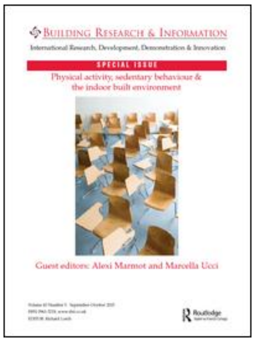

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RESEARCH PAPER

Modifying the classroom environment to increase standing and reduce sitting

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A reduction in sedentary behaviour (*e.g.* the length of time spent sitting) may prevent or reverse childhood obesity. The effectiveness of a 'dynamic classroom' environment in increasing standing and reducing sitting time in children was determined. A controlled trial with 26 ($n = 18$ intervention) New Zealand children (aged 9.8 ± 0.4 years; mean ± SD) was conducted. The intervention class received height-appropriate workstations for 22 weeks while the control class retained traditional desks and chairs. Children's sitting and standing were measured at three time points (baseline, week 5, week 9). Pain, inattention and hyperactivity were also assessed. At week 22, qualitative data were collected via a focus group and an interview and analyzed using the thematic framework. Mean differences were interpreted using standardized magnitude thresholds. On weekdays (during waking hours) there was on average a large increase in overall standing, 55 minutes per day over nine weeks of intervention compared with the control classroom. Children's overall sitting time reduced, but the changes were small. There were no substantial differences between the control and intervention classrooms in pain and inattention-hyperactivity mean scores. Children enjoyed working at the height-appropriate standing workstations. Teachers were supportive of the dynamic classroom environment. Height-appropriate standing workstations can be successfully integrated into classrooms to increase overall standing and decrease sitting time.

Keywords: active design, active living, children, health, school classrooms, sitting, standing desks

Introduction

Sedentary behaviour is defined as any waking behaviour characterized by low energy expenditure (< 1.5 metabolic equivalents) while in a sitting or reclining position (Sedentary Behaviour Research Network, 2012). Evidence indicates that sedentary behaviour is associated with harmful health effects, even in individuals who meet public health guidelines for physical activity (Tremblay et al., 2011). Preliminary evidence for a dose relationship between sedentary behaviour and negative health outcomes in youth has led to the generation of guidelines for sedentary behaviour. The most recent Australian guidelines state that children should spend fewer than two hours per day engaging with electronic media for entertainment, and that they should break up their long bouts of frequently sitting (Department of Health, 2014). In children and adolescents, the most frequently assessed sedentary behaviour is television viewing (Hardy, Dobbins, Booth, Denney-Wilson, & Okely, 2006), which has been linked to the current childhood obesity epidemic (Vandewater, Shim, & Caplovitz, 2004).

Obesity is a complex disorder, which is affected by many interacting factors that are potentially modifiable. These factors include hours spent using screen-based technology, time spent sitting, diet, and access to sedentary-supportive built and social environments (Han, Lawlor, & Kimm, 2010; Sallis, Floyd, Rodríguez, & Saelens, 2012; Salmon, Tremblay, Marshall, & Hume, 2011a). In children, increased television viewing resulted in higher energy intakes due to the higher consumption of fatty snacks and high-energy drinks while watching television (Lobstein & Dibb, 2005). A decrease of approximately 0.5 kg/m^2 in body mass index (BMI) was observed when children's screen time reduced by about 80 minutes per day (Robinson, 1999). Additionally, television viewing is significantly related to lower cardiorespiratory fitness in children, which has also been associated with overweight and obesity (Landhuis, Poulton, Welch, & Hancox, 2008; Tremblay et al., 2011). To reduce, reverse and prevent obesity in adults and children, sedentary behaviour habits should be modified starting in childhood (Landhuis et al., 2008). Children should be encouraged to expend energy and avoid prolonged sitting (Salmon, 2010) as evidence shows energy expenditure increases when children replace sitting with standing (Benden, Blake, Wendel, & Huber, 2011; Lanningham-Foster et al., 2009).

Energy expenditure that accompanies changes in posture, fidgeting, standing or intermittent walking is referred to as non-exercise activity thermogenesis (NEAT). Activities of NEAT can be used to interrupt periodically sitting during daily routines leading to an increase in overall daily physical activity and energy expenditure. Recent studies have shown that children spend approximately six to seven hours per day at school, and approximately half (49%) of that time day is spent sitting in class (Aminian, Duncan, White, & Hinckson, 2014; Hinckson, Hopkins, Aminian, & Ross, 2013; Ridgers et al., 2012). Therefore, classrooms may be an effective setting for intervening to reduce sitting time (Salmon, Tremblay et al., 2011) by substituting seated with standing desks (Koepp et al., 2012).

Prolonged bouts of sitting in the classroom result in back pain in children (Salminen, 1984; Troussier, Davoine, De Gaudemaris, Fauconnier, & Phelip, 1994; Troussier et al., 1999). Prolonged static sitting, and sitting with a flexed trunk increases spinal load and intra-discal pressure causing pain (Wilke, Neef, Hinz, Seidel, & Claes, 2001). Prevalence of pain, specifically low back pain, can be reduced by replacing sitting with standing (Salminen, 1984). Trevelyan and Legg (2006) suggested that one strategy to reducing back pain in children during classroom time was to implement interventions that aim to decrease classroom sitting time.

In general, children who are physically active tend to show better mental health profiles than those who are less active (Bailey, 2006). Physically active students including children with attention-deficit hyperactivity disorder (ADHD) perform better academically (Schilling, Washington, Billingsley, & Deitz, 2003; Taras, 2005) showing improved classroom behaviour (Bluechardt, Wiener, & Shephard, 1995; Schilling et al., 2003). In contrast, those who are involved in sedentary activities are more aggressive, acquire fewer social skills (Iannotti et al., 2009) and perform poorly academically (Kristjánsson, Sigfusdottir, Allegrante, & Helgason, 2009). Children with ADHD commonly demonstrate out-of-seat behaviours (*i.e.*, frequently walking around the classroom) because of inattention and impulsiveness, and consequently have significant deficiency in their school performance and social interaction (Loe & Feldman, 2007). A 10-week physical activity training programme, including motor skills exercises, showed a positive impact on children's motor performance and behavioural scores such as social, thought and attention (Verret, Guay, Berthiaume, Gardiner, & Béliveau, 2012).

On the basis of previous evidence, the purpose of this study was 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 Swiss (exercise) balls, beanbags and 'mat space'.

Methods

Participants

Twenty-six children aged 9–11 years (12 boys and 14 girls) from two primary schools, one experimental and one control, in Auckland, New Zealand, participated in this study. A sample of convenience of two primary schools from the lowest socio-economic area in North Shore City and Auckland City participated in the study. As of 2012, a total of one primary school in North Shore City and two in Auckland City were classified as lowest socio-economic area (decile 1). The greater Auckland region includes North Shore City, Auckland City, Manukau City and Waitakere City with 75, 159, 131 and 73 primary schools respectively. The Ministry of Education in New Zealand uses the decile classification system to determine the amount of additional educational funding for schools based on their socio-economic backgrounds, where 1 is lowest and 10 is highest (Education Review Office, 2013). The low socio-economic schools also comprised similar ethnic background. In this study, control and experimental classes included a similar ethnic makeup, including 44–57% Pacific Islanders and 27–44% New Zealand Maori. The study began in March 2012, coinciding with the end of summer and beginning of the autumn season in the southern hemisphere. From each school, one classroom with children Years 5 and 6 was chosen based on the availability of the classroom teacher to participate in the study for the nine weeks; the experimental class ($n = 18$) received the intervention and the control class ($n = 8$) acted as the control group. All child participants were healthy. Two children in the intervention classroom were identified as children with ADHD. Both intervention and control schools were selected from the lowest socio-economic area and were matched by the school roll's ethnic makeup. The study was approved by the Institution's Ethics Committee (Reference number 10/259). Children's assent and parents' consent were obtained. Teachers and principals' consents were also obtained before commencing the study.

Study design

Postural allocation (sitting/lying, standing and stepping) was objectively measured at baseline (week 0), midline (week 5) and final (week 9) measurement points in both experimental and control classrooms. Pain, inattention and hyperactivity–impulsivity were also assessed using questionnaires. The intervention lasted for nine weeks but the programme continued for the ensuing 13 weeks. Practicality, strengths and challenges of the intervention in the experimental classroom were evaluated at week 22 via an interview and a focus group (Figure 1).

'Dynamic classroom' design

Prior to this study, data from semi-structured interviews with 18 teachers and principals in 2011 informed the classroom intervention. In this study, traditional desks and chairs were removed from the classroom and replaced with five height-appropriate standing workstations: one round workstation in the middle of the classroom, three semicircled workstations situated strategically around the central workstation, and one workstation for computers (Figure 2). The workstations (Ghanghao Furniture Factory, China) were modified to adjustable standing height. Each semicircular workstation, which accommodated four to five children, was adjusted to the children's height; children with similar floor-to-elbow height were grouped together. When children needed to sit because of tiredness, sitting on Swiss balls was suggested as a first option to encourage active sitting. Sitting on beanbags, benches and a 'mat space' were offered subsequently. Swiss balls were stored in a net assembled on the classroom ceiling to ensure children's safety and space. Each child also received a sports shoulder bag in which to store their belongings, as the workstations were without drawers. There were no costs to the school; the researchers bore all costs.

Measures

ActivPAL

The ActivPAL (PAL Technologies Ltd, Glasgow, UK; Version 6.3.0) uni-axial physical activity monitor uses trademarked algorithms to measure time spent sitting/lying, standing and stepping, and to calculate total steps and sit-to-stand transitions from the frequency of upper leg movement for more than seven days. The ActivPAL summarizes data in 15-second epochs over 24 hours at a sampling frequency of 10 Hz (Ryan, Grant, Tigbe, & Granat, 2006). The validity and reliability of the ActivPAL monitor have been investigated in children (Aminian & Hinckson, 2012; Hinckson, Hopkins et al., 2013). The lightweight (15 g) units were placed in silicon pockets and were attached on front of the thigh using water-resistant Velcro belts in agreement with the manufacturer's guidelines (Hinckson, Hopkins et al., 2013). Children were instructed to wear the ActivPAL at all times. A log was provided to note the times the monitor was removed. The non-wear times were set to missing and were removed for analysis only if the reason for removing the device was not given in the log sheet for imputation.

Nordic Musculoskeletal Questionnaire

Pain was assessed using a modified version of the Nordic Musculoskeletal Questionnaire, which contains a set of standardized questions for assessing musculoskeletal pain at various regions around the body

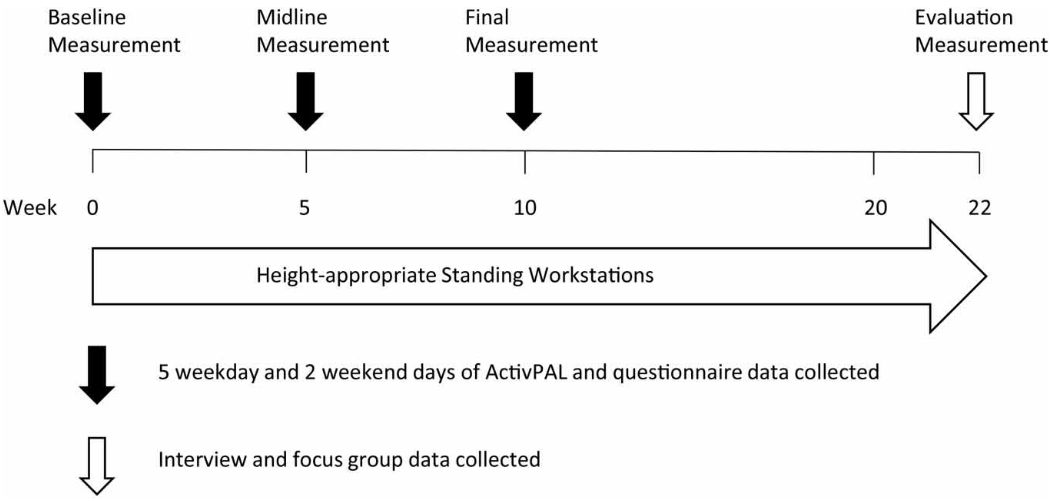

Figure 1 'Dynamic Class' intervention design

Figure 2 Height-appropriate standing workstations in Year 5 and 6 children in the experimental classroom in Auckland, New Zealand, March–June 2012

(neck, shoulder, elbow, wrist, back, hips, knee and foot/ankle). Relevant aspects of the questionnaire about the correctness of chair and desk dimensions, and time spent watching television and using a computer were used. The reliability of the questionnaire has been shown to be acceptable in adult participants (Kuorinka et al., 1987), and it has been used extensively with children (Trevelyan & Legg, 2006). The questionnaire has been recently used in a study of musculoskeletal discomfort with New Zealand school students (Grimes & Legg, 2004).

SWAN questionnaire

The Strengths and Weakness of ADHD symptoms and Normal behaviour (SWAN) questionnaire is a brief behavioural screening questionnaire (30 questions) for use by teachers. It focuses on children's ability to control activity, and inhibit impulses. It uses a seven-point scale (-3 to $+3$) and was designed to measure a wider range of population variation. It can differentiate between those affected by ADHD and those who are not; therefore, the full range of behaviour in the general population was measured.

Height, weight and waistline

In line with the ISAK protocols, (Norton & Olds, 1996) a stadiometer (Design No. 1013522, Surgical and Medical Products, Seven Hills, Australia), a digital scale (Model Seca 770, Seca, Hamburg, Germany) and a measuring tape (Model Seca 201) were used to measure children's height, weight and waistline. BMI was calculated from weight (kg) divided by squared height (m^2) (Aminian & Hinckson, 2012).

Procedures

Two primary schools initially confirmed to take part in the study via e-mail communication. The researchers then contacted the two participating schools'

Table 1 Indicative questions used to evaluate the 'Dynamic Class' intervention process

Children focus group
What did you think about the standing workstations in your classroom?
Did you stand most of the time in the classroom? How did you feel about that?
Let's talk about your energy levels during the day. How did you feel during or after school?
Do you think that every classroom should have standing workstations? Why? Why not?
What was the best thing about standing workstations?
What was the not so good thing about standing workstations?
Teacher interview
What did you think about the standing workstations in the classroom?
Let's talk about energy levels of the children during the weeks of the standing workstations. What were they?
Do you think that every classroom should have standing workstations? Why? Why not?
What was the best thing about standing workstations in the classrooms?
What was the not so good thing about standing workstations in the classrooms?
Did you notice any changes in behaviour during the weeks of the standing workstation? Please explain.
Have you noticed any changes to children's learning during the standing workstation weeks?

principals and teachers to discuss the aim and design of the project. Participants' demographic data, such as gender and age, were collected from the school roll. After measuring children's height, weight and waistline for the baseline measurement, the ActivPAL monitors were attached to participants' thighs for seven consecutive days. Although participants were asked to wear the ActivPAL at all times, teachers and parents received a log sheet to record the time and date their student/child did not wear the device for any reason.

Teachers were also asked to evaluate each child's behaviours by completing the SWAN questionnaire. Participating students also completed the Nordic Musculoskeletal Questionnaire under the supervision of the teacher and the researcher to ensure the questions were fully understood and answered. The experimental class received the height-appropriate standing workstations, Swiss balls, beanbags, benches and mats. The teachers were asked to conduct the classes as normal. After four and eight weeks, the children's free-living activities were assessed for another seven consecutive days by the ActivPAL as the midline and final measurements respectively (Figure 1).

Teachers and participating students in the experimental and control classes completed the SWAN and the Nordic Musculoskeletal Questionnaires for the midline (week 5) and final (week 9) measurements. The researcher monitored the experimental class on three different days per week to collect participants' informal feedback about the intervention, and to ensure that the needs of each participant, including the stability and height suitability of workstations, accessibility of Swiss balls, replacement of damaged equipment, and responding to questions, were met during the study. At the final measurement, children's height, weight and waist circumference were measured.

While the intervention was planned for one school term, the teacher and children of the experimental class asked to use the height-appropriate standing workstations for another term. However, it was not convenient for the school (*i.e.*, hectic with end-of-term activities and staff changes) for another set of measurements. They agreed to qualitative data collection only. Therefore, at week 22, eight children volunteered for a focus group (four boys) and a semi-structured interview with the intervention class teacher were conducted (see Table 1 for the indicative questions). The length of the focus group and interview were approximately 1 hour and 40 minutes respectively, and each was conducted at the school of the participant. Through the focus group and interview, the children's and teacher's feedback was obtained with respect to practicality, and the barriers and facilitators of the height-appropriate standing workstations. A recorder was used to record all conversations with the participants' permission. On completion, the height-appropriate standing workstations, Swiss balls, beanbags, sport shoulder bags and mats were donated to the school. At the end of the study, the children in both experimental and control classes were thanked and received 'Catch Balls', stickers and certificates as a gift from the researchers.

Data analysis

The 'Pre–post parallel groups trial' spreadsheet (Hopkins, 2006) was used to examine the differences in weighted means for wear time in time spent sitting/lying, standing and stepping, as well as transition and step counts between the experimental and control groups to compare for magnitude. The magnitude of each effect was evaluated by standardization (the difference in mean minutes of activity divided by the between-subject standard deviation) (Cohen, 1988). To make meaningful conclusions (inferences) from findings about the effect of the 'dynamic classroom' intervention on children's free-living activities, uncertainty in the estimates of changes were presented as likelihood (possibly, 25–75%; likely, 75–95%; very likely, >95%; almost certainly, >99.5% beneficial, substantially positive, or harmful effect) that the magnitude of the true effect (true difference between groups) is trivial or substantial (Batterham & Hopkins, 2006). The following scale was used to evaluate the magnitude of the standardized difference in means: < 0.2, trivial effects, or substantial effects: 0.2–0.59, small; 0.6–1.19, moderate; > 1.20, large (Hopkins, Marshall, Batterham, & Hanin, 2009).

A modified version of the Nordic Musculoskeletal Questionnaire was used to assess pain. Children's responses to the pain questions were 'yes' or 'no'. All questions were coded numerically. Answers were coded as either 1 or 0 if they experienced pain or no pain, respectively. Body regions that were split into left and right sides were grouped together (*i.e.*, left wrist and right wrist) and coded as 1 if pain was experienced on either side.

Using the SWAN rating scale (Swanson et al., 2006), teachers were asked to rate children's behaviours on a seven-point scale (−3, far above; −2, above; −1, slightly above; 0, average; 1, slightly below; 2, below; 3, far below). Each child's total score on the inattention and hyperactivity–impulsivity questions were then averaged, with higher scores indicating greater ADHD symptomology.

Paired samples *t*-tests were performed with SPSS Version 20 (SPSS Inc., Chicago, IL, US) to compare baseline and final mean scores between the experimental and control classes for all questionnaire data. The level of statistical significant was < 0.05.

The five-stage thematic-framework approach (familiarization, identifying a thematic framework, indexing, charting, mapping and interpretation) was used to analyze interview data (Pope, Ziebland, & Mays, 2000). The framework approach takes into consideration the participants' accounts while using a deductive approach for the indexing of the data. All interviews were transcribed and then checked word for word against the voice recordings. The transcripts were then coded in a systematic way. The researcher (S.A.) listed interesting features of the transcript text, and allocated codes to similar data and then identified themes from the codes. From the identified themes, the researcher defined and named the themes to explore the essence of each theme. Thematic networks were used to explore the links between participants' responses and the actual meanings embedded in their dialogue.

Table 2 Characteristics of participants at baseline (mean ± SD)

	Control group (n = 8)	Experimental group (n = 18)	All children (n = 26)
Age (years)	9.8 ± 0.5	9.8 ± 0.4	9.8 ± 0.4
Boy-to-girl ratio	4:4	8:10	12:14
Height (m)	1.5 ± 0.1	1.5 ± 0.1	1.5 ± 0.1
Weight (kg)	54 ± 15	44 ± 14	47 ± 15
BMI (kg·m^{-2})	24 ± 7	23 ± 8	23 ± 8
Waist (cm)	30 ± 5	27 ± 4	28 ± 5

Note: BMI = body mass index.

Results

Twenty-six children provided valid data for analysis; one child from the experimental class lost the ActivPAL monitor during the baseline measurement, and one from the control class did not provide complete data. However, all participating children in both classes provided complete questionnaire data. All children in the experimental class ($n = 19$) participated in the study, but only nine of the 20 children in the control group provided parental consent to participate. Due to the collaborative approach of modern teaching and learning in New Zealand schools, it was assumed that nine children was a sufficient number to describe activity within a control classroom since children in a classroom act as a unit. Any child participant who provided at least eight hours per day (three weekdays and one weekend day) was included in the analysis. Participants' descriptive characteristics are presented in Table 2. Although, on average most children in both control and experimental classes were overweight, there were no significant differences between the two groups in terms of weight ($t = 1.55$, $p = .13$), BMI ($t = 1.60$, $p = .12$), and waist ($t = 1.81$, $p = .08$).

Descriptive statistics (mean ± SD) of participants in overall, before, during and after school sitting, standing and stepping time, step counts and sit-to-stand transitions at baseline, midline and final intervention measurement are presented in Table 3.

Table 3 Average daily mean (± between-subject SD) in overall, before, during and after school sitting, standing and stepping time, step counts and sit-to-stand transitions at baseline, midline and final intervention measurement in Auckland, New Zealand, March–June 2012

	Group[a]	Mean (SD) baseline	Mean (SD) midline[b]	Mean (SD) final[c]
Overall[d]				
Sitting (h)	C	9.34 (1.32)	8.86 (0.81)	8.08 (3.10)
	E	9.56 (1.27)	8.34 (1.68)	7.64 (2.06)
Standing (h)	C	3.02 (0.91)	2.82 (0.29)	2.77 (0.76)
	E	3.16 (0.75)	3.36 (0.71)	3.71 (0.92)
Stepping (h)	C	2.60 (0.42)	2.44 (0.42)	1.89 (0.21)
	E	2.27 (0.70)	2.22 (0.57)	1.80 (0.39)
Step counts	C	12 749 (2249)	12 205 (2355)	9269 (1061)
	E	10 880 (3384)	10 945 (2783)	8344 (1824)
Sit-to-stand transitions	C	112 (17)	107 (14)	74 (20)
	E	118 (26)	86 (20)	84 (19)
Before school[e]				
Sitting (h)	C	1.00 (0.61)	0.89 (0.40)	0.74 (0.56)
	E	0.86 (0.42)	0.75 (0.56)	0.59 (0.37)
Standing (h)	C	0.50 (0.14)	0.55 (0.16)	0.41 (0.23)
	E	0.42 (0.17)	0.41 (0.17)	0.37 (0.20)
Stepping (h)	C	0.43 (0.11)	0.47 (0.15)	0.28 (0.14)
	E	0.27 (0.07)	0.23 (0.09)	0.18 (0.07)
Step counts	C	2220 (563)	2552 (888)	1315 (911)
	E	1327 (322)	1143 (416)	921 (399)
Sit-to-stand transitions	C	14 (7)	15 (7)	11 (9)
	E	13 (5)	10 (5)	7 (4)
During school[f]				
Sitting (h)	C	3.59 (0.45)	3.74 (0.48)	3.24 (0.81)
	E	3.88 (0.36)	3.12 (0.35)	2.81 (0.36)
Standing (h)	C	1.24 (0.37)	1.19 (0.30)	1.60 (0.69)
	E	1.21 (0.35)	1.72 (0.42)	2.06 (0.44)
Stepping (h)	C	1.15 (0.20)	1.07 (0.26)	1.09 (0.21)
	E	0.88 (0.25)	1.12 (0.28)	0.95 (0.23)
Step counts	C	5544 (1195)	5231 (1306)	5264 (999)
	E	4312 (1320)	5493 (1550)	4318 (1026)
Sit-to-stand transitions	C	50 (8)	51 (11)	40 (13)
	E	49 (10)	38 (8)	37 (9)
After School[g]				
Sitting (h)	C	4.74 (0.82)	4.23 (0.59)	4.13 (2.11)
	E	4.82 (1.15)	4.43 (1.45)	4.15 (1.67)
Standing (h)	C	1.28 (0.66)	1.08 (0.25)	0.78 (0.53)
	E	1.52 (0.40)	1.21 (0.51)	1.30 (0.63)

(*continued*)

Table 3 Continued

	Group[a]	Mean (SD) baseline	Mean (SD) midline[b]	Mean (SD) final[c]
Stepping (h)	C	1.02 (0.43)	0.91 (0.33)	0.53 (0.31)
	E	1.12 (0.49)	0.86 (0.46)	0.67 (0.26)
Step counts	C	4985 (2280)	4422 (1723)	2690 (1434)
	E	5241 (2389)	4245 (2262)	3071 (1252)
Sit-to-stand transitions	C	48 (11)	41 (10)	24 (11)
	E	56 (15)	39 (12)	39 (13)

Notes: [a] h = hours; SD = standard deviation; C = control; E = experimental.
[b] Week 5 of intervention.
[c] Week 9 of intervention.
[d] Weekday data between 05:00 and 24:00 hours were included for analysis.
[e] Before-school data between 05:00 and 09:00 hours.
[f] During-school data between 09:00 and 15:00 hours.
[g] After-school data between 15:00 and 24:00 hours.

Table 4 compares average daily weekday (waking hours) mean differences between the control and experimental classes in time spent sitting, standing and stepping, step and sit-to-stand transitions before, during and after implementing the intervention.

Differences between baseline and final measurement

- *Overall results*

  During weekdays, there was an overall decrease in sitting time by 45 minutes and a 55-minute increase in standing time over the nine weeks of the intervention. The results, however, were unclear as the confidence limits for the means were wide (CL ± 122 and ± 129 minutes respectively; data not shown). There was also a *likely* increase in stepping time, and the number of the steps (see the explanation under data analysis section for the terms *possibly*, *likely*, *very likely*, *almost certainly*, clear and unclear); 26 minutes and 1859 counts respectively. Sit-to-stand transitions remained *possibly* unchanged. However, the above results were unclear.

- *Before school results*

  Time spent sitting (12 minutes) and standing (one minute), and sit-to-stand transitions decreased but the results were unclear apart from sit-to-stand transitions. Stepping time (two minutes), and step counts showed a *possibly* small increase over the nine weeks of the intervention, but the results were unclear.

- *During school results*

  There was a moderate reduction (*possibly* 36 minutes) in sitting time but the result was unclear. There was an increase in children's standing time (*likely* 24 minutes), stepping time (*likely* 11 minutes) and number of steps but the results were unclear. Sit-to-stand transitions *possibly* decreased but it was unclear.

- *After school results*

  There was a *possibly* small reduction (seven minutes) in sitting time but the result was unclear. There were moderate to small increases in time spent standing (*likely* 29 minutes) and stepping (*possibly* 10 minutes), and steps (*possibly*) and sit-to-stand transitions (*likely*).

Differences between baseline and midline measurement

- *Overall results*

  During weekdays, there was a *likely* decrease (41 minutes) in sitting time. Standing and stepping time, and step counts *possibly* increased; 23 minutes, seven minutes and 468 counts respectively. Sit-to-stand transitions *very likely* decreased. Apart from sit-to-stand transitions, the results were unclear.

- *Before school results*

  Sitting time *possibly* remained unchanged. There was a decrease in time spent standing (*possibly* four minutes) and stepping (*likely* five minutes), and number of steps and sit-to-stand transitions. All results were unclear.

- *During school results*

  Time spent sitting *possibly* three minutes increased, but the result was unclear. There was a clear increase in standing (*almost certainly* 34 minutes) and stepping (*very likely* 19 minutes). Step counts also *likely* increased, but the result was unclear. However, there was a clear decrease in the number of sit-to-stand transitions.

Table 4 Average daily mean differences (E-C) with standardized differences in sitting, standing and stepping time, step counts and sit-to-stand transitions for overall, before, during and after school 'dynamic classroom' intervention between midline–baseline, final–midline and final–baseline

	Mean difference (standardized difference) midline–baseline[a]	Inference[b]	Mean difference (standardized difference) final–midline	Inference	Mean difference (standardized difference) final–baseline	Inference
***Overall*[c,g]**						
Sitting (h)	−0.68; (−0.52)	Likely ↓	0.42; (0.33)	Possibly ↑	−0.75; (−0.58)	Possibly ↓
Standing (h)	0.39; (0.48)	Possibly ↑	0.42; (0.52)	Likely ↑	0.91; (1.13)	Likely ↑
Stepping (h)	0.11; (0.17)	Possibly ↑	0.15; (0.22)	Possibly ↑	0.43; (0.65)	Likely ↑
Step counts	468; (0.14)	Possibly ↑	411; (0.13)	Possibly ↑	1859; (0.57)	Likely ↑
Sit-to-stand transitions	−24; (−0.99)	Very likely ↓*	29; (1.19)	Very likely ↑*	0.00; (0.00)	Possibly
***Before school*[d,h]**						
Sitting (h)	0.00; (0.00)	Possibly	0.07; (0.14)	Possibly ↑	−0.20; (−0.42)	Likely ↓
Standing (h)	−0.07; (−0.38)	Possibly ↓	0.12; (0.69)	Possibly ↑	−0.02; (−0.10)	Possibly ↓
Stepping (h)	−0.08; (−0.67)	Likely ↓	0.07; (0.65)	Possibly ↑	0.03; (0.22)	Possibly ↑
Step counts	−543; (−0.92)	Likely ↓	687; (1.16)	Likely ↑	360; (0.61)	Possibly ↑
Sit-to-stand transitions	−4; (−0.73)	Likely ↓	3; (0.61)	Likely ↑*	−4; (−0.74)	Likely ↓*
***During school*[e,i]**						
Sitting (h)	0.05; (0.11)	Possibly ↑	−1.31; (−3.15)	Likely ↓	−0.60; (−1.44)	Possibly ↓
Standing (h)	0.56; (1.54)	Almost certainly ↑*	−0.20; (−0.56)	Possibly ↓	0.40; (1.11)	Likely ↑
Stepping (h)	0.32; (1.16)	Very likely ↑*	−0.22; (−0.81)	Likely ↓	0.19; (0.71)	Likely ↑
Step counts	1459; (1.02)	Likely ↑	−1322; (−0.93)	Likely ↓	675; (0.47)	Possibly ↑
Sit-to-stand transitions	−11; (−1.16)	Likely ↓*	8; (0.78)	Possibly ↑	−6; (−0.57)	Possibly ↓
***After school*[f,j]**						
Sitting (h)	0.09; (0.08)	Possibly ↑	−0.20; (−0.19)	Possibly ↓	−0.11; (−0.11)	Possibly ↓
Standing (h)	−0.09; (−0.19)	Possibly ↓	0.49; (0.98)	Likely ↑*	0.48; (0.95)	Likely ↑
Stepping (h)	−0.16; (−0.32)	Possibly ↓	0.29; (0.59)	Likely ↑*	0.17; (0.35)	Possibly ↑
Step counts	−517; (−0.22)	Possibly ↓	1105; (0.46)	Likely ↑*	763; (0.32)	Possibly ↑
Sit-to-stand transitions	−10; (−0.68)	Likely ↓*	16; (1.04)	Almost certainly ↑*	7; (0.49)	Likely ↑

Notes: E-C = experimental–control; ↑ = increase; ↓ = decrease; * = clear results. Unclear effects have confidence limits spanning positive and negative smallest worthwhile change (SWC) = 0.2).

[a] Standardized differences magnitude: < 0.2, trivial effects, or substantial effects: 0.2–0.59, small; 0.6–1.19, moderate; > 1.20, large (Hopkins et al., 2009).

[b] Inferences are a qualitative assessment of the magnitude (standardized difference) of the true effect using the following scale: possibly, 25–75%; likely, 75–95%; very likely, > 95%; almost certainly, > 99.5% (Hopkins et al., 2009).

[c] Weekday data between 05:00 and 24:00 hours were included for analysis.

[d] Before-school data between 05:00 and 09:00 hours.

[e] During-school data between 09:00 and 15:00 hours.

[f] After-school data between 15:00 and 24:00 hours.

[g] Standard deviation range was 0.76–3.89, 0.52–1.42 and 0.70–0.79 for sitting, standing and stepping respectively.

[h] Standard deviation range was 0.81–1.69, 1.10–1.89 and 1.78–3.81 for sitting, standing and stepping respectively.

[i] Standard deviation range was 2.42–6.62, 0.79–3.18 and 1.41–4.18 for sitting, standing and stepping respectively.

[j] Standard deviation range was 0.74–3.35, 0.62–2.20 and 0.61–1.18 for sitting, standing and stepping respectively.

- *After school results*

  Sitting time *possibly* increased (five minutes). There was a *possibly* decrease in standing (five minutes), stepping (10 minutes), and step counts. Sit-to-stand transitions *likely* decreased. All results were unclear apart from sit-to-stand transitions result.

Differences between midline and final measurement

- *Overall results*

  During weekdays, there was an increase in sitting (*possibly* 25 minutes), standing (*likely* 25 minutes), stepping (*possibly* nine minutes), number of steps and sit-to-stand transitions. Apart from sit-to-stand transitions, all results were unclear.

- *Before school results*

  There was an increase in sitting (*possibly* four minutes), standing (*possibly* seven minutes), stepping (*possibly* four minutes), step counts and sit-to-stand transitions. However, only sit-to-stand transitions result was clear.

- *During school results*

  Sitting time *likely* decreased by one hour and 19 minutes. Time spent standing (*possibly* 12 minutes) and stepping (*likely* 13 minutes), and step counts also decreased. However, number of sit-to-stand transitions *possibly* increased. All results were unclear.

- *After school results*

  Sitting time *possibly* decreased by 12 minutes but the result was unclear. There was *likely* a clear increase in standing (29 minutes), stepping (17 minutes), and step counts. Sit-to-stand transitions *almost certainly* increased with a clear result.

In addition, when the control and the experimental classes' baseline data were compared, a *possibly* small increase in time spent sitting (0.22; 0.17) and standing (0.14; 0.17), and sit-to-stand transitions (6; 0.23), and a *likely* small reduction in stepping time (−0.33; −0.50) and step counts (−1869; −0.57) in the experimental class were observed. However, except for step counts, all results were unclear.

Questionnaires

The results of the Nordic Musculoskeletal Questionnaire showed that children experienced little to no musculoskeletal pain. There were no substantial differences between baseline (42%, 21%, 42%, 21%, 26% and 63%) and final (37%, 11%, 37%, 32%, 37% and 37%) measurements in the experimental class for neck, elbow, wrist, hip/thigh, knee and foot/ankle pain respectively. Shoulder and back pain in both baseline and final measurements for the experimental class were the same, 21% and 32% respectively. Additionally, in the final measurement, 63% of children in the experimental class reported that the height of their desk was correct compared with baseline (42%). Furthermore, the experimental class reported 71 minutes per day less television viewing and computer use in the final measurement compared with baseline, which was significant ($t = 2.67$, $p = .02$).

The analysis of the SWAN questionnaire showed that the mean scores and standard deviations of the baseline measurement on inattention and hyperactivity–impulsivity were −0.14 ± 1.1 and 0.14 ± 1.0 for the experimental class, and 1.3 ± 1.8 and 0.76 ± 2.0 for the control class respectively. After eight weeks, the mean scores of inattention and hyperactivity–impulsivity decreased in both the experimental (−0.21 ± 0.90 and 0.03 ± 0.90) and control (0.44 ± 1.3 and 0.69 ± 1.3) classes respectively. Although the experimental class showed 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 two classes in the final measurement.

Monitoring

Children were willing to work at the height-appropriate standing workstations; however, lack of space to store personal items and books was noted. For teaching maths and sciences, the teacher worked with one group on the 'mat corner' while the rest of the students worked at the standing workstations. On average, up to four students sat on the Swiss balls in the classroom. Two beanbags were shared between the students, and were used frequently. The researchers also observed that sometimes some children would rest their heads on the workstations to write. Through discussion with the teacher and the students, it was recognized that despite the suitability of the heights of the workstations, their habitual behaviours and poor postures encouraged them to rest their heads on the workstations while writing. Children showed a great interest in using the ActivPAL monitors. They found that the device was light and easy to carry on the thigh so wearing the device did not limit their daily school activities.

Focus group with children

The majority of children were happy with the height-appropriate standing workstations in the classroom. Children thought that the workstations facilitated group work, made writing easier, and there was enough space to move and interact with each other and teachers in the class. Some children expressed that their core got stronger because of standing: 'Your legs get stronger because they have to hold your weight.' Other children mentioned that standing made them more alert and focused, while sitting on the chairs made them lazier: 'I can be more focused and do my class work better with standing because nobody is interrupting me when they are moving around.' Overall, they preferred to have the height-appropriate standing workstations in the class compared with the traditional seated desks. However, one child complained of experiencing neck and leg pains caused by using the height-appropriate standing workstations. Some explained that after four weeks of standing they felt tired. A child also mentioned that sometimes the workstations were overcrowded, and some children took other children's stationery. Additionally, at times, children fought over the Swiss balls as no more than three children were allowed to use the balls in the classroom at one time because the teacher found them disruptive.

Semi-structured interview with the teacher

Increased space, social interactions, happier children, and better, quicker and easier supervision were the most positive outcomes of standing around the workstations, according to the teacher. 'It was easier to look over the students' shoulders to see what they are actually doing,' the teacher explained. The circular height-appropriate standing workstation in the centre of the class was also very useful for group work and teaching.

The teacher did not observe much difference in children's energy levels in the experimental class compared with the previous traditional classroom environment. However, the teacher noted that the children behaved better in the dynamic environment because they were happier and more motivated. Swiss balls were useful for the restless children who needed to move all the time, but not for all. Most of children preferred to sit on the beanbags or mat rather than on Swiss balls. The teacher also suggested that a mixed set-up including a few seated desks, a few Swiss balls, more beanbags and the height-appropriate standing workstations would work better. Storing personal items and books in the sports bags was not a successful strategy as it was hard for children to take their books and stationery out of them. The teacher also explained: 'When children are happier, they behave better, do better, then the teacher is happier as well. In fact, I am more positive than probably I thought I would'; and added: 'The majority of them [students] would prefer to stay with what [height-appropriate standing workstations] we have now than go back to the old desks.'

According to the principal, the total cost of traditional desks and chairs for one classroom of 20 children was NZ$4899. The total cost of the equipment in the intervention class was NZ$2844, including the cost of normal workstations, the modification of workstations to height-adjustable workstations, Swiss balls, a large net in which to store the Swiss balls, along with ropes, wires and pins for assembly, shoulder bags for children to store stationery, beanbags, a mat and presents.

Discussion

This is the first study to implement a 'dynamic classroom' environment in a real school setting by completely removing traditional desks and chairs and replacing them with height-appropriate standing workstations. The intervention was effective in increasing standing in children by almost an hour per day in the final measurement when compared with baseline. This is the only study that reported standing results for the entire day. In the present study, during school the 'dynamic classroom' intervention was effective in increasing children's standing by more than 24 minutes per day in the final measurement when compared with baseline. In a study by Cardon, De Clercq, De Bourdeaudhuij, and Breithecker (2004) children spent 31% of their time standing compared with 97% sitting still in the traditional classroom environment, when the traditional desks were replaced with standing desks. The results of this study showed that after school, children stood more. It seemed that despite standing during a school day, children in the present study remained active (standing and stepping) after school. This suggests that children perhaps do not compensate for their reduced sitting during the school day with more sitting after school, similar to previous findings (Long et al., 2013). Increasing standing time is important, as it can lead to an increase in energy expenditure (Benden et al., 2011). Even though energy expenditure was not measured in this study, it has been shown that 0.16 kcal/minute mean difference between intervention (classroom with standing desks/workstations) and control (classroom with desks and chairs) groups was equal to 19.2 kcal per two-hour lesson block for five days (Benden, Zhao, Jeffrey, Wendel, & Blake, 2014). While a greater energy expenditure would have been expected if measured in this study, nevertheless modifying a traditional classroom to an dynamic one with height-appropriate desks/workstations seems promising in achieving a certain caloric energy expenditure for children. A daily reduction of 41 kcal per day in youth's daily energy gap has been suggested in reversing the childhood obesity trend (Wang, Orleans, & Gortmaker, 2012).

Even though children's overall sitting time across different measurement points reduced during weekdays, the changes were moderate to small and unclear (25–45 minutes). This may be because the week-to-week variability in measuring sitting was higher due to the small sample size (Hinckson, Hopkins et al., 2013). In addition, even though there were no substantial differences between weight, BMI, and waist circumference of experimental and control classes, children in both groups were on average overweight. Under different circumstances, it would be possible that more standing and stepping and less sitting would have been observed, and consequently the results may have been different. By comparison, only one intervention study (Salmon, Arundell et al., 2011) in primary school children has investigated prolonged sitting in the classroom setting. Salmon and colleagues intended to reduce classroom sitting by 32 minutes per day for 18 months. Children were asked to stand for 30 minutes per day in the classroom during lessons, and two-hour classroom teaching was interrupted with two-minute activity breaks. The mid-intervention results of the study showed a nine-minute decrease in sedentary time (Carson et al., 2013), and an increase in moderate to vigorous physical activity at recess by 38% in the sedentary behaviour group (Yıldırım et al., 2014). However, with any accelerometer worn on the hip, differentiating sedentary activities based on posture is difficult (Hart, Ainsworth, & Tudor-Locke, 2011). In the present study, the thigh-mounted ActivPAL monitor was used to asses sedentary activities (particularly sitting) more accurately.

In this study, on weekdays, stepping time and step counts increased overall but the changes were small. During school, the average increase in stepping and step counts was highest perhaps due to the novelty of the dynamic classroom, and the reactivity of the ActivPAL monitor. However, the potential novelty and reactivity issues were minimized as the authors previously explored the most feasible strategies to intervene in the classroom by interviewing teachers and principals of New Zealand primary schools. The feasibility of these strategies were then tested in a classroom (Hinckson, Aminian et al., 2013), and a control classroom was included in the intervention study (Hinckson, Hopkins et al., 2013). Furthermore, in the final measurement, children's step counts increased overall and during school. The latter increase was due to perhaps the increased space provided by removing traditional desks and chairs and replacing them with height-appropriate standing workstations that occupied less space.

The present study was based on an intervention study conducted by Lanningham-Foster et al. (2008) where a simulated activity-permissive environment was compared with a traditional and a standing classroom. In the Lanningham-Foster study, the activity-permissive environment was designed in an athletic club, which included a few standing desks, vertical mobile whiteboards, wireless laptop computers, basketball hoops, indoor football (soccer), climbing mazes and activity-promoting games. The 'standing' classroom environment consisted of a few traditional desks and chairs, three stability balls and individual height-adjustable standing desks. In the latter study, in which physical activity was expressed from accelerometry data in terms of speed (m/s^2), a 50% increase was reported in children's physical activity levels in the activity-permissive environment over a 12-week period. Lanningham-Foster et al. also reported that there was no significance difference in children's movements between the traditional and standing classroom environments. The authors were unable to differentiate real differences between sitting and standing because they only measured speed of movements and not standing time or step count. Furthermore, Lanningham-Foster et al. objectively monitored children's physical activities for four weeks during one to four school days. Whereas in the present study with a 22-week duration (testing and evaluation), children's free-living activities were measured by the ActivPAL monitor for three entire weeks, which included before, during and after school hours.

Findings of this study also showed that on weekdays the number of sit-to-stand transitions overall decreased across all periods apart from the after-school period at the final measurement point. It seemed that children's sit-to-stand transitions decreased substantially initially after school due to perhaps the novelty of the intervention, but by the end of the intervention there was a substantial increase, especially after school.

Children's neck, elbow, wrist and foot/ankle pain in the present study reduced over nine weeks of participating in the dynamic class, but the reduction was not substantial. Knee and hip/thigh pain, however, seemed to increase slightly, which was not substantial. Other studies showed that prolonged static sitting, especially with a flexed trunk, increased spinal load and can possibly lead to back pain (Wilke, Neef, Caimi, Hoogland, & Claes, 1999; Wilke et al., 2001). In the present study, no back pain was reported in the experimental class in the final measurement compared with baseline, perhaps because of the standing workstations. It has been shown that uncomfortable classroom furniture can have a negative impact on children's classroom performance and behaviours as a result of back pain caused by prolonged sitting (Oyewole, Haight, & Freivalds, 2010).

Furthermore, the 'dynamic classroom' intervention seemed to decrease inattention and hyperactivity–impulsivity in children with ADHD, but no substantial changes were observed during and after the intervention. In contrast, Mahar et al. (2006) found that children's concentration scored 8% higher in Fisher's LSD tests due to a 10-minute activity break during class after 12 weeks. Inattention and hyperactivity–impulsivity develop rapidly with increasing age (Spira & Fischel, 2005). In older children it was shown that hyperactivity–impulsivity decreased and inattention type behaviour became more predominant (Barkley, 1997). Therefore, it is important to differentiate whether a behaviour is part of a developmental stage or ADHD (Spira & Fischel, 2005).

The focus group and interview revealed that children preferred to engage with their class work at the height-appropriate standing workstations rather than sitting desks. School staff were supportive of the dynamic classroom environment as it offered increased space, social interactions, happier children, and better, quicker and easier supervision. The teachers were aware of the benefits of physical activity for children's physical and psychosocial health, and learning. It was commented that some children's concentration improved when they worked at height-appropriate standing workstations. The experimental class teacher thought that using more than four Swiss balls in the class was disruptive. However, he supported the use of Swiss balls in the classroom. He believed that sitting on Swiss balls improved children's postures and behaviour, especially in children with ADHD. A set-up including standing desks and workstations may ensure the suitability of the intervention for all children accounting for individual differences in body size. In addition, the teachers' engagement during recruitment and the data-collection process as well as their willingness to participate is essential to ensure better participation and valid data.

There were limitations to this study. There were issues associated with the control classroom. While the teacher in the control classroom agreed to participate, the teacher did not engage fully with the recruitment process, resulting in only nine children returning parental consent forms. From these participating children, only eight provided valid data. In addition, despite modification to the standing workstation to be height-appropriate standing workstations for the children, this was not possible for all children; one child had an unexpected height of 160 cm compared with her peers and the highest workstation was not fully appropriate.

Caution must be taken when interpreting the results of this study due to the small sample size; however, these results provide the foundation for further research regarding reducing sitting and encouraging standing in the classroom. Furthermore, a longer period may be required to determine whether a 'dynamic classroom' intervention causes any musculoskeletal pain in participants (Leboeuf-Yde & Ohm Kyvik, 1998). Additionally, the cost of the intervention was low: the intervention, implementation and height-appropriate standing workstations' total cost was approximately 40% cheaper than the standard seated desks and chairs.

Conclusions

Modifying a traditional classroom into a dynamic classroom reduced sitting and increased standing time in primary school children, but the reduction in sitting time was unclear. Participation in a dynamic class did not cause any musculoskeletal discomfort. In addition, there was no significant impact on the children's ability to focus their attention or control hyperactivity–impulsivity. There was a positive reaction from the teacher and children in the experimental classroom to the dynamic classroom environment, particularly the use of height-appropriate standing workstations. A randomized control trial over a longer period with a larger sample size is needed to confirm the results of the 'dynamic classroom' intervention across schools.

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