

Original article

The impact of height-adjustable desks and classroom prompts on classroom sitting time, social, and motivational factors among adolescents

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Abstract

Purpose: This quasi-experimental study examined the impact of height-adjustable desks in combination with prompts to break up prolonged sitting time during class time and identified social and motivational factors associated with breaking up sitting time among adolescents. Teachers' perceptions of strategies were also examined.

Methods: Over 17 weeks, 1 classroom in a government secondary school in Melbourne, Australia, was equipped with 27 height-adjustable desks and prompts (posters and desk stickers) to break up classroom sitting time. Teachers received professional development in the use of the desks and prompts. One group of adolescents ($n = 55$) had 2–5 lessons/week using the height-adjustable desks in an intervention classroom, and a comparison group matched by year level and subject ($n = 50$) was taught in traditional “seated” classrooms. Adolescents wore an *activPAL* monitor at baseline (T0), 4 weeks (T1), and 17 weeks (T2) and completed a survey at T0 and T2. Six teachers participated in interviews at T2. Effect sizes were calculated (d).

Results: Linear mixed models found that, compared to the traditional “seated” classrooms, the adolescents in the intervention classroom had significantly lower sitting time (T1: -9.7 min/lesson, $d = -0.96$; T2: -6.7 min/lesson, $d = -0.70$) and time spent in sitting bouts > 15 min (T2: -11.2 min/lesson, $d = -0.62$), and had significantly higher standing time (T1: 7.3 min/lesson, $d = 0.84$; T2: 5.8 min/lesson, $d = 0.91$), number of breaks from sitting (T1: 1.3 breaks/lesson, $d = 0.49$; T2: 1.8 breaks/lesson, $d = 0.67$), and stepping time (T1: 2.5 min/lesson, $d = 0.66$). Intervention classroom adolescents reported greater habit strength ($d = 0.58$), self-efficacy for breaking up sitting time ($d = 0.75$), and indicated that having a teacher/classmate remind them to stand as helpful ($d = 0.50$).

Conclusion: This intervention shows promise for targeting sitting behaviors in the classroom and indicates that incorporating social and motivational strategies may further enhance outcomes.

Keywords: Adolescent; School; Sedentary behavior; Sitting; Standing

1. Introduction

There is inconsistent evidence regarding the relationship between time spent sitting and health risk markers in youth.^{1–3} However, youth spend approximately 60% of their waking hours

sitting, and around 70% of their sitting occurs at school.^{4–7} Some countries have generated public health guidelines recommending that adolescents reduce and break up their sitting time throughout the day.^{8,9} Thus, reducing and breaking up prolonged periods of sitting time at school represents a potential preventative health strategy for young people.

Emerging research has examined the feasibility and impact of height-adjustable desks in the classroom on adolescents' sitting time.¹⁰ These desks can either be set at a fixed standing height

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(stand-biased desks) or be adjustable (height-adjustable), thus allowing adolescents to vary their posture between sitting and standing during classroom lessons.¹¹ Systematic reviews of pilot studies in elementary (primary) school settings suggest that these environmental classroom interventions reduce sitting volume^{10–12} and prolonged sitting.¹³ While evidence on the effectiveness of classroom desk-based interventions in the secondary school setting is limited, preliminary pilot research has demonstrated that 25% less sitting occurs in adjustable desk-based classrooms compared to a traditional “seated” classroom.¹⁴

Although research on the impact of using standing desks in school settings shows promise, it has tended to primarily focus on modifying the physical classroom environment without additional behavior change strategies, such as motivational approaches.^{10,11} While changing classroom environments to make them more activity permissive is an important step, it is possible that intervention success may be further enhanced if evidence-based behavior change strategies are also used.^{15,16} Indeed, workplace interventions implemented to reduce adults’ sitting time that involved modifying the physical environment as well as incorporating behavior change strategies have been more effective than environment-only interventions.¹⁷ Further research is needed to examine the effectiveness of using strategies that go beyond just providing height-adjustable desks in the classroom in order to reduce and break up adolescents’ sitting time.

Theories of behavior change, such as social cognitive theory¹⁸ and the theory of planned behavior,¹⁹ have commonly been used in the development of strategies to promote physical activity in youth.²⁰ However, these theories presume that underlying controlled cognitive processes (i.e., conscious or reflective) precipitate behavior, whereas sitting is, at least in part, an effortless and automatic behavior.²¹ The extent to which automatic and controlled cognitive dual processes engage and interact can be influenced by the physical and social contexts in which behavior occurs. Specifically, in novel contexts, controlled cognitive processes will have more of an influence on behavior than automatic processes (i.e., habit) in determining behavior, whereas in familiar and unvarying settings, behavior will be guided by automatic processes, with cognitive processes having little or no impact.^{21–23} Both processes have been proposed to exert a unique influence on sedentary behavior;²⁴ however, limited research has examined this in relation to reducing sitting time or breaking up sitting time in the school setting.

A potentially useful model to guide the development of strategies targeting reductions in sitting time among youth is the Capability, Opportunity, Motivation, Behavior model, which specifies that capability (e.g., an individual’s psychological and physical capacity to engage in behavior), opportunity (e.g., factors that lie outside the individual that make behavior possible or prompt it, such as environmental and social factors), and motivational factors (e.g., conscious and automatic processes that drive behavior) influence behavior change (individually and in interaction with each other).¹⁵ Combining environmental changes in the school setting with motivational and capability-building factors may be a promising approach for reducing and breaking up sitting time in youth. To our knowledge, no studies have examined the social and individual

motivational factors that may reduce sitting volume and increase the frequency of breaking up sitting time in the classroom.²⁵ From a social perspective, it is likely that teachers and peers in the classroom can serve to encourage and prompt the use of height-adjustable desks intended to reduce and break up classroom sitting time. From a motivational perspective, it is also likely that adolescents’ confidence (i.e., self-efficacy) in their ability to reduce and break up their sitting time, in combination with the habit of automatically sitting in the classroom, may influence their behavior. However, such influences have not been explored using dual process theories or models, such as the Capability, Opportunity, Motivation, Behavior model.

The primary aim of this quasi-experimental study was to examine the impact of combining environmental change and classroom prompts in a secondary school classroom (with teachers receiving professional development in implementing these changes and prompts) on adolescents’ sitting time, prolonged sitting bouts, standing and stepping time, and breaks from sitting during class. Secondary aims included examining intervention effects on adolescents’ habit strength, self-efficacy, and perceived influences on taking breaks from sitting. Process evaluation explored teachers’ perceptions of the feasibility of using height-adjustable desks and other classroom strategies to encourage adolescents to reduce and regularly break up sitting time in class.

2. Methods

2.1. Study design

This study used a quasi-experimental design. Adolescents and teachers in 1 government secondary school (a public high school) in Melbourne, Australia, took part in the study. The intervention was conducted in 1 classroom used by multiple classes and ran for 2 school terms (June to November 2015).

2.2. Participants

Recruitment and methodology for this study have been described elsewhere.¹³ In brief, 1 classroom was selected by the school to be the intervention classroom. All teachers and adolescents in 4 classes scheduled to have all lessons for a specific subject in the intervention classroom were invited to take part in the study (i.e., intervention group). A comparison group was recruited from adolescents in 4 classes matched by year level and subject, but whose classes were held in traditional “seated” classrooms. The comparison group did not have access to the intervention classroom and received no other special attention. A presentation about the evaluation components of the project was delivered to all eligible adolescents. Parent and teacher consent forms were distributed to those interested in participating in the evaluation. Adolescents were required to provide written assent. Fig. 1 displays participant numbers and flow for each assessment throughout the study. No information was obtained about nonresponders. Ethics approval was received from the Deakin University Human Ethics Advisory Group - Health (HEAG-H 93_2014) and the Department of Education and Training (2014_002402).

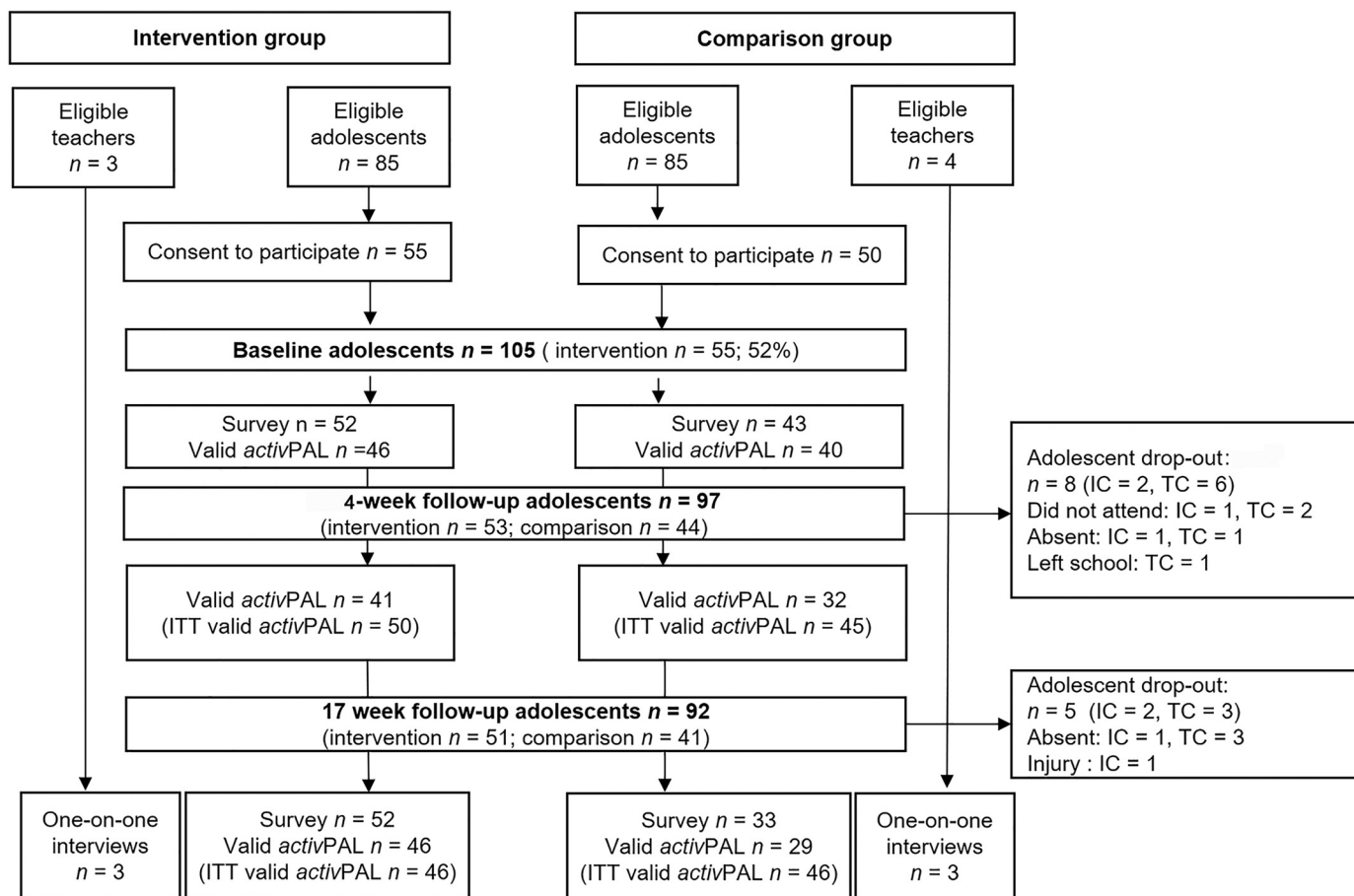


Fig. 1. Participant flow and total numbers and number of participant with valid and/or completed data (i.e., survey) through the study. IC = intervention classroom; ITT = intention to treat; TC = traditional classroom.

2.3. Intervention

The intervention classroom was equipped with 27 height-adjustable desks (i.e., 1 Ergotron LearnFit desk (Learnfit, Ergotron Inc., Saint Paul, MN, USA) for each student and the teacher). Because the desk's minimum seated height did not enable adolescents to sit and work at the desk with their usual classroom chairs, medium-height backless laboratory stools (Furnware Bodyfurn Lab stool, Melbourne, VIC, Australia) were also provided. Three posters were displayed in the classroom to provide environmental prompts. The posters depicted (1) how to use the height-adjustable desks, (2) the health benefits of breaking up sitting time, and (3) tips and strategies to reduce and break up classroom sitting time. As a further prompt, small stickers were placed on each height-adjustable desk. The stickers included a message to break up sitting time every 15 min for at least 2 min ([Supplementary materials](#)). While no dose-response evidence is available regarding how frequently sitting should be interrupted, or for how long, the frequency of breaks was informed by cross-sectional studies and acute experimental trials among children^{1,3} and adults^{26–29} that suggested sitting periods of longer than 15 min may have negative health consequences.

In addition to the height-adjustable desks, a 1-h professional development session was held for teachers delivering lessons in the intervention classroom. The professional development session was delivered by project staff and included information about how to use the desks, evidence on the health benefits of breaking up sitting time, and tips and strategies for adolescents to reduce and break up their classroom sitting time (e.g., stand up when using your computer or tablet, reading, working in a group, asking questions, and talking; “nominate a standing captain or a time keeper” who is responsible for encouraging and reminding the class to break up sitting time every 15 min). Each teacher was provided with a printed copy of this information. Two of the 3 teachers attended the professional development session; the other teacher was given a copy of the presentation and an explanation about the content. Using the tips and strategies given to them during the professional development session, teachers of adolescents in the intervention group were asked to inform and encourage their adolescents with these recommendations. It is important to note that, although adolescents were encouraged to break up their classroom sitting time when teachers and/or classmates suggested it, they were not required to.

2.4. Measures and data management

Adolescents in the intervention and comparison groups underwent baseline assessments before the height-adjustable desks were placed in the classroom (baseline; T0), and further assessments took place at Week 4 (T1) and Week 17 (T2). At T0 and T2, adolescents completed a survey. At T0, adolescents reported their sex, age, and grade level.

2.5. Primary outcomes

A thigh-mounted *activPAL3C* monitor (PAL Technologies Ltd., Glasgow, UK) was used to determine total time spent sitting, prolonged sitting bout duration (>15 min duration without interruptions), time spent standing and stepping, and frequency of breaks from sitting (defined as the number of transitions from sitting/lying to a standing/upright position) during class time. The *activPAL* monitor has demonstrated reliability and validity for use in free-living studies involving children.^{4,30} Adolescents wore the monitor (which was sewn into a pocket at the front of an elastic garter) at mid-thigh during waking hours for 5 consecutive weekdays at each of the 3 assessment points. They were instructed to remove the devices for sleep and water-based activities (i.e., swimming and showering). To allow for days when adolescents were absent from school to be excluded from the data, a logbook was provided so that adolescents could record when they were at school.

Monitor data were collected in 15-s epochs, downloaded using the manufacturer's proprietary software (*activPAL* Professional Version 7.2.32; PAL Technologies Ltd., Glasgow, UK) and processed using a customized Microsoft excel macro. If the device recorded 20 consecutive minutes of 0 accelerometer counts (vertical axis), it was assumed that the device had been removed (non-wear time).³⁰ The school timetable was used to identify when adolescents had lessons (57 min in duration) in the intervention classroom, and data during this time were extracted for analysis. Adolescents in the intervention group had a minimum of 2 and a maximum of 5 lessons per week in the intervention classroom. Data from the comparison group were matched for subject and time. To be included in the analyses, adolescents were required to have worn the monitors for at least 50% of the lesson⁴ on a day they were recorded as being present at school. For each participant, time spent sitting, prolonged sitting, standing, stepping, and frequency of breaks in sitting were calculated for each relevant classroom lesson, then averaged across valid classroom lessons. For inferential purposes, variables were standardized by wear time (variable of interest/class wear time).

2.6. Secondary outcomes

2.6.1. Habit strength for regularly breaking up classroom sitting time

A 4-item subscale, adapted from the Self-Report Behavioral Automaticity Index,^{31,32} was used to determine the habit strength of regularly breaking up sitting time with standing during lessons. Using a 6-point Likert scale (1 = *strongly agree* to 6 = *strongly disagree*), adolescents reported the extent to which they agreed with 4 specific items:

“We are interested in knowing what you think about regularly breaking up sitting with standing (e.g., every 15 min) during classroom lessons.”

Regularly standing up during lessons is something . . . : (1) “I do almost automatically.” (2) “I do without having to remember to do so.” (3) “I do without thinking.” (4) “I start doing before I realize I’m doing it.”

For analytical purposes, response scores were reversed and averaged to create an overall score for habit strength for breaking up sitting time (a higher score equates to stronger habit strength). The scale had excellent internal consistency (Cronbach's $\alpha = 0.95$).

2.6.2. Task self-efficacy for replacing classroom sitting with standing

Adolescents were asked to respond to the following question: During classroom lessons, how confident are you that you can: (1) “Break up sitting with standing every 15 min”, (2) “Change between sitting and standing regularly during classroom lessons”, (3) “Stand for a quarter of classroom lessons”, (4) “Stand for half the classroom lessons”, and (5) “Stand for most of the classroom lesson”. Response options ranged from 0 (*cannot do at all*) to 10 (*highly certain can do*). This section of the survey was developed by the research team, guided by the intervention message and past scales measuring task self-efficacy beliefs.³³

2.6.3. Perceived social and motivational influences on breaking up sitting

Using a 6-point Likert scale (1 = *strongly disagree*, 6 = *strongly agree*), adolescents rated the extent to which they agreed that 10 social and motivational factors influenced their ability to “break up sitting in class every 15 min”. The items, developed by the research team and/or adapted from past research,¹⁴ were: (1) Having a teacher/classmate remind me, (2) Having class activities as “standing activities”, (3) Hard if friends/classmates were not doing it, (4) Low priority, (5) Don't have motivation, (6) Too much classwork, (7) Not enough energy, (8) Wouldn't benefit my ability to complete work, (9) Feel too self-conscious doing so, and (10) Don't believe it would benefit my health. Each item was treated separately.

2.7. Process evaluation

All teachers involved in the study completed a 15-min, one-on-one, face-to-face interview (i.e., open-ended questions) at the 17-week follow-up. The interview was audio recorded. Intervention teachers were asked if they found the message to “break up sitting every 15 min” feasible to implement within their classroom lessons. They were also asked their opinions of the messages intended to encourage adolescents to regularly break up classroom sitting and what strategies they believed to be most effective in breaking up classroom sitting time.

Using a 6-point Likert scale (1 = *strongly disagree*, 6 = *strongly agree*), adolescents were asked to indicate the extent to which they looked at the wall posters and desk sticker to remember to break up classroom sitting time (i.e., “I looked at the poster”, “I looked at the wall/desk sticker”).

2.8. Statistical analyses

Data were analyzed using STATA (Version 15.0; StataCorp LLC, College Station, TX, USA). Descriptive statistics were used to present the sociodemographic characteristics of the sample; durations of sitting; prolonged sitting bout duration (>15 min); standing and stepping times; frequency of breaks in sitting; and levels of habit, self-efficacy, and perceived influences on regularly breaking up classroom sitting time. Up to 30% of the *activPAL* data, social data and motivational data were missing at the second or third time points. Therefore, to maximize the analytical sample, all analyses were conducted on an intention-to-treat basis, and missing data were treated with last observation carried forward (Fig. 1). Available case inferential analyses were conducted to accommodate the different sample sizes across outcomes. Differences in baseline age and sex between those with complete valid *activPAL* data for all 3 time points and those without complete data were examined using a *t* test and χ^2 test for independence, respectively. Linear mixed models (with random intercepts for class groups) were used to examine intervention effects on all outcomes between the intervention and comparison groups at T1 and T2, adjusting for baseline levels of the dependent variables, age, and sex. Intervention effect sizes (*d*) were calculated as the adjusted mean difference between treatment and control groups divided by the pooled standard deviation.³⁴ Effect sizes between 0.20 and 0.49 were considered to be “small”, effect sizes between 0.50 and 0.79 were considered to be “medium”, and effect sizes ≥ 0.80 were considered to be “large”.³⁵ A narrative description of themes arising from the qualitative interviews with teachers is provided (Section 3.4 *Teachers’ perceptions*).

3. Results

3.1. Demographics

Overall, 105 adolescents (age: 14.8 ± 1.7 years (mean \pm SD), range: 12–17 years) in School Year 7, 10, and 11 and who had written parental consent (response rate = 62%) took part in the study. All adolescents in the class were able to use the height-adjustable desks and prompts; however, those with consent took part in the evaluation for the current study. For adolescents with valid *activPAL* data, the device was worn for 98%–100% of the lesson. There were no age or sex differences between those with valid *activPAL* data for the 3 time points and those without valid *activPAL* data. Six teachers (all female) participated in the interviews.

3.2. Classroom sitting, standing and stepping time, and frequency of breaks from sitting

Table 1 shows adolescents’ demographic characteristics and the time spent in sitting, prolonged sitting bouts (>15 min), standing and stepping times, and the number of breaks from sitting during classroom lessons at baseline, T1 (4 weeks post-baseline), and T2 (17 weeks post-baseline). Adolescents in the intervention group were significantly older than adolescents in the comparison group; there were no other significant between-group differences at baseline. On average, at baseline, adolescents were sitting for approximately 80% of the time during their classroom lessons. At T2, adolescents in the intervention classroom were sitting for 67% of the time during their lessons compared with adolescents in traditional classrooms, who were sitting for 83% of the time during their lessons.

Table 2 shows that compared to adolescents in traditional classrooms, the intervention group spent 9.7 min less time sitting at T1 ($d = -0.96$, large effect) and 6.7 min less time sitting at T2 per lesson ($d = -0.70$, medium effect), as well as less time in prolonged sitting bouts at T2 only ($d = -0.62$, medium effect). The intervention group

Table 1

Adolescents’ demographic characteristics and duration (min/lesson) of sitting, prolonged sitting bouts (>15 min), standing and stepping times, and number of breaks from sitting during lessons at T0, T1, and T2 (mean \pm SD).

	Intervention group			Comparison group		
	T0	T1	T2	T0	T1	T2
Participants (<i>n</i>)	46	41	47	40	32	29
Age (year)	15.2 ± 1.7	15.4 ± 1.7	15.6 ± 1.7	14.3 ± 1.6	14.4 ± 1.6	14.7 ± 1.6
Girls (%)	38.2	34.7	38.3	48.0	54.9	55.2
Duration (min/lesson) ^{a,b}						
Sitting	46.2 ± 5.9	35.6 ± 13.4	38.1 ± 12.3	45.7 ± 7.2	46.9 ± 11.8	47.1 ± 11.3
Sitting in >15-min bouts	30.0 ± 16.4	20.0 ± 17.4	20.5 ± 16.3	23.4 ± 12.1	30.0 ± 23.4	33.4 ± 24.9
Standing	5.5 ± 3.3	15.3 ± 11.7	11.3 ± 9.1	6.5 ± 4.8	8.1 ± 11.4	5.4 ± 6.7
Stepping	5.3 ± 3.4	6.0 ± 5.4	7.7 ± 6.4	4.8 ± 3.0	2.1 ± 2.5	4.5 ± 6.0
Breaks in sitting (<i>n</i>)	3.0 ± 2.9	4.4 ± 2.9	4.6 ± 3.0	3.6 ± 2.3	2.8 ± 2.5	2.3 ± 2.3

Notes: T0 = baseline; T1 = 4 weeks; T2 = 17 weeks.

^a Each lesson equals 57 min.

^b Data obtained from *activPAL3C* monitors.

Table 2
Intervention effects on adolescents' sitting time, prolonged sitting bouts (>15 min), standing and stepping times, and breaks from sitting during lessons^a at T1 and T2.

	Group differences ^b					
	T1			T2		
	Mean (95%CI)	β	<i>p</i>	Mean (95%CI)	β	<i>p</i>
Sitting (min/lesson)	-9.7 (-15.0 to -4.4)	-0.4	0.001	-6.7 (-11.0 to -2.5)	-0.3	0.001
Sitting bouts > 15 min (min/lesson)	-7.7 (-17.5 to 2.0)	-0.2	0.141	-11.2 (-18.0 to -4.5)	-0.3	0.002
Standing (min/lesson)	7.3 (2.5 to 12.2)	0.3	0.003	5.8 (2.0 to 9.5)	0.3	0.002
Stepping (min/lesson)	2.5 (0.7 to 4.3)	0.3	0.010	1.2 (-1.1 to 3.4)	0.1	0.252
Breaks from sitting (<i>n</i> /lesson)	1.3 (0.3 to 2.4)	0.3	0.009	1.8 (0.5 to 3.0)	0.3	0.004

Notes: T1 = 4 weeks post-baseline; T2 = 17 weeks post-baseline.

^a Each lesson equals to 57 min. Data obtained from *activPAL3C* monitors.

^b Results from intention to treat linear mixed models comparing intervention and comparison groups (coefficients (*b*), 95%CI, *p* value, standardized beta weights (β)), adjusting for baseline levels of outcomes, age, and sex.

Abbreviation: 95%CI = 95% confidence interval.

spent more time standing at T1 and T2 (7.3 min ($d=0.84$) and 5.8 min ($d=0.91$) large effects, respectively) and 2.5 min more time stepping at T1 ($d=0.66$, medium effect). Compared to adolescents in traditional classrooms, the intervention group also recorded a greater number of breaks from sitting at T1 ($d=0.49$, small-to-medium effect) and T2 ($d=0.67$, medium effect).

3.3. Social and motivational influences on regularly breaking up classroom sitting time

Table 3 shows that the intervention group had greater increase in self-reported habit strength ($d=0.58$, medium effect) and self-efficacy for regularly breaking up classroom sitting time ($d=0.75$, medium effect) at T2 compared to the comparison group. Relative to adolescents who used traditional classrooms, the intervention group also had higher

agreement that having a classmate or teacher remind adolescents to take breaks was an important factor in regularly breaking up classroom sitting time ($d=0.50$, medium effect).

3.4. Teachers' perceptions

All intervention teachers reported that the message to break up sitting every 15 min was feasible and that planning for movement and breaks in sitting time in advance was critical. One teacher suggested that a message relating to standing for a certain number of times per lesson may be easier to remember and implement than a time-based message. Teachers reported that a combination of teacher-directed and student-directed strategies appeared most effective, and variation was also important as the novelty wore off. Younger adolescents were identified as being able to respond better to teacher-directed strategies (e.g., having group "standing activities"), whereas

Table 3
Changes in social and motivational influences on breaking up classroom sitting time every 15 min (mean \pm SD) and impact on the intervention group relative to the control group at T2.

	Intervention group mean (SD) ^a		Comparison group mean (SD) ^a		Group differences ^b		
	T0	T2	T0	T2	<i>b</i> (95%CI)	β	<i>p</i>
Habit strength (score)	9.0 \pm 5.7	9.8 \pm 5.7	7.4 \pm 4.0	6.1 \pm 3.0	2.8 (0.9, 4.8)	0.3	0.004
Self-efficacy for regular breaks in sitting	7.1 \pm 3.0	7.4 \pm 2.7	5.5 \pm 3.2	4.6 \pm 3.4	2.3 (1.0, 3.5)	0.3	0.000
Influences on breaking up classroom sitting time every 15 min							
Having a teacher/classmate remind me	4.2 \pm 1.7	4.4 \pm 1.7	3.5 \pm 2.0	2.9 \pm 1.8	0.9 (0.1, 1.6)	0.2	0.027
Having class activities as "standing activities"	4.4 \pm 1.6	4.0 \pm 1.7	3.1 \pm 1.8	2.9 \pm 1.8	0.1 (-0.7, 0.8)	0.0	0.509
Hard if friends/classmates were not doing it	3.7 \pm 1.7	3.6 \pm 1.7	3.4 \pm 1.8	3.1 \pm 2.0	0.2 (-0.6, 1.1)	0.1	0.625
Low priority	3.2 \pm 1.6	3.3 \pm 1.5	3.2 \pm 1.6	2.7 \pm 1.8	0.6 (-0.1, 1.3)	0.2	0.157
Don't have motivation	3.1 \pm 1.8	3.1 \pm 1.7	2.8 \pm 1.5	2.9 \pm 1.9	0.4 (-0.4, 1.2)	0.1	0.344
Too much classwork	3.1 \pm 1.8	2.9 \pm 1.5	2.9 \pm 1.6	2.8 \pm 1.9	-0.1 (-0.9, 0.6)	-0.0	0.723
Not enough energy	2.6 \pm 1.8	2.8 \pm 1.6	2.6 \pm 1.4	2.5 \pm 1.7	0.5 (-0.3, 1.2)	0.1	0.210
Wouldn't benefit my ability to complete work	3.0 \pm 1.9	2.8 \pm 1.4	3.2 \pm 1.6	2.4 \pm 1.7	0.4 (-0.3, 1.1)	0.1	0.305
Feel too self-conscious doing so	2.5 \pm 1.6	2.5 \pm 1.6	2.7 \pm 1.7	2.6 \pm 1.8	-0.1 (-0.8, 0.6)	-0.0	0.815
Don't believe it would benefit my health	2.3 \pm 1.6	2.4 \pm 1.3	2.8 \pm 1.4	2.3 \pm 1.7	0.4 (-0.3, 1.0)	0.1	0.268

Notes: T0 = baseline; T2 = 17 weeks post-baseline.

^a Means and standard deviation (SD) come from all available data (before the last case was carried forward).

^b Results from intention to treat linear mixed models comparing intervention and comparison groups (coefficients (*b*), 95%CI, *p* value, standardized beta weights (β)), adjusted for baseline level of outcome, age, and sex.

Abbreviation: 95%CI = 95% confidence interval.

older adolescents responded better to student-directed strategies (e.g., given the choice to stand or sit during an activity) that supported a greater level of autonomy.

Teachers perceived the following student-directed strategies to be effective: adolescents using a timer/alarm, writing 15-min time blocks on a board at the front of the class and progressively crossing them off, and having a designated “standing captain” who took responsibility for reminding the class to stand. One teacher also reported encouraging adolescents to develop awareness and monitor how their bodies were feeling (i.e., somatic awareness) and stand if they were feeling sore or stiff, for example. Teachers also reported the importance of peer influences, where if one student stood up, others would follow. One challenge with student-directed strategies related to adolescents remembering to stand, with one teacher indicating that “I had to remind the time keeper he was the time keeper”. Teachers reported that they were sometimes hesitant to remind adolescents to break up their sitting time because they did not want to disrupt their concentration. For these reasons, one teacher considered student-directed strategies to be less disruptive than teacher-directed strategies.

With respect to classroom behaviors, teachers indicated that the intervention had a positive impact. They mentioned that the intervention classroom generated a “positive mindset” or “calming effect”, the adolescents’ attitude was “positive and helpful” and the standing position “encouraged questioning” during the class. A less positive effect was that while standing, some adolescents would walk over to their classmates to talk and it was necessary to direct them back to their workstations.

The 3 teachers who used the traditional classrooms were also interviewed and there was no indication of a contamination effect. Teachers had limited awareness of the intervention and did not believe their teaching practice had changed.

3.5. Adolescents perceptions

For 49% of the adolescents, classroom wall posters were useful in helping them remember to break up classroom sitting time; the desk stickers were helpful for 46% of the adolescents.

4. Discussion

This quasi-experimental study found that adolescents who attended lessons in classrooms with height-adjustable desks and classroom prompts that encouraged them to regularly break up their sitting time had less time in accumulated and prolonged sitting bouts and had more breaks in sitting time compared to adolescents attending lessons in traditional classrooms. However, the difference in sitting time in the intervention group was less pronounced at 17 weeks compared to 4 weeks. This attenuation is consistent with a previous study that used stand-biased desks in an elementary school setting, where reductions in sitting were reported to be *likely* at 5 weeks and only *possible* at 17 weeks.³⁶ Conversely, in the current study differences between groups in the number of prolonged sitting bouts and the frequency of breaking up sitting time were greater at 17 weeks than at 4 weeks. Other studies have shown

attenuation in breaks from sitting time relative to comparison groups over time.^{36,37} While it is not possible to separate the effects of the desks from social and individual motivational factors, the maintenance of changes in frequency of breaks and prolonged bouts of sitting time over 17 weeks may have been in part due to the additional intervention components that directly targeted breaking up sitting time (e.g., messages and strategies to encourage breaking up sitting time every 15 min). In addition, 49% of the adolescents agreed that looking at the wall posters helped them to remember to break up classroom sitting time, while 46% agreed that looking at the desk stickers did so. Therefore, having constant reminders (e.g., prompts) may assist with the maintenance of behavior change. Long-term follow-up is needed to determine whether these effects are sustained over time and whether these changes have a health benefit.

Over the intervention period, adolescents’ self-efficacy and habit strength for breaking up classroom sitting time increased, as did the perception that having a teacher or classmates remind them to take breaks positively influenced their ability to “break up sitting in class every 15 min”. The study was not powered to conduct mediation analyses to determine whether these factors explained the reductions in sitting time or increases in breaks. However, the significant impact of the intervention on these factors highlights the importance of habit strength and self-efficacy constructs in dual-process theories of behavior change.^{24,25,33} To the best of our knowledge, these results are the first to identify potential motivational processes associated with reduced sitting time and the frequency of sedentary breaks within secondary school classrooms.²⁵ It can be speculated that if regularly breaking up sitting time is encouraged and becomes the norm within the classroom environment, then breaking up sitting time during class is likely to be viewed as socially acceptable and potentially socially rewarding. The habit of breaking up sitting time may also be favorably influenced by teachers’ and fellow adolescents’ behaviors that serve to cue and reinforce breaks in sitting. This may be further facilitated by a supportive classroom environment (i.e., height-adjustable desks).³⁸ The support and cues from teachers and peers combined with a supportive physical environment may also contribute to increased self-efficacy for breaking up sitting time amongst adolescents.

The process evaluation with teachers in the current study revealed that adolescents had trouble remembering to monitor the prescribed timing of breaks in sitting. Teachers also expressed concerns about interrupting adolescents’ concentration if they initiated a break. An intervention strategy highlighting the ideal number of breaks in sitting per classroom lesson (e.g., “3 breaks in sitting per classroom lesson”) may be easier to remember than the time-based strategy used in the current study. Teachers also perceived that a combination of teacher-directed and student-directed strategies was most effective. Primarily favorable perceptions of height-adjustable desks in classrooms have been reported in studies with primary (elementary) school children.^{9,36} However, secondary schools may be more challenging in this regard; unlike primary school adolescents, secondary adolescents move from room to room for different classes, potentially making

it difficult to develop the habit of reducing and breaking up sitting time during class due to the lack of a stable context for enacting the behavior.

Strengths of the study included the incorporation of additional intervention materials with the height-adjustable desks, such as messages guiding breaks in sitting time; a teacher professional development session related to the topic; and an emphasis on incorporating various strategies to regularly break up classroom sitting time. The study also assessed primary and secondary outcomes at 4 weeks and 17 weeks, which provides additional information about the trajectories of behavior change.

There were a number of limitations in the present study. This was a non-randomized study design that involved a comparison group within the same school and campus, which could have led to an intervention contamination effect, although there was no evidence of contamination based on interviews with teachers and the student survey data. The adolescents' low exposure to the desks (2–5 lessons of approximately 20 lessons per week) is another limitation of this study. Although there were significant average reductions in sitting time for lessons in the intervention classroom, these reductions may not have affected the adolescents' daily volume of overall sitting time, which was not examined in this study. Adolescents may have compensated for their reduced sitting time during class by increasing sitting time at other times of the day.³⁹ This study involved an evaluation of changes in sitting patterns during lesson times; however, capturing effects on sitting time across the school day could have helped in understanding the behavioral impacts of the intervention beyond the classroom. When we explored intervention effects during waking hours (data not shown), we found that the differences between the 2 groups of adolescents (intervention *vs.* traditional) were maintained at 4 weeks but were less clear at 17 weeks. The novelty of only equipping 1 classroom with height-adjustable desks may have favorably biased the sitting time and motivational results in the current study. At the same time, the stools that accompanied the height-adjustable desks may have prompted adolescents to sit more. The study was not statistically powered to test whether the changes in social and motivational factors mediated changes in sitting time and breaking up sitting time. Nevertheless, the inclusion of these specific dual-process theory constructs as secondary outcomes was a unique aspect of this intervention.¹⁶

Further research is needed to test the impact of greater exposure to height-adjustable desks in the classroom over a longer period is needed. The number of desks available and the desk layout in the classroom could also affect use and subsequent sitting time and therefore needs further exploration. For example, similar reductions in sitting among primary (elementary) school children were found in an Australian school that provided desks to every child in the class compared to a UK school that provided 6 height-adjustable desks at the back of 1 classroom that children took turns using.⁶ However, the changes in social and motivational factors and positive teacher perceptions indicate future studies should consider the use of multi-component approaches beyond just changing the physical classroom environment. Future research is needed to determine whether new "standing" habits can be created over a sustained period.

5. Conclusion

The present study found that height-adjustable desks, in combination with the incorporation of teacher professional development on the topic and prompts to reduce and break up adolescent's sitting time, appeared to be effective and feasible in reducing total classroom sitting time and prolonged sitting bouts and in increasing the frequency of breaks. The improvements in adolescents' habit strength and self-efficacy for breaking up their sitting time may be key influencing factors that need further exploration.

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Authors' contributions

BS contributed to the study conception, design, and data collection, carried out the analysis and interpretation of data, and drafted the manuscript; AMCA contributed to the study design, analysis and interpretation of the data, participated in the data collection, and drafted the manuscript; AT contributed to the study conception, interpretation of data, and critical revision of the manuscript; DWD contributed to the study conception; DEC contributed to the study design; GA contributed to the analysis and interpretation of data; BH contributed to the study design and evaluation; LA contributed to the analysis and interpretation of the data and to drafting the manuscript; JS contributed to the study conception and design, drafting of the manuscript, and interpretation of data. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

JS has a potential conflict of interest in that her spouse established a business to manufacture height-adjustable desks for schools in 2017 (after this intervention occurred). She had no involvement in the data analysis. The other authors declare that they have no competing interests.

Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:[10.1016/j.jshs.2020.05.002](https://doi.org/10.1016/j.jshs.2020.05.002).

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