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BRIEF REPORT

Sit–Stand Tables With Semi-Automated Position Changes: A New Interactive Approach for Reducing Sitting in Office Work

Dechristian França Barbieri[1], Svend Erik Mathiassen[2], Divya Srinivasan[2,3], Wilian Miranda Dos Santos[4], Roberto Santos Inoue[5], Adriano Almeida Gonçalves Siqueira[4], Helen Cristina Nogueira[1], and Ana Beatriz Oliveira[1,]*
[1]Laboratory of Clinical and Occupational Kinesiology, Department of Physical Therapy, Federal University of São Carlos, Washington Luís Road, Km 235, SP310, 13565-905 São Carlos, SP, Brazil
[2]Department of Occupational and Public Health Sciences, Centre for Musculoskeletal Research, University of Gävle, Gävle, Sweden
[3]Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
[4]Department of Mechanical Engineering, University of São Paulo, São Carlos, SP, Brazil
[5]Department of Electrical Engineering, Federal University of São Carlos, São Carlos, SP, Brazil

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*Corresponding author. E-mail: biaoliveira@ufscar.br

OCCUPATIONAL APPLICATIONS Sit–stand tables with semi-automated position changes were developed in order to remind users to switch regularly between sitting and standing postures during office work. Tests of the system showed good user compliance: Desk usage patterns were sustained during the entire 2 months following intervention. Users reported the new system did not interfere with their work, that it impacted their perception of health and well-being positively, and that they would have liked to continue using the system beyond the intervention period. This could thus be a promising intervention to ensure adequate use of sit–stand desks and sustain their use over time.

TECHNICAL ABSTRACT ***Background***: Introducing sit–stand tables has been proposed as an initiative to decrease sedentary behavior among office workers and thus reduce risks of negative cardiometabolic health effects. However, ensuring proper and sustainable use of such tables has remained a challenge for successful implementation. ***Purpose***: Assess a new system developed to promote and sustain the use of sit–stand tables. ***Methods***: The system was programmed to change the position of the table between "sit" and "stand" positions per a regular preset pattern if the user agreed to the system-generated prompts prior to each change. The user could respond to the system-generated prompts by agreeing, refusing, or postponing the changes by 2 minutes. We obtained user compliance data when this system was programmed to a schedule of 10 minutes of standing after every 50 minutes of sitting. Compliance was investigated among nine office workers who were offered the semi-automated sit–stand table for 2 months. ***Results***: The system issued 12 to 14 alerts per day throughout the period. Mean acceptance rates ranged from 75.0% to 82.4%, and refusal rate ranged from 11.8% to 10.1% between the first and eighth weeks of intervention (difference not statistically significant). During the first week after introduction, the table was in a standing position for a mean of 75.2 minutes—increasing slightly to 77.5 minutes in the eighth week. ***Conclusions***: Since the workers were essentially sitting down before the table was introduced, these results suggest that the system was well accepted, and led to an effective reduction of sitting during working hours. Users also reported that the system contributed positively to their health and well-being, without interrupting their regular work, and that they would like to continue using the sit–stand table even beyond the 2-month period as part of their regular work. Compliance beyond 2 months of use, however, needs to be verified.

KEYWORDS Alternative workstation, reminder system, sedentary behavior, occupational sitting time

INTRODUCTION

There is a great concern about office workers sitting too much since it may lead to serious health effects (Chau et al., 2010; van Uffelen et al., 2010; Thorp, Owen, Neuhaus, & Dunstan, 2011; Neuhaus et al., 2014). Interventions to break up sitting have therefore been advocated—particularly for office workers (van Uffelen et al., 2010). One initiative to promote breaks from continuous sitting is to provide workers with a workstation that allows for both sitting and standing (Davis, Kotowski, Sharma, Herrmann, & Krishnan, 2009; Toomingas, Forsman, Mathiassen, Heiden, & Nilsson, 2012; Straker, Abbott, Heiden, Mathiassen, & Toomingas, 2013; Neuhaus et al., 2014). The effects of introducing and using sit–stand tables has been investigated since the 1990s (Karlqvist, 1998), and a number of studies suggest that adjustable tables can, indeed, encourage posture variation (Davis & Kotowski, 2014), decrease sedentary behavior, increase metabolic demands, and decrease musculoskeletal symptoms without affecting work productivity (Proper, Singh, Van Mechelen, & Chinapaw, 2011; Karakolis & Callaghan, 2014). Commissaris and colleagues (2016) recently performed a systematic review of interventions practicable during productive work time for the purpose of reducing sedentary behavior and increasing physical activity. They found alternative workstations including sit–stand desks to be the most effective intervention to reduce sedentary behaviors at work—given the present limited scientific evidence for the effectiveness of other kinds of interventions. This conclusion was also reached in another review by Neuhaus and colleagues (2014).

However, problems continue to exist in the actual implementation of sit–stand tables in workplaces. One important issue is that workers need education to support the correct use of such tables, and sustain their use over time (Wilks, Mortimer, & Nylén, 2006; Karakolis & Callaghan, 2014). Most intervention studies of sit–stand stations have observed patterns of usage for a few months, at the most, after the introduction. A study of workers with long-term access to sit–stand stations as part of their regular work environment raised concerns as to the sustainability of the positive attitude to use the tables observed after their introduction since workers with sit–stand tables differed only little in sedentariness from those without (Straker et al., 2013). These authors concluded that it is likely a major challenge to effectively and sustainably make workers aware about the use of sit–stand tables and to ensure sustained compliance after an initial period of observance. Regular reminders to workers of changing table configuration, and thus gross body posture, may promote the use of sit–stand tables according to intentions; in particular, if such prompts are accompanied by an easy-to-use solution for adjusting the table (De Cocker et al., 2015).

Thus, our aim was to develop a system integrated with regular sit–stand tables that prompted the user to stand for 10 minutes after every 50 minutes of accumulated sitting, and to automatically perform that change, conditional on the user agreeing to the prompt. In the present study, we describe the technical solution and report data concerning compliance and usage patterns of workers being offered the system.

METHODS

Design of the Semi-Automatic System

The system was designed to control the adjustment of sit–stand tables: allowing the worker to interact with pre-scheduled prompts of changes in table configuration, so as to work in a sitting or standing position. The

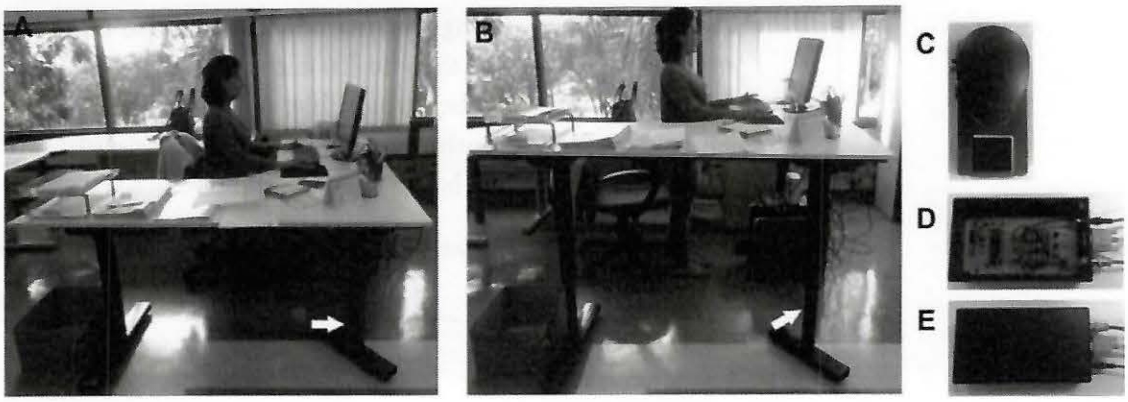

FIGURE 1 Electric lifting legs (arrows) of the sit–stand table (A and B); control box (C); and interface control board (D and E).

system also recorded and stored data regarding the actual table positions during a whole working day.

The Table With the Integrated System

The workstation (Fig. 1) integrated commercially available legs for sit–stand tables (DESKLINE DL7, LINAK, São Paulo, Brazil) with a system for control and interaction. The control and interaction system consisted of three components: (1) three linear electric actuators (lifting legs) used to move the table; (2) a control box containing the power driver and the position controller; and (3) an interface board connecting the user's personal computer (PC) with the control box, thus allowing the user to interact with the table through his/her PC.

The sit–stand table could be manually controlled using electronic controls in the desk panel control box (Fig. 1C): allowing the user to move the table to sit and stand at discretion, and to access and save preset positions. The interface board consisted of a 5V-operated 6-relay board driven by a PIC 18F4550 microcontroller (Microchip Technology, Inc., Chandler, AZ, USA), which in turn was connected to the computer through serial communication using the RS232 standard. Custom software was developed for the interface board to automatically simulate the manual functions of the desk panel control box.

Worker Interface

A control software with a graphical user interface (GUI; Fig. 2) was designed using MATLAB (MathWorks, Inc., Natick, MA, USA) to be integrated in desktop PCs running the Microsoft Windows Operating Systems. This software allowed the user to preset the duration of the table in each position (i.e., to decide the frequency of sit–stand shifts). For instance, a preset pattern could be to stand for 10 minutes for every accumulated 50 minutes of sitting (Fig. 2A), in accordance with the current recommendations of the regulatory computer work norm in Brazil (NR17, 2007).

The software triggered an auditory signal 30 seconds prior to each preset shift and an alert window appeared on the computer screen—requiring an answer from the worker (Fig. 2B). The worker had three options to

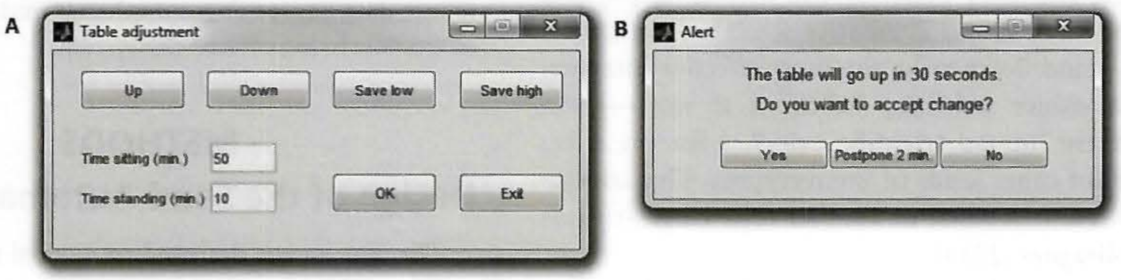

FIGURE 2 Graphic user interface (A) to set the reference position for both sit (down, save low) and stand (up, save high), and save the time schedule for periods in each position (time sitting and time standing); Interface (B) to alert the workers about upcoming changes in table position.

respond (Fig. 2B): "Yes"—the adjustable table would change to the next programmed position according to the preset schedule; "Postpone 2 min"—the table would not change position, but the alert window would appear again after 2 minutes; and "No"—the table would remain in its current position, and the software would resume counting down on a completely new period according to the preset schedule (Fig. 2A). Workers were allowed to answer "No" or "Postpone" in response to the system alerts at their discretion any number of times throughout the working day. Thus, the table only changed position according to the preset schedule if the worker selected the option "Yes"; otherwise, it remained in its current position. If the worker did not respond to the system alert, the table stayed in its current position until the user responded. Thus, the worker was in control of the semi-automated system—in as much as the table would only change position if the worker accepted the prompted change as per the preset schedule (Fig. 3).

Table Usage Record

The integrated software on the user's computer registered and stored every change of table height and the corresponding time stamp. Data were then saved in a .mat file on the worker's computer at the end of each day, and could thus be shared with other computers using standard procedures.

Participants and Data Collection

Nine office workers (three men, six women) participated in an assessment of compliance associated with the integrated system. The mean age of the subjects was 42.0 (*SD* 6.8) years, stature 166.0 (*SD* 7.0) cm, body mass 65.0 (*SD* 14.3) kg, and body mass index (BMI) 24.0 (*SD* 3.5) kg/m^2. All participants were employed at a public university in Brazil and worked as administrators of undergraduate and graduate courses or in management of finances and human resources. Their

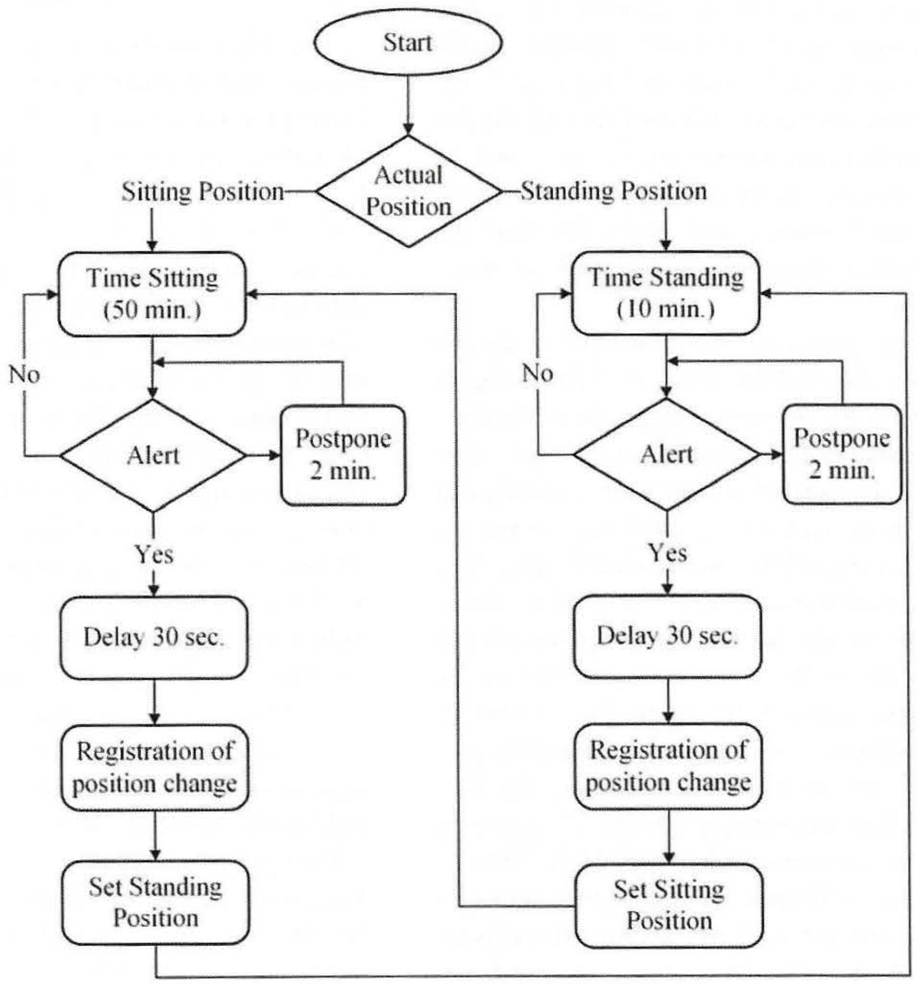

FIGURE 3 Flow-chart illustrating the operation of the system alerting, implementing, and recording table position changes.

routine office work was characterized by a majority of their working time spent on computer work as well as non-computer tasks at their desks. Inclusion criteria for participation in this experiment were: (a) no self-reported musculoskeletal discomfort or pain in the low back, neck–shoulder, hand–arm, or legs in the preceding 3 months before the start of the study, (b) reported computer use at work for more than 4 hours per day, (c) computer work performed for more than 5 years, and (d) absence from work for no more than 1 month in the preceding year, excluding the holiday period. The study was approved by the Human Ethics Committee of the Federal University of São Carlos (Process #13880213.9.0000.5504), and all workers who participated signed the consent form.

The nine office workers were provided with sit–stand tables pre-programmed with a schedule of 10 minutes standing for every 50 minutes of sitting. No other changes to their workstations or computer equipment occurred. They were informed about the benefits of changing posture during work using the adjustable table, and they received standard ergonomics information on recommended sitting/standing postures and computer equipment setups. Positions of the table in "stand" and "sit" configurations were specifically adjusted for each worker by the researcher just after introducing the table, and the setup was saved in the memory of the table. Workers then used the table for 2 months, and during this time, the researcher visited them about once every 2 weeks to ensure smooth operation.

Throughout the 2-month period of table usage, the table software recorded and time-stamped every change of table position when the worker was logged on to the computer. Workers were instructed to log on to their computers as soon as they arrived at work every morning and to stay logged in throughout the work day, except for lunch breaks. User compliance was evaluated using three variables: (1) the absolute number of table position change alerts issued by the system; (2) the proportions (in percent) of different answers to these alerts, (i.e., accepts to the change [Yes], postponements [Postpone 2 min.], refusals to stand [No], refusals to sit [No], missing answers [i.e., non-responses]); and (3) the total duration per day with the table in standing and sitting positions. Data are presented as medians and interquartile ranges (25th–75th percentiles), and the difference in compliance variables between the first and last week of the 2-month intervention period was tested for statistical significance using the non-parametric Wilcoxon signed-rank test.

In the last week of the 2-month period, the workers answered the following four questions related to acceptability on Likert scales, from 1 (*least likely*) to 5 (*most likely*), describing their experiences when using the system:

A. Did the use of the adjustable sit–stand table affect your health and well-being positively?
B. Would you like to continue using this sit–stand table in your work?
C. Was it easy to use the alert windows?
D. Did the transitions from sit to stand and vice versa interrupt your work?

In addition, the workers were asked to indicate with "yes" or "no" if the preset pattern of 10 minutes of standing following 50 minutes of sitting was adequate; "no" indicated that they would have preferred to stand for longer continuous periods.

RESULTS

The office workers had mean work days of about 8 hours, and summary results are presented in Table 1. During the testing period, the system issued means of 14.0 alerts per day in the first week of table use and 12.0 in the last week. Acceptance, as measured by the proportion of answers "yes" to the alerts, did not change significantly during the intervention period, although the median increased slightly from 75.0% to 82.4% between the first and last week of the intervention. While the workers very rarely refused a change in table position from "stand" to "sit," they did sometimes refuse the change from "sit" to "stand" (about 10% of prompts). The table was in the "standing" position for somewhat more than 1 hour per day, both in the first (75.2 minutes) and eighth (77.5 minutes) weeks of the intervention period; results on more detailed daily usage patterns will be reported in a separate article. Thus, results suggest a good compliance with the preset time schedule of table position changes, as well as a good sustainability with no significant change in acceptance rates or time spent with the table in "sit" and "stand" positions during the intervention period.

Ratings of acceptability are shown in Fig. 4. A median response of 4.0 was given regarding whether the sit–stand tables contributed positively to health and well-being (Question A). Almost all reported that they would like to continue using the table in their

TABLE 1 Table use by nine office workers during 2 months of access to the sit–stand table system.

	First week	Eighth week	*p*-value*
Alerts (number/day)	14.0 (12.0–17.0)	12.0 (11.0–14.5)	0.910
Answer "Yes" (%)	75.0 (70.8–92.2)	82.4 (54.8–89.9)	0.375
Answer "Postpone" (%)	0.0 (0.0–5.3)	0.0 (0.0–5.9)	0.625
Answer "No" to stand (%)	11.8 (0.0–16.7)	10.1 (0.0–29.0)	0.313
Answer "No" to sit (%)	0.0 (0.0–8.3)	0.0 (0.0–0.0)	0.371
Missing answer (%)	0.4 (0.0–2.8)	0.0 (0.0–2.4)	0.688
Table in "standing" position (min/day)	75.2 (66.8–84.7)	77.5 (37.2–87.8)	0.652
Table in "sitting" position (min/day)	375.0 (308.3–439.0)	434.2 (423.2–443.7)	0.164

Note. The table shows the absolute number of table position change alerts (stand and sit), and the proportions (%) of different answers to these alerts (i.e., accepts to changing table height [Yes], postponements [Postpone 2 min.], refuses to stand [No], refuses to sit [No], and missing answers). Total durations per day with the table in standing and sitting positions are also shown. Data are presented as median and interquartile range (25th–75th) across subjects in the first and eighth week after introduction of the table, with *p*-values referring to the difference between the weeks.
*Wilcoxon signed-rank test for repeated measurements.

regular work (Question B; median = 5.0). The system was perceived as being easy to use (Question C; median = 5.0), and the transition between table positions was reported to only minimally interrupt regular work (Question D; median = 1.0). Only one of the nine users reported "No" to the question of whether the preset pattern of 10 minutes of standing following 50 minutes of sitting was adequate. The worker responding "No" stated that he would have liked to stand for longer durations than offered by the preset pattern.

DISCUSSION

The new semi-automatic system for automated table position changes accompanied by alerts appeared to satisfy the primary intention of reducing sitting time and promoting changes in posture among academic office workers. While the present study did not include a control group without access to sit–stand tables, previous investigations in the same population before the intervention showed that workers were at their desk (i.e., sitting) for about 80% of their working day (Barbieri, Srinivasan, Mathiassen, Nogueira, & Oliveira, 2015), corresponding to about 380 minutes. Assuming that table position ("sit" versus "stand") is a valid proxy for the worker's posture while being at the desk, the present results suggest these 380 minutes were reduced by about 75 minutes (i.e., by about 20%). This effect is of the same order of magnitude as that in several previous studies of sit–stand station interventions (Neuhaus

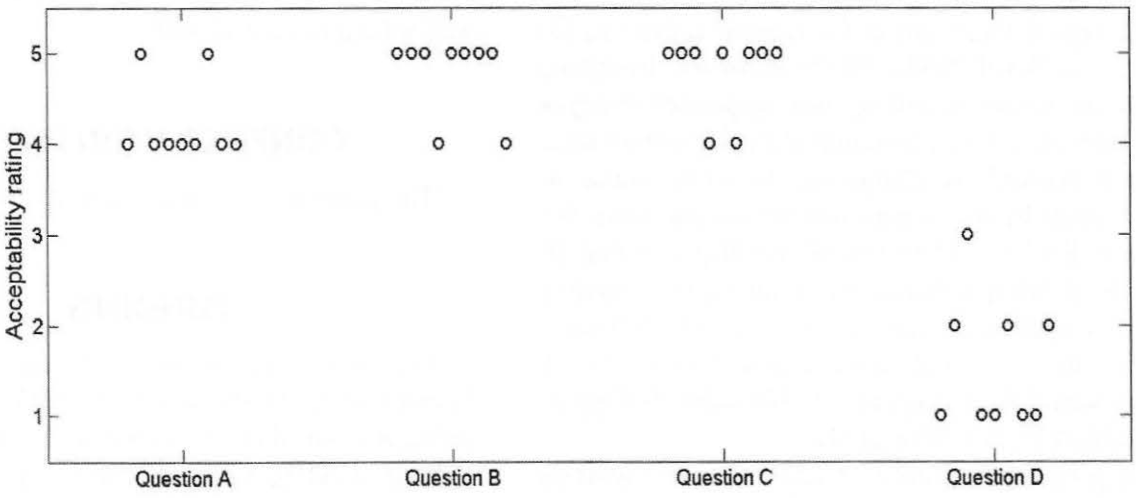

FIGURE 4 Ratings of acceptability from each of the nine subjects, illustrated by circles, to the following four questions. Question A: Did the use of the adjustable sit–stand table affect your health and well-being positively? Question B: Would you like to continue using this sit–stand table in your work? Question C: Was it easy to use the alert windows? Question D: Did the transitions from sit to stand and vice versa interrupt your work? Ratings on Likert scales: for questions A, B, and C, 1 indicates poor acceptability and 5 indicates great acceptability; for question D, 1 indicates great acceptability and 5 indicates poor acceptability.

et al., 2014; Commissaris et al., 2016). One previous study (Davis et al. 2009) implemented encouraging reminders as part of a sit–stand desk intervention among call center workers. However, these workers had access to sit–stand stations for only 2 weeks, and the reminders were not integrated in the table system as in the present case, and did not automatically change table positions in response to user preferences. Furthermore, the authors did not report any information on sit–stand table usage or intervention compliance, thus precluding comparisons with our results.

The effects observed in our study persisted throughout the 2-month period of use, which encourages access to the system for even longer periods, and introduction of the system even in other jobs characterized by extensive sedentary behavior at a permanent workstation. The average cost for rebuilding the commercially available sit–stand table corresponded to about 10% of its retail price. Mechanical and electrical problems occurring both with our system and others (Hedge & Ray, 2004) may result in workers having a negative perception of the system, and problems were therefore identified and solved within—at the most—2 days. Further research is needed, though, to understand whether our system with reminders and semi-automated position changes will produce other changes in users' behavioral patterns compared with regular sit–stand desks without such reminders, as well as how our system would compare to other solutions encouraging workers to stand more.

We tested a duration of 10 minutes of standing for every 50 minutes of sitting work, which was guided by the population being academic office workers, and thus a typical target group for recommendations, for instance, in Brazil (NR17, 2007). However, depending on the occupational setting, more aggressive strategies of posture change can be handled by our system since the time schedule of change can be set according to choice, both by the worker and the management. For instance, Roelofs and Straker (2002) suggested that 30 minutes of sitting followed by 30 minutes of standing would be appropriate for bank tellers, and discussions of different sit to stand ratios ranging from 1:3 to 3:1 can be found in Callaghan, De Carvalho, Gallagher, Karakolis, & Nelson-Wong (2015).

The present population of academic office workers had considerable autonomy with respect to how to use their working time and how to arrange their work. On the other hand, they were—to a very large extent—devoted to working at their permanent workstation, with few tasks requiring them to leave it. Thus, compliance with the system alerts may be different in populations with less autonomy and more alternating tasks. Future research may show whether introduction of the system leads to the intended effects on sitting behavior even in other occupational settings, and whether effects persist beyond the initial 2 months after introduction of the semi-automated sit–stand tables. Compliance with alternative position change patterns also needs to be investigated so that the pattern can be optimized with respect to compatibility with work tasks as well as effects on health and performance. To this end, the added value in terms of behavior changes of ergonomics information campaigns accompanying the system should be considered (Alkhajah et al., 2012; Robertson, Ciriello, & Garabet, 2013; Straker et al., 2013).

In conclusion, sitting time, as estimated through table position, was reduced among academic office workers introduced to a commercially available sit–stand table equipped with a versatile semi-automatic system for automated table position changes accompanied by alerts on the user's computer screen. These users responded positively to the semi-automated sit–stand tables in terms of ease of usage. They accepted the system-generated changes in table position about 75% of the time, and the resulting effects on table position and, thus, sitting time, persisted throughout the 2-month period of use. However, further studies on a larger sample of workers and with a longer follow-up time are important to confirm these results, and the usability and effects of the system need be tested in other occupational settings with substantial seated work.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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ORCID

Svend Erik Mathiassen http://orcid.org/0000-0003-1443-6211

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