the classroom is reported in Fig 2.

Effects of Standing Desks on Sedentary Behavior and Physical Activity

Standing Time: The effects of standing desks on standing time were reported in 5 studies, and all indicated improvements in the amount of time children spent standing. In 2 studies, relative to baseline, there was a significant increase, ranging from 26.4% to 30.6%, in the proportion of time children spent standing (P < .05) after the introduction of standing desks in the classroom.[26,32] In 2 other studies, children stood for 24 and 40 minutes longer per school day and waking day, respectively, after implementation of the standing desk intervention.[27,30] Small and large effect sizes were also found (0.38 and 0.71),[26,30] indicating that students stood for the majority of the observation periods. In the 1 study that did not report pre–post data or P values, the mean proportion of time spent standing during the final week of the intervention was 91%.[24]

Sitting Time and Use of Desks: Sitting time was reported in 4 studies, and each observed a significant decrease in the duration of time children spent sitting after the implementation of the standing desks, ranging from

TABLE 1 Characteristics of Reviewed Studies

Author (Country)	Aim	School Description	Sample Description	Study Description	Intervention Description
Clemes et al, 2015[26] (Australia and England)	This article reports the findings of 2 controlled intervention pilot studies conducted in the UK and Australia, which adopted similar intervention strategies, to examine the influence of sit-to-stand desks on elementary schoolchildren's classroom sitting time and total school day sitting	School type: 2 primary schools, 1 in each location Location: Melbourne, Australia, and Bradford, England, UK	Mean ± SD age: UK sample: 10.0 ± 0.3 y Australian sample: 11.6 ± 0.5 y Age range: UK sample: 9–10 y Australian sample: 11– 12 y Grade(s): UK sample: 5 Australian sample: 6 Girls: UK sample: 46.7% Australia sample: 56.8% Race/ethnicity: UK sample: 23% white (mostly South Asian) Australian sample: NR BMI: UK sample, 18.3 ± 3.2 Australian sample, 19.4 ± 3.3 Sample size (*n*)[a]: UK sample: 30 (intervention, 16; control, 14) Australian sample: 44 (intervention, 24; control, 20)	Study design: UK sample: Quasi-experimental Australian sample: RCT, 2-group (intervention and control classrooms) design Sampling method: UK sample: Unclear Australian sample: 2 of 3 classrooms randomly selected to participate. Intervention recipients: 1 fifth-grade classroom and 1 sixth-grade classroom. The control groups were 1 fifth-grade classroom and 1 sixth-grade classroom	Type of desk: UK—6 sit-to-stand desks with stools were rotated around the classroom so each student stood for at least 1 h per school day. Australia—All students and the teacher were provided with a sit-to-stand desk and the standard desk chair. Students were encouraged to stand for at least 30 min per day. In both study settings, teachers also provided students with information on the benefits of reducing sedentary behavior and classroom sitting time reduction strategies. Control classrooms retained traditional sitting desks Treatment length: January–April 2014 (UK; 9 wk total), September–November 2013 (Australia; 10 wk total) Dates of data collection: Baseline and weeks 9–10 Data collection instrument: Children wore activPAL accelerometers (PAL Technologies, Ltd, Glasgow, Switzerland) over 7 d during the weeks of baseline and follow-up. Only data pertaining to school days and waking hours were analyzed

TABLE 1 Continued

Author (Country)	Aim	School Description	Sample Description	Study Description	Intervention Description
Aminian et al, 2015[27] (NZ)	To design, implement, and test a "dynamic classroom" environment with height-appropriate standing workstations to increase standing and reduce sitting in primary schoolchildren. A dynamic classroom also included exercise balls, beanbags, and mat space	School type: 2 primary schools from the lowest socioeconomic area in study location Location: Auckland, NZ	Mean age: intervention, 9.8 ± 0.4 y; control, 9.8 ± 0.5 y Age range: 9–11 y Grade(s): 4 and 5 Girls: intervention, 55.6%; control, 50.0% Race/ethnicity: 27%–57% white (mostly Pacific Islander or NZ Maori) BMI (mean ± SD): intervention, 23 ± 8; control, 23 ± 8 Sample size (n)[a]: 26 (intervention, 18; control, 8)	Study design: Quasi-experimental design (control group, but classrooms were not randomized to intervention or control groups) Sampling method: Convenience Intervention recipients: 1 primary school classroom	Type of desk: 5 height-appropriate standing workstations: 1 round workstation in the middle of the classroom, 3 semi-circled workstations situated strategically around the central workstation, and 1 workstation for computers. Exercise balls, beanbags, and mats were made available for children to sit when tired. Control classrooms retained traditional sitting desks Treatment length: March–June 2012 (9 wk of data collection) Dates of data collection: Baseline, week 5, and week 9 Data collection instrument: Children wore activPAL accelerometers (PAL Technologies, Ltd, Glasgow, Switzerland) over 7 d during the weeks of the intervention data collection Pain and screen time were reported by using a modified version of the Nordic Musculoskeletal Questionnaire Teachers used the Strengths and Weakness of ADHD-symptoms and Normal-behaviors Rating scale for behavioral screening
Benden et al, 2014[25] (US)	To examine the energy expenditure and level of physical activity affected by stand-biased desks in a large sample of elementary schoolchildren in multiple grades and schools, across an entire school year	School type: 3 elementary schools (24 classrooms total) Location: Central Texas	Mean age: intervention, 8.45 ± 0.84 y; control, 8.49 ± 0.84 y Age range: NR Grade(s): 2, 3, and 4 Girls: intervention, 50.00%; control, 49.63% Race/ethnicity: intervention, 70.30% white; control, 67.41% white BMI: intervention, 17.44 ± 3.26; control, 17.73 ± 3.00 Sample size (n)[a]: 337 (intervention, 202; control, 135)	Study design: RCT, 2 group (intervention and control classrooms) design Sampling method: 3 of 10 schools in the district randomly selected. Classrooms randomized to intervention (n = 12) or control (n = 10) groups[b] Intervention recipients: 4 second-grade, 6 third-grade, and 2 fourth-grade classrooms. The control groups were 4 second- grade, 4 third-grade, and 2 fourth-grade classrooms	Type of desk: Stand-biased workstations: Modifiable standing height desks and standing height stools were provided to students. Control classrooms retained traditional sitting desks Treatment length: 2012–2013 school year (~9 mo) Dates of data collection: 4 wk-long intervals during school year between 9:00 AM and 11:00 AM during lecture times Data collection instrument: SenseWear Armband (BodyMedia, Inc, Pittsburgh, PA) to assess step count and energy expenditure

TABLE 1 Continued

Author (Country)	Aim	School Description	Sample Description	Study Description	Intervention Description
Hinckson et al, 2013[30] (NZ)	To examine the acceptability of introducing standing workstations in elementary school classrooms; to quantify changes in children's time spent sitting, standing, and walking; step counts; sit-to-stand transitions; and musculoskeletal discomfort	School type: 2 elementary schools	Mean age: 10.0 ± 1.0 y	Study design: Quasi-experimental design (control group, but unclear if classrooms were randomized to intervention or control groups)	Type of desk: Standing circular workstations of 4 to 5 children each. Standing workstations were adjusted to children's height (83 cm, 96 cm, and 109 cm for lowest, middle, and highest workstations, respectively). Children with similar floor-to-elbow height were grouped together. Exercise balls, beanbags, and mats were made available for children to sit when tired. Control groups retained usual sitting desks
		Location: Auckland, NZ	Age range: NR	Sampling method: Convenience; classrooms placed in intervention (n = 2) or control (n = 1) groups	Treatment length: 4 wk; March 2012–May 2012
			Grade(s): 3 and 4 Girls: 53.3% Race/ethnicity: NR	Intervention recipients: 4 third- and fourth-grade classrooms. The control group was 1 fourth-grade classroom	Dates of data collection: Baseline and week 4 Data collection instruments: Children wore activPAL accelerometers (PAL Technologies, Ltd, Glasgow, Switzerland) over 7 d at baseline and during the fourth week of the intervention
			BMI: 23.11 ± 7.25 Waist circumference: 27.97 ± 4.65 cm Sample size (n)[a]: 30 (intervention, 23; control, 7)		Children completed the Nordic Musculoskeletal Questionnaire to assess musculoskeletal aches and pains
Koepp et al, 2012[29] (US)	To examine the implementation of standing desks on classroom performance, behavior, and in-class physical activity and BMI	School type: 1 elementary school	Mean age: 11.3 ± 0.5 y	Study design: Pre–post, no control	Type of desk: Individual, adjusted standing-biased desks and stools
		Location: Idaho Falls, ID	Age range: NR	Sampling method: Convenience	Treatment length: 5 mo; January 2010–June 2010
			Grade(s): 6	Intervention recipients: 1 sixth-grade classroom	Dates of data collection: baseline (September–December 2009) and postintervention (June 2010)
			Girls: 37.5% Race/ethnicity: NR		Data collection instruments: Pedometers used to assess in-class step counts
			BMI[c]: 16.0		Classroom behaviors were reported by teacher observations. Classroom behavior variables included classroom management, concentration, and discomfort
			Sample size (n)[a]: 8		Height was measured by using a calibrated tape measure and weight by using a digital scale

TABLE 1 Continued

Author (Country)	Aim	School Description	Sample Description	Study Description	Intervention Description
Benden et al, 2011[24] (US)	To determine the effect of desks that encourage standing rather than sitting on caloric expenditure in children	School type: 1 elementary school	Mean age: NR	Study design: RCT, 2-group (intervention and control classrooms) design	Type of desk: Stand-biased workstations, modifiable standing height desks, and standing height stools were provided to students and teachers. Control classrooms retained usual sitting desks
		Location: Central Texas	Age range: NR	Sampling method: Convenience; classrooms randomized to intervention (n = 2) or control (n = 2) groups	Treatment length: 2009–2010 school year (~9 mo)
			Grade(s): 1	Intervention recipients: 4 first-grade classrooms	Dates of data collection: 4 intervals during school year between 8:00 AM and 10:00 AM
			Girls: NR Race/ethnicity: NR BMI: NR Sample size (n)[a]: 58 (intervention, 31; control, 27)		Data collection instrument: BodyBugg Armband (BodyMedia Inc., Pittsburgh, PA) to assess caloric expenditure
Lanningham-Foster et al, 2008[31] (US)	To examine the hypothesis that elementary school-aged children will be more physically active while attending school in a novel, activity-permissive school environment compared with their traditional school environment, as well as replacing traditional classroom tables and chairs with vertical workstations	School type: 1 elementary school	Mean age: Children in school, 10.2 ± 0.6 y; children in summer break, 9.9 ± 1.4 y	Study design: Quasi-experimental, 2-group design (intervention group and control group, which underwent monitoring during the summer months when school was not in session). Intervention group exposed to 3 different environments	Type of desk: Students attended school in 3 different environments: traditional school with chairs and desks, an activity-permissive environment (a large "village square" with standing desks and mobile whiteboards and laptops that allowed for activity-permissive lessons, which also included sport apparatus and activity-promoting games and permitted students to move during lesson plans), and their traditional school with standing desks (adjustable vertical desks that permitted standing or kneeling, as well as antifatigue mats and stability balls)
		Location: Rochester, MN	Age range: NR	Sampling method: Convenience; students placed in intervention (n = 1) or control (n = 1) groups	Treatment length: 12 wk; March to May (year not specified). Week 1: traditional classroom; weeks 2–3: activity-permissive classroom; weeks 4–12: standing desk classroom
			Grade(s): 4 and 5	Intervention recipients: 4 third- and fourth-grade classrooms. The control group was 1 fourth-grade classroom	Days of data collection (physical activity monitoring): Traditional school (n = 4/week); activity-permissive (n = 1 to 3/week); standing classroom (n = 4 on week 12)
			Girls: children in school, 58.3%; children in summer break, 37.5%		Data collection instrument:
			Race/ethnicity: NR		A triaxial accelerometer was used to measure physical activity in the intervention group and an inclinometer was used in the control group. Each school environment had 3–4 d of in-school accelerometer observation
			BMI: Children in school, 19.7 ± 4.9; children in summer break, 21.1 ± 4.7		Each child's weight and height were measured by using a calibrated digital scale and attached stadiometer
			Sample size (n)[a]: 40 (control, 16; intervention, 24)		

TABLE 1 Continued

Author (Country)	Aim	School Description	Sample Description	Study Description	Intervention Description
Cardon et al, 2004[32] (Germany)	To evaluate the differences between a traditional school and a "moving school" in posture, duration, and frequency of sitting in the classroom in elementary schoolchildren	School type: 2 elementary schools	Mean age: intervention, 8.8 ± 0.6 y; control, 8.0 ± 0.5 y	Study design: RCT, 2-group (intervention and control classrooms) design	Type of desk: "Moving school" with a variety of resources that enabled ergonomic–physiologic learning. Movement is encouraged by work organization (eg, information stations) and creating circumstances that encourage movement (eg, standing desks). The intervention classroom is equipped with ergonomic furniture allowing varying working postures and contributing to physiologically correct sitting with movement, called dynamic sitting. All tables had an inclinable top, and standing desks and floor space are available for variations in the daily working routine (eg, mats on the floor)
		Location: Hanover, Germany (intervention); Flanders, Belgium (control)	Age range: NR	Sampling method: Convenience; classrooms randomized to intervention (n = 2) or control (n = 2) groups	Treatment length: 1.5 y
			Grade(s): 1	Intervention recipients: 4 first-grade classrooms	Dates of data collection: NR
			Girls: intervention, 45%; control, 52%		Data collection instrument:
			Race/ethnicity: NR		Portable ergonomic observations assessed duration and frequency of different postures in the classroom. For each category, it is registered during which percentage of the observed time interval (duration) and how many times (frequency) they occur in each student. Students were filmed for 30-min observations
			BMI: NR		Accelerometers assessed in-class physical activity during 30-min observations
			Sample size (n)[a]: 47 (intervention, 22; control, 25)		Self-reported back and neck pain questionnaire

NR, not reported; NZ, New Zealand; UK, United Kingdom; US, United States.

[a] Where possible, sample size is identified as those participants completing both time points from which the analyses are derived.

[b] Two classrooms were excluded from analyses because they adopted an alternative seating arrangement.

[c] Calculated by authors.

59 to 64 minutes,[27,30] and a 9.4% and 9.8% reduction.[26] Small to intermediate effect sizes (ie, 0.27, 0.32, 0.49) were also observed.[26,30] In another study, only 2 of 19 students opted for traditional seated desks in the intervention classroom that had both standing and traditional seated desks available.[32]

Screen time, a proxy often used for sedentary behavior, was examined in 1 study. The investigators found that the intervention classroom reported 71 minutes per day of less television viewing and computer use in the final measurement compared with baseline (t = 2.67; P = .02).[27]

Physical Activity: The effects of standing desk interventions on step counts and time spent stepping were examined in 6 studies. In 4 studies, the amount of time spent stepping and total step counts improved relative to baseline or control after implementation of the standing desk intervention, but mean differences or effect sizes were either not significant or were small or modest.[26,27,29,30] However, after adjustment for sociodemographic characteristics and BMI in 1 large RCT, the classrooms with standing desks had a higher mean step count compared with the control group during the fall semester (1.61 steps/min; P < .001), but the difference

TABLE 2 Sedentary Behavior, Physical Activity, Health Outcomes, and Academic Outcomes of Reviewed Interventions

Author	Sedentary Behavior and Physical Activity	Health	Academic
Clemes et al, 2015[26]	Sitting time (% of wear time), UK sample (mean ± SD): Control: pre, 68. ± 20; post, 65.4 ± 20.1 (P = NS) Intervention: pre, 71.8 ± 10.6; post, 62.0 ± 15.8 (P = .03) Effect size[a]: 0.27 (0.13) Sitting time (% of wear time), Australian sample (mean ± SD): Control: pre, 70.8 ± 5.8; post, 64.8 ± 10.8 (P < .05) Intervention: pre, 67.9 ± 8.4; post, 58.5 8.4 (P < .001) Effect size[a]: 0.32(0.16)) Standing time (% of wear time), UK sample: Control: pre, 24.0 ± 20.8; post, 21.9± 12.8 Intervention: pre, 20.1± 8.7; post, 23.5 ± 12.5 (P = NS) Effect size[a]: 0.06 (0.03) Standing time (% of wear time), Australian sample: Control: pre, 15.1 ± 2.7; post, 20.7 ± 5.9 (P = .001) Intervention: pre, 18.1 ± 4.5; post, 26.4 ± 7.5 (P < .001) Effect size[a]: 0.38 (0.19) Stepping time (% of wear time), UK sample: Control: pre, 7.4 ± 3.6; post, 12.8 ± 8.2 (P = NS) Intervention: pre, 8.2± 2.8; post, 14.5 ± 7.9 (P < .01) Effect size[a]: 0.11 (0.06) Stepping time (% of wear time), Australian sample: Control: pre, 14.2 ± 3.9; post, 14.5 ± 5.6 (P = NS) Intervention: pre, 14.0 ± 5.2; post, 15.1± 3.0 (P = NS) Effect size[a]: 0.14 (0.07)		

TABLE 2 Continued

Author	Sedentary Behavior and Physical Activity	Health	Academic
Aminian et al, 2015[27]	Sitting time (hours; mean ± SD): Control: pre, 3.59 ± 0.45); post, 3.24 ± 0.81) Intervention: pre, 3.88 ± 0.36; post, 2.81 ± 0.36 Inference[b]: Possibly decrease for intervention Standing time (hours; mean ± SD): Control: pre, 1.24 ± 0.37; post, 1.60 ± 0.69 Intervention: pre, 1.21 ± 0.35; post, 2.06 ± 0.44 Inference[b]: Likely increase for intervention Stepping time (hours; mean ± SD): Control: pre, 1.15 ± 0.20; post, 1.09 ± 0.21 Intervention: pre, 0.88 ± 0.25; post, 0.95 ± 0.23 Inference[b]: Likely increase for intervention Step counts (*n*; mean ± SD): Control: pre, 5547 ± 1195; post, 5264 ± 999 Intervention: pre, 4312 ± 1320; post, 4318 ± 1026 Inference[b]: Possibly increase for intervention Sit-to-stand counts (*n*; mean ± SD): Control: pre, 50 ± 8; post, 40 ± 13 Intervention: pre, 49 ± 10; post, 37 ± 9 Inference[b]: Possibly decrease for intervention Screen time: The intervention class reported 71 min per day less television viewing and computer use in the final measurement compared with baseline ($t = 2.67$; $P = .02$).	Pain (only reported in intervention group) Neck: pre, 42%; post, 37% Elbow: pre, 21%; post, 11% Wrist: pre, 42%; post, 37% Hip/thigh: pre, 21%; post, 32% Knee: pre, 26%; post, 37% Foot/ankle: pre, 63%; post, 37% Shoulder: pre, 21%; post, 21% Back: pre, 32%; post, 32% (all P = NR)	Inattention (mean ± SD) Control: pre, 1.3 ± 1.8; post, 0.44 ± 1.3 Intervention: pre, –0.14 ± 1.1; post, –0.21 ± 0.90 ($P = .16$) Hyperactivity-impulsivity (mean ± SD) Control: pre, 0.76 ± 2.0; post, 0.69 ± 1.3 Intervention: pre, 0.14 ± 1.0; post, 0.03 ± 0.90 ($P = .13$)
Benden et al, 2014[25]	Step counts[c]: Fall semester: intervention versus control: 1.61 steps/min ($P = .0002$) Spring semester: intervention versus control: 0.12 steps/min ($P = .8193$)	Caloric expenditure[c]: Fall semester: intervention versus control, 0.16 kcal/min ($P < .0001$) Spring semester: intervention versus control, 0.08 ($P < .001$)	

TABLE 2 Continued

Author	Sedentary Behavior and Physical Activity	Health	Academic
Hinckson et al, 2013[30]	Sitting time (hours; mean ± SD): Control: pre, 9.30 ± 1.46; post, 9.00 ± 0.80 Intervention: pre, 9.26 ± 1.15; post, 8.27 ± 1.45 Effect size (90% CL): 0.49 (0.64) Inference[b]: Likely small decrease for intervention Standing time (hours; mean ± SD): Control: pre, 3.18 ± 0.94; post, 2.85 ± 0.30 Intervention: pre, 3.08 ± 0.84; post, 3.75 ± 0.88 Effect size (90% CL): 0.71 (0.48) Inference[b]: Very likely large increase for intervention Stepping time (hours; mean ± SD): Control: pre, 2.70 ± 0.44; post, 2.49 ± 0.40 Intervention: pre, 2.38 ± 0.69; post, 2.32 ± 0.53 Effect size (90% CL): 0.29 (0.82) Inference[b]: Unclear Step counts (*n*; mean ± SD): Control: pre, 12 884 ± 2191; post, 12 424 ± 2160 (*P* = NR) Intervention: pre, 11 681 ± 3306; post, 11 255 ± 2500 (*P* = NR) Effect size (90% CL): 0.01 (0.94) Inference[b]: Unclear Sit-to-stand counts (*n*; mean ± SD): Control: pre, 102 ± 30; post, 98 ± 26 Intervention: pre, 116 ± 23; post, 93 ± 17 Effect size (90% CL): 0.96 (0.54) Inference[b]: Very likely large decrease for intervention		
Koepp et al, 2012[29]	Pedometer (step counts/day, mean ± SD): Pre, 1886 ± 809; Post, 2249 ± 990; Mean difference: 362.53 (*P* = NS)	BMI (mean ± SD): Pre, 19.4 ± 5.3; Post, 19.3 ± 5.2 Mean difference: –0.087 (*P* = NS) Weight (kg; mean ± SD): Pre, 91.1 ± 36.0; Post, 98.0 ± 38.6 Mean difference: 6.949 (*P* < .05)	Classroom behavior: There were changes in classroom behavior (classroom management, concentration and discomfort), but each variable was not statistically significant[d] (*P* = NS)
Benden et al, 2011[24]	Standing time: Intervention: mean standing time in homeroom during the final week of intervention: 91% of homeroom time[e] (*P* = NR)	Caloric expenditure: Intervention, 0.182 kcal/min (95% CI: 0.026–0.338)[e] (*P* < .05) Students in the intervention group burned 17% more calories than did those in the control group[d,e] (*P* = NR) Overweight/obese caloric expenditure: Control, 1.18 kcal/min Intervention, 1.56 kcal/min (*P* = NR) Among students who were overweight/obese (>85th percentile BMI), those (*n* = 19) in the intervention group experienced a 32% increase in calorie expenditure compared with those in the control group (1.56 kcal/min vs 1.18 kcal/min) (*P* = NR)	Classroom behavior: The majority of parents (70%) whose children were in the intervention classrooms felt that standing in the classroom positively affected their child's classroom behavior (*P* = NR)

TABLE 2 Continued

Author	Sedentary Behavior and Physical Activity	Health	Academic
Lanningham-Foster et al, 2008[31]	Physical activity in standing classroom: There was no significant difference in physical activity in the standing classroom environment between weeks 3 (baseline) and 12 (postintervention)[d,e] Physical activity, compared by environment: Activity-permissive classroom: 115 ± 3.0 m/s^2 ($P < .001$ compared with traditional and standing classroom) Traditional classroom: 71 ± 0.4 m/s^2 Standing classroom: 71 ± 0.7 m/s^2		
Cardon et al, 2004[32d]	Physical activity (accelerometer) (counts/min): control, 134 ± 94; intervention, 538 ± 229 ($P < .001$) Standing (mean ± SD): Frequency (*n*): control, 3.12 ± 3.48; intervention, 32.79 ± 15.86 ($P < .001$) Duration (% of time): control, 2.42 ± 1.42; intervention, 30.63 ± 24.75 ($P < .001$) Walking around (mean ± SD): Frequency (*n*): control, 2.11 ± 1.69; intervention, 24.05 ± 14.13 ($P < .001$) Duration (% of time): control, 1.75 ± 0.95; intervention, 10.47 ± 4.90 ($P < .001$) Being active (mean ± SD): Frequency (*n*): control, 1.60 ± 1.34; intervention, 14.00 ± 10.31 ($P < .001$) Duration (% of time): control, 1.0 ± 0.00; intervention, 7.79 ± 5.15 ($P = .225$) Static sitting (mean ± SD): Frequency (*n*): control, 1.50 ± 1.00; intervention, 4.17 ± 4.35 ($P = .240$) Duration (% of time): control, 97.13 ± 3.82; intervention, 1.0 ± 0.00 ($P < .001$) Dynamic sitting[f] (mean ± SD): Frequency (*n*): control, 2.38 ± 2.10; intervention, 13.72 ± 7.65 ($P < .001$) Duration (% of time): control, 3.25 ± 2.87; intervention, 53.11 ± 23.23 ($P < .001$) On floor (mean ± SD): Duration (% of time): control, 0.00 ± 0.00; intervention, 21.10 ± 16.18 ($P = .253$)	Back or neck pain[a] (reported for 1 week): Control, 26.1% Intervention, 47.4% ($P = .21$)	Reading/writing (mean ± SD): Frequency (*n*): control, 3.45 ± 2.01; intervention, 6.78 ± 6.89 ($P = .063$) Duration (% of time): control, 29.90 ± 20.31; intervention, 26.47 ± 19.31 ($P = .604$)

CL, confidence limit; NR, not reported; NS, not significant.

[a] The first author calculated the value of Cohen's *d* and the effect size *r*, using the means and SDs of 2 groups (intervention and control) when available.

[b] Average daily mean differences (intervention – control) with standardized differences. Terms for chances of intervention: possibly, 25% to 75%; likely, 75% to 95%; and very likely, > 95%. Term for magnitude: trivial, <0.2; small, 0.2 to 0.59; moderate, 0.6 to 1.19; and large, > 1.20.

[c] Covariates included treatment group, semester (fall versus spring), gender, grade, race, BMI categories, and the interactions between these covariates and the treatment group. The random effects consisted of a random intercept for each child, which is nested in the random effect of classroom.

[d] No pre–post measurement or data reported.

[e] No control condition data were presented.

[f] Dynamic sitting is defined as sitting with continuous movement around the center of gravity (eg, tipping on a chair).

Sedentary behavior and physical activity	Clemes et al, 2015[26a]	Aminian et al, 2015[27a]	Benden et al, 2014[25a]	Hinckson et al, 2013[30b]	Koepp et al, 2012[29a]	Benden et al, 2011[24a]	Lanningham-Foster et al, 2008[31b]	Cardon et al, 2004[32b]
Standing time	↑↔	↑		↑				↑
Stepping time	↑↔	↑		↔				↑
Step counts		↑	↑↔	↔	↔		↔	↑
Sitting time	↓↓	↓		↓				
Sit-to-stand counts		↓		↓				
Screen time		↓						

FIGURE 2
Summary of observed changes in sedentary behavior and physical activity for the intervention group after the integration of standing desks in the classroom*. *Results only included if a *P* value was reported. ↑ indicates a significant increase; ↓ indicates a significant decrease; ↔ indicates no significant change; and double arrows represent the directionality of the results if 2 intervention groups were reported in 1 study. [a]Sit-to-stand desk. [b]Standing desk.

decreased to 0.12 step/min ($P = .819$) in the spring semester.[25] In another study that examined differences between 3 intervention exposures (activity-permissive classroom versus traditional desk classroom versus standing desk classroom), significantly more movement for the activity-permissive classroom compared with the 2 other exposures was found (115 m/s^2 vs 71 m/s^2 vs 71 m/s^2; $P < .001$).[31] However, it is worth noting that there may have been an order effect because the same sample experienced all 3 conditions.

However, in another study that used accelerometry to evaluate physical activity, significantly more movement in the standing desk classroom compared with the control classroom was found over a 30-minute period of observation (538 ± 229 vs 134 ± 94 cpm; $P < .001$).[32] In addition, a significantly greater frequency (24.05 vs 2.11 times; $P < .001$) and duration (10.47% vs 1.75% of time; $P < .001$) of time spent "walking around" for the intervention classroom compared with the control classroom was shown. In measurements of "being active," the standing desk classroom had more frequent bouts of activity versus the control classroom (14.00 vs 1.60; $P < .001$), but there was no significant difference in duration of being active over the 30 minutes of observation (7.79% vs 1.00% of time; $P = .225$).

Effects of Standing Desks on Health Indicators

Caloric Expenditure and BMI: Caloric expenditure was evaluated in 2 studies by using an armband fitness tracker. In 1 study, children in the standing desk classroom burned 0.182 kcal/min more compared with those in the control classroom of traditional seated desks.[24] The difference was most pronounced among children who were overweight/obese. In this subgroup, children exposed to the standing desks burned 1.56 kcal/min versus the control rate of 1.18 kcal/min; however, the authors did not indicate whether this finding was statistically significant. The other study was a large RCT which found, after adjustment for sociodemographic characteristics and BMI, that the classrooms with the standing desks had a higher mean caloric expenditure by 0.16 kcal/min ($P < .0001$) compared with the control group during the fall semester; this difference decreased to 0.08 kcal/min ($P < .01$) in the spring semester. In terms of BMI, 1 pre–post study with no control group found no significant or clinical difference in BMI after implementing a 5-month standing desk intervention.[29]

Neck, Back, and Other Indicators of Pain: The impact of standing desks on neck and back pain was examined in 2 studies. The investigators of 1 study administered a survey during the intervention and found that a greater percentage of children in the intervention group reported neck or back pain than children in the control group (47.4% vs 26.1%), but this finding was not statistically significant ($P = .21$).[32] In another study, neck, shoulder, back, elbow, wrist, hip/thigh, knee, and foot/ankle pain was assessed in the intervention group at baseline and follow-up.[27] Although *P* values were not reported, 4 of the indicators of pain indicated a decline in the percentage of children reporting pain after implementation of the standing desk intervention, most notably foot/ankle (63% to 37%) and elbow (21% to 11%). Two other indicators of pain increased from baseline to follow-up, including hip/thigh (21% to 32%) and knee (26% to 37%), and pain did not change for the shoulder or back.

Effects of Standing Desks on Academic Indicators

Three studies examined the impact of standing desks on classroom behavior and academic indicators.[27,29,32] Improvement in classroom behavior, in terms of classroom management, student concentration in academic materials, and student discomfort, reportedly improved in 1 study, but the findings were not statistically significant.[29] Similarly, no significant differences between the control and intervention classrooms were reported in terms of frequency (6.78 vs 3.45 times; $P = .064$) and duration (29.90% vs 26.47%; $P = .604$) of time spent reading or writing over a 30-minute period of observation.[32] Inattention and hyperactivity-impulsivity were examined in another study, and although the intervention group demonstrated a greater reduction in inattention and hyperactivity-impulsivity, there were no significant differences ($t = 1.59$, $P = .16$; $t = 1.58$, $P = .13$, respectively) between the 2 groups in the final measurement.[27]

DISCUSSION

Our review provides initial evidence, derived from examining the findings of intervention trials, that integrating standing desks in schools has the potential to reduce sitting time and increase standing time among elementary schoolchildren. The effects of standing desks on changes in physical activity during the school day were mixed, with some studies reporting no significant change in step counts and stepping time, while others reported increases in classroom physical activity. Although some favorable outcomes were observed in terms of improved classroom behavior and increased energy expenditure, the results were not statistically significant, they had small to intermediate effect sizes, or too few studies were available to make inferences. Nonetheless, the strong, cumulative evidence for reduced sitting time and increased standing time indicates that standing desks have the capacity to reduce sedentary behavior, even when supplementing standing desks with adjustable stools or swinging foot pendulums.

Despite the heterogeneity of outcomes that each study reported and the somewhat equivocal or limited findings, all of the studies identified either a reduction in sedentary time or an increase in standing time. Although heterogeneity in terms of study design, intervention methodology, and sample size did not permit a meta-analysis on overall reduction in sedentary time, 1 study did report an overall reduction in sedentary time of 59 minutes during waking hours[30] and another reported a reduction of 64 minutes during the school day.[27] Indeed, similar observations have been noted among the adult population, in whom a recent systematic review and meta-analysis confirmed that activity-permissive workstations effectively and feasibly reduced sedentary time by 77 minutes per 8-hour workday.[33] Evidence-based guidelines have recently been developed for employers to promote the avoidance of prolonged periods of sedentary work, indicating a gradual increase of 2 to 4 hours of standing or light activity per workday.[34]

One of the studies included in the present review illustrates the potential health benefits of reducing sedentary time. This study evaluated the impact of stand-biased desks with height-appropriate stools used by students in fourth grade classrooms.[24] After 6 weeks, 70% of the students never used their stools to sit and the other 30% stood for the majority of the time that they were at their desks. Furthermore, accelerometer data established that students burned 32 calories more per hour than before implementation of the intervention. During a typical school day, this change would translate into 225 additional calories burned, the equivalent of walking, skateboarding, or roller-skating for 1 hour after school.[35] Over the course of a school year, students who stand most of the day could be expected to expend 40 000 calories more than they would have had they been seated all day. Theoretically, this intervention could thus result in a net reduction of ∼12 pounds (5.4 kg) per year in weight gain.

However, standing for long periods without moving also has the potential to increase neck and back pain and result in a reduction in blood pressure.[36] The frequency of sit-to-stand transitions, how to stand (eg, shifting weight from 1 foot to the other), and having a resting bar or pendulum for the foot may all be important considerations for future studies and for policy and practice. Furthermore, the design and cost-effectiveness of standing desks versus traditional classroom desks need to be considered. Some estimates suggest sit-to-stand desks cost ∼20% more than traditional seated desks,[24] whereas others found standing workstations to cost 40% less than standard desks.[26] One study examined the effect of sit-to-stand desks in 1 classroom equipped with such desks for all students and another classroom that rotated the use of sit-to-stand desks among students; interestingly, the investigators noted similar reductions in sitting time relative to control conditions, despite the differences in desk provision.[25] Thus, creative and less costly approaches to integrating standing desks in schools may be considered.

Collectively, this evidence suggests that standing desk interventions may reduce sedentary behavior and could therefore have implications for health promotion initiatives in the school setting. Indeed, the efficacy and effectiveness of other health promotion interventions in the school setting have been established; these interventions include those that aim to increase physical activity and improve dietary behavior through health education, curriculum-based behavior change, parental education and support, environmental modification, use of other activity-permissive equipment (ie, exercise balls), and/or policy change,.[37–40] Results of most school-based health promotion programs demonstrate significant improvements in knowledge, self-efficacy, and health behavior for physical activity and healthy eating.[41]

These observations provide support for ecological models that identify those modifiable individual (student and parent), interpersonal (peers and teachers), and community/environmental (school neighborhoods, grounds, building design, facilities, and equipment) determinants of sedentary behavior and physical inactivity that may interact to drive long-term behavior change, improve metabolic functioning, and potentially help to prevent weight gain.[42–44] Because of the ubiquitous opportunities for students to be sedentary during the school day, such as during transportation, class, and at lunch, a multipronged approach to promoting the avoidance of prolonged periods of sedentary behavior is warranted.

Further research is needed to determine the efficacy, effectiveness, and feasibility of implementing standing desks on a larger scale with longer term follow-up. Although the studies included in this review provide evidence of the potential for standing desks to improve standing time and reduce sedentary behavior in elementary schools, most were relatively small-scale studies and were therefore limited by a small sample size, low statistical power, nonrandomized study design, lack of intention-to-treat analyses, order effect of intervention delivery, and long-term follow-up, or they lacked valid and reliable measures of sedentary behavior. Furthermore, few of the studies examined the same outcomes in terms of health indicators (ie, energy expenditure, BMI) or academic parameters (ie, test scores) to comment on those outcomes.

Further studies are needed with adequately powered RCT designs, the use of objective measures that allow quantitative estimates of energy expenditure (ie, accelerometry or inclinometers) and that examine the impact of standing desks according to gender, race/ethnicity, and age group (including adolescents in middle and high school). Assessment of strategies that may be used to successfully implement standing desks in the classroom is also needed, such as the degree of teacher instruction and development of educational curricula to teach students about the benefits of standing and reducing time spent sedentary. Qualitative research is also needed to assess the perceptions of educators, administrators, students, and parents on integrating standing desks into the school setting.

In addition to the methodologic limitations of the studies included in this review, our findings must be interpreted in the context of the following limitations. First, although exhaustive search methods were used to eliminate any potential bias, it is possible that not all quantitative studies were identified. In addition, the exclusion of unpublished and gray literature may have contributed an element of publication bias, with potential implications for the robustness of the findings; however, such studies may have lower methodologic quality[45] and likely did not evaluate the effects of the intervention on the same students. Second, the sample characteristics of race/ethnicity and school characteristics were omitted from several of the reviewed studies, potentially influencing the generalizability of the findings to other contexts. Third, some of the studies reviewed did not report tests of statistical significance or pre–post data; when complete data were available, however, effect sizes were calculated. It is also worth noting that our findings must be interpreted with caution as few studies have been published in this area and most studies included in this review lacked long-term follow-up.

CONCLUSIONS

The early evidence found that standing desk interventions in the school setting have the potential to reduce sitting time and increase standing time in elementary grade children. In essence, it can be hypothesized that students could effectively learn while simultaneously reducing the high volumes of sedentary time accumulated through passive and static sitting in the classroom. However, additional research is needed to examine the impact of standing desks on academic performance, precursors of chronic disease risk, and other outcomes. The implementation of standing desks in schools may be a feasible, acceptable, and beneficial environmental strategy to reduce sedentary behavior in the school setting, but further and more rigorous research studies are needed to determine the efficacy and effectiveness of this approach.

ABBREVIATIONS

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: randomized controlled trial

DOI: 10.1542/peds.2015-3087

Accepted for publication Nov 16, 2015

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Mr Minges was funded by a predoctoral fellowship from the National Institute of Diabetes and Digestive and Kidney Disease/National Institutes of Health (T32-DK07718). Dr Chao was funded by a predoctoral fellowship from the National Institute of Nursing Research/National Institutes of Health (F31-NR014375). Dr Owen was funded by a National Health and Medical Research Council Program Grant (no. 569940), a Senior Principal Research Fellowship (National Health and Medical Research Council #1003960), and the Victorian Government's Operational Infrastructure Support Program. Dr Salmon was funded by a Principal Research Fellowship, National Health and Medical Research Council (APP1026216). Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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