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Original research

Impact of a classroom standing desk intervention on daily objectively measured sedentary behavior and physical activity in youth☆

Danilo R. Silva[a,b], Cláudia S. Minderico[b], Fernando Pinto[c], Paul J. Collings[d,e], Edilson S. Cyrino[a], Luís B. Sardinha[b,*]

[a] Study and Research Group in Metabolism, Nutrition, and Exercise — GEPEMENE, Londrina State University, Brazil
[b] Exercise and Health Laboratory, CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, Portugal
[c] Departament of Social Sciences, Eça de Queiros High School, Portugal
[d] Bradford Institute for Health Research, Bradford Teaching Hospitals NHS Foundation Trust, United Kingdom
[e] University of York, Department of Health Sciences, United Kingdom

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ABSTRACT

Objectives: We investigated the impact of a standing desk intervention on daily objectively monitored sedentary behavior and physical activity in 6th grade school students.
Design: Cluster non-randomised controlled trial.
Method: Two classes (intervention students: $n = 22$ [aged 11.8 ± 0.4 years]; control students: $n = 27$ [11.6 ± 0.5 years]) from a public school in Lisbon were selected. The intervention involved replacing traditional seated classroom desks for standing desks, for a total duration of 16 weeks, in addition to performing teacher training and holding education/motivation sessions with students and parents. Sedentary behavior (ActivPAL inclinometer) and physical activity (Actigraph GT3X+ accelerometer) were measured for seven days immediately before and after the intervention.
Results: There were no differences in baseline behaviors between intervention and control groups ($p > 0.05$). At follow-up (16 weeks), it was observed that the intervention group had decreased time spent sitting (total week: −6.8% and at school: −13.0% relative to baseline) and increased standing (total week: 16.5% and at school: 31.0%) based on inclinometer values (p-value for interaction group*time <0.05). No significant differences in activity outcomes were observed outside school time (week or weekend) between groups.
Conclusion: We conclude that a 16 week classroom standing desk intervention successfully reduced sitting time and increase standing time at school, with no observed compensatory effects outside of school time.
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1. Introduction

Defined as any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture,[1] sedentary behavior constitutes a growing public health problem.[2,3] It is estimated that sitting time is responsible for 433,000 deaths/year worldwide (almost 4% of the total).[4] Although the strongest evidence for harmful effects associated with prolonged sitting is observed in adulthood, sedentary children and adolescents tend to have poorer physical and mental health.[5] Sedentary lifestyles also seem to exhibit strong tracking from childhood to adulthood.[6]

Objective measures indicate that school-aged children spend almost 70% of their waking hours in sedentary behavior,[7] with much of this sedentary time taking place in schools. Uninterrupted sitting time at school has been related to musculoskeletal pain (e.g. neck, lower back, hip, and knee discomfort).[8] Nevertheless, despite many interventions that have targeted reduced recreational screen time[9] and encouraging active rather than passive travel[10] in youth, less attention has been paid to the school setting.

Recently, some single and multi-component interventions have been performed to reduce sitting time at school. Changes to the general school environment, curriculum or orientation/education sessions have been trialed to improve activity and dietary habits.[11] Considering that more than 90% of classroom time is spent sitting,[12] a promising strategy may be replacement of traditional seated

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* Corresponding author.
E-mail address: lsardinha@fmh.ulisboa.pt (L.B. Sardinha).

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desks for standing desks. Few trials of this description have been conducted, but findings to date suggest that standing desks of different types (e.g. height adjusted/stand-biased, individual/in group use) may be an effective method to reduce classroom sitting time by around 40–60 min/day,[13] with no reported adverse effects on cognitive function or academic achievement.[14,15] However, most of current evidence is based on pilot studies[16] with some focusing exclusively on postural and feasibility issues.[17,18] Furthermore, studies have thus far only been conducted in Australia, New Zealand, the UK and USA. To broaden the evidence base investigation in different cultural, economic and educational systems is needed.

These future studies should further consider possible variability of children's physical activity dimensions[19] in line with the concept of the "activitystat" hypothesis.[20] This biological centered hypothesis has been proposed to explain physical activity compensatory behaviors, and implies that changes in a specific domain, for example decreased sitting in school, could be compensated or offset by increased sedentary time on the same day after school, or on subsequent days.[21,22] Hence, in order to comprehensively understand the effects of domain-specific health behavior interventions, an integrative approach that considers 24 h movement behaviors is warranted.[23] It remains unclear if reduced sitting time achieved in school time by introduction of classroom standing desks may impact on physical activity or sedentary behavior performed outside of school time during the week or at the weekend. Therefore, our primary aim was to investigate the impact of a 16 week standing desk intervention on classroom sitting time; secondly, we verified the effects of the intervention on whole-day objectively measured sedentary behavior and physical activity both during the week and at the weekend.

2. Methods

The ERGUER/Portugal project is a school-based cluster controlled trial. The clusters were two sixth grade classes recruited from a large public school located in Lisbon. Students were aged between 11 and 13 years-old, had no limitations to perform postural changes and provided parent/guardian consent to participate in the study. Classes were labeled as either the intervention (IG) or control group (CG). Fifty-one students were eligible (IG = 22 and CG = 29) for the study, however two CG students did not return consent. Thus, the final sample was composed of 49 students (IG = 22 and CG = 27). Adjustable sit-stand desks were introduced to the intervention classroom for a period of 16 weeks, separated by two measurement (pre- and post-intervention) time-points. The study was approved by the local ethics committee.

The intervention took place over a period of 16 weeks (February–May) and involved environmental (physical and social) changes and school teacher training. The physical environment was modified by exchanging traditional seated desks for the LearnFit® Adjustable Standing Desk (Ergotron, USA). In addition to allowing postural changes, these desks can be moved and thus expand possibilities for classroom based activities. Also, in order to promote family support, three meetings with parents/guardians were conducted during the intervention. The first to explain the rationale and components of the study, invite students to participate and collect the written informed consent. The second meeting served to update the parents/guardians about the classroom work, and to collect prior perceptions and suggestions in order to improve pedagogical strategies and maintain motivation related to the intervention. In the final meeting the main results of the intervention were presented, individualized reports discussed, and further perceptions of parents/guardians about the intervention were collected. Throughout the intervention, six teacher training problem-solving sessions (four hours each) were conducted by physical education and psychology professionals. The first session involved dissemination of study information including the project rationale; teachers were then required to present perceived barriers/difficulties and good practices in order for group discussions to take place (next four sessions). In each session teacher perceptions about the effectiveness of the intervention were collected. The sixth and final session were used to present the results and collect concluding perceptions from teachers. Teachers that attended sessions received professional credits for carrier progression. The information gathered from both parents and teachers was used to continually modify the intervention. For example, some parents reported that their child felt tired when standing, and thus teachers were advised to allow tired children to sit briefly for recuperation. Furthermore, peer-to-peer teacher recommendations, such as adopting a U-shaped arrangement of classroom desks, were promoted as examples of best practice that teachers were encouraged to replicate.

Subjects taught in school (seven classes timetabled daily with each class lasting 50 min) included Mathematics, Portuguese, History, English, Technology, Visual Arts, Music, and Physical Education. All Physical Education, Visual Arts and Music classes were conducted in different rooms to that which housed the standing desks. Thus, of the 35 weekly classes, 29 in total were held in the intervention classroom.

Body mass index (BMI, kg/m^2) was calculated from measured weight (nearest 0.1 kg) and height (nearest 0.1 cm). Waist circumference was measured to the nearest 0.1 cm, 1 cm above the iliac crest (Sanny® metal tape). Somatic maturation was estimated by the peak of height velocity from trunk-encephalic height (50 cm bench).

The ActivPAL™ micro inclinometer (PAL Technologies Limited, Glasgow, UK) was used to assess time spent lying/sitting (main outcome), standing, stepping, sit-to-stand transitions, and total number of steps. The device was attached to students at the anterior mid-line of the right thigh by adhesive waterproof film (3 M™ Tegaderm™). Participants were asked to wear the inclinometer continuously for seven days, including when showering and sleeping, but were requested to remove the device for swimming. These data were reduced by ActivPAL™ software v.7.2.32 with 15 s epochs (at 20 Hz). In addition, the Actigraph GT3X+ accelerometer was used to capture habitual physical activity. High correlations between ActivPAL™ monitor with direct observation for the time spent sitting/lying, standing, and walking in children have been found.[24] However, ActivPAL™ seems to be less accurate when measuring fast walking and running in children.[23] In contrast, Actigraph accelerometers are more valid for assessing moderate-to-vigorous physical activity (MVPA) in children,[25] and less accurate in identifying the transition between sitting and standing. In other words, Actigraph poorly distinguishes light physical activity from sedentary time,[26] and thus in the present investigation ActivPAL was used for the lower spectrum of physical activity (i.e. sitting and standing time), while the Actigraph was incorporated for assessment of MVPA.

Participants were instructed to wear the Actigraph on the right rip (near the iliac crest) during waking hours for seven days. The device, initialized to collect data in 15 s epochs (at 30 Hz), was attached via an elasticated belt and was removed only for water-based activities. The Choi et al.[27] criteria were used to identify periods of monitor non-wear and Evenson et al.[28] cutoff were used to derive MVPA using Actilife v.6.10.4 software. For both devices, activity records that had four or more days (including one weekend day) each with ≥600 min of wear were considered valid. Participants manually recorded if the device was removed at all, the time and reason. Using the same diary record, information regarding sleep timings was collected. In addition, data from the accelerom-

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