A Cluster Randomized Controlled Trial to Reduce Office Workers' Sitting Time: Effect on Activity Outcomes

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ABSTRACT

HEALY, G. N., E. G. EAKIN, N. OWEN, A. D. LAMONTAGNE, M. MOODIE, E. A. H. WINKLER, B. S. FJELDSOE, G. WIESNER, L. WILLENBERG, and D. W. DUNSTAN. A Cluster Randomized Controlled Trial to Reduce Office Workers' Sitting Time: Effect on Activity Outcomes. *Med. Sci. Sports Exerc.*, Vol. 48, No. 9, pp. 1787–1797, 2016. **Purpose**: This study aimed to evaluate the initial and long-term effectiveness of a workplace intervention compared with usual practice, targeting the reduction of sitting on activity outcomes. **Methods**: Office worksites (≥1 km apart) from a single organization in Victoria, Australia, were cluster randomized to intervention ($n = 7$) or control ($n = 7$). Participants were 231 desk-based office workers (5–39 participants per worksite) working at least 0.6 full-time equivalent. The workplace-delivered intervention addressed organizational, physical environment, and individual behavioral changes to reduce sitting time. Assessments occurred at baseline, 3 months, and 12 months, with the primary outcome participants' objectively measured (activPAL3^{TM} device) workplace sitting time (minutes per 8-h workday). Secondary activity outcomes were workplace time spent standing, stepping (light, moderate to vigorous, and total), and in prolonged (≥30 min) sitting bouts (hours per 8-h workday); usual duration of workplace sitting bouts; and overall sitting, standing, and stepping time (minutes per 16-h day). Analysis was by linear mixed models, accounting for repeated-measures and clustering and adjusting for baseline values and potential confounders. **Results**: At baseline, on average, participants (68% women; mean ± SD age = 45.6 ± 9.4 yr) sat, stood, and stepped for 78.8% ± 9.5%, 14.3% ± 8.2%, and 6.9% ± 2.9% of work hours, respectively. Workplace sitting time was significantly reduced in the intervention group compared with the controls at 3 months (−99.1 [95% confidence interval = −116.3 to −81.8] min per 8-h workday) and 12 months (−45.4 [−64.6 to −26.2] min per 8-h workday). Significant intervention effects (all favoring intervention) were observed for standing, prolonged sitting, and usual sitting bout duration at work, as well as overall sitting and standing time, with no significant or meaningful effects observed for stepping. **Conclusions**: This workplace-delivered multicomponent intervention was successful at reducing workplace and overall daily sitting time in both the short term and the long term. **Key Words:** WORKPLACE, CARDIOMETABOLIC BIOMARKERS, ACCELEROMETRY, SEDENTARY, PHYSICAL ACTIVITY

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Too much sitting is now recognized as a public health concern (6). On average, sedentary time (sitting or reclining while awake with low energy expenditure) (33) occupies more than half of adults' waking hours (22), with this proportion expected to escalate (26). In office workers, workplace sitting is the largest contributor to daily sitting time (28). Further, much of this sitting time is accumulated in prolonged, unbroken bouts of 30 min or more (11,14,32)—a pattern that may entail greater cardiometabolic risk than sitting for short periods at a time (8,16). With office workers constituting the largest single occupational sector in the United States, and the proportion of industrial sectors that

involves sedentary work increasing (39), the office workplace has been identified as a key setting in which to target reductions in prolonged sitting time (15).

Workplace-delivered interventions have the advantage of being able to address multiple influences on prolonged sitting behavior (27), including intrapersonal, interpersonal, policy, and environmental (physical and social) factors (4,40). Several studies have now demonstrated the effectiveness, feasibility, and acceptability of a range of strategies to reduce sitting time in the office workplace (23,29,35,36,38). Consistent with workplace health promotion frameworks (40), interventions that address multiple levels of influence (i.e., the environment, the organization, and the individual) (14,24) have tended to show greater reductions in sitting than single-component interventions, such as individual-based counseling (17), computer prompt software (11), and sit–stand workstations (24). However, recent reviews (21,23,35) have noted that many studies have methodological limitations, including nonrandomized study designs, small sample sizes, short follow-up periods (typically 3 months or less), and/or poor control for confounding (15,23,29,35,36,38). To address these limitations, we examined the initial (3-month) and long-term (12-month) effects of a multicomponent workplace intervention targeting reductions in workplace sitting on participants' activity outcomes.

METHODS

Stand Up Victoria was a 12-month cluster randomized controlled trial. Ethics approval was granted by Alfred Health Human Ethics Committee (Melbourne, Australia), with prospective trial registration with the Australian New Zealand Clinical Trials register (ACTRN12611000742976). The study was conducted in accordance with the CONSORT guidelines for cluster randomized controlled trials (http://www.consort-statement.org/). A detailed study protocol (9), including the properties of the measures used and description of the intervention development process (25) (including findings from the pilot study [14]), are available; brief details are provided in the following section.

Setting and Participants

The study was conducted in partnership with the Department of Human Services (DHS)—a large Australian Government organization with more than 35,000 staff nationwide. Recruitment occurred between April 2012 and October 2013. Study sites were identified as potentially eligible by the DHS-appointed research liaison person if they were from geographically separate (≥1 km apart) DHS buildings (sites) in the state of Victoria (metropolitan and regional) and were not currently delivering a physical activity program to staff. Within each site, a team (i.e., a distinct working group within the site that had a dedicated line manager and regular group meetings and interactions) was identified. Before randomization, written informed consent was obtained from the divisional manager of each team for their employees to participate in the study, for the environmental component to be incorporated into the office workspace, and for health coaching elements to be conducted during work time.

After randomization, an information session about the study was presented for consenting teams within each site, with summary material also provided via e-mail. Potential participants completed an expression of interest from either directly following the information session or via e-mail afterward. Employees within these participating teams were initially considered eligible at the telephone screening if they worked at least 0.6 full-time equivalent hours; were age 18–65 yr; were English speaking; had designated access to a telephone, Internet, and desk within the workplace; were not pregnant; were ambulatory; had no physical or health problems that may limit their ability to stand for at least 10 min at a time; and had no planned absence from work for more than 2 wk or a planned relocation to another workplace during the first 3 months of intervention (during implementation of the individual strategies). Potential participants also needed to have undergone baseline assessment and remain willing and eligible to take part by the time the intervention commenced to be considered eligible for the intervention. All participants provided written informed consent. Participants and study staff were unblinded to group allocation.

Assignment to Study Group

Randomization to either the intervention or the control arms of the trial was at the level of the worksite via simple cluster randomization. This was achieved by generating a randomization plan for up to 24 clusters in one block (www.randomization.com) by a research staff member not involved in recruitment or data collection. Participating sites were then randomly matched against the randomization plan using a list randomizer (www.random.org).

Control—Usual Practice

The control group underwent the same assessment protocol as the intervention group. Control participants received written feedback on their activity and biomarker outcomes at 3 months (baseline and 3-month results provided) and 12 months.

Intervention

As previously described (9,25), Stand Up Victoria was a multicomponent intervention to reduce workplace sitting time. It was composed of organizational-, environmental-, and individual-level strategies and targeted change at both the individual and the cluster levels. Extensive formative research was used to guide intervention development (14,25), which drew upon social cognitive theory and an ecological model of sedentary behavior (27). The intervention targets of "Stand Up, Sit Less, Move More" were informed by occupational health and safety guidelines (18), public health guidelines (3), and experimental evidence (8). These targets aimed to reduce

sitting time—particularly sitting time accrued in prolonged unbroken bouts of at least 30 min—replacing it with either standing or stepping, and to do this across the whole day (both in and out of the workplace).

Organizational strategies. An initial consultation with senior management established the departmental resources available to support the program at an organizational level. Then a 3-h group consultation workshop with representatives from each of the intervention sites (managers, team champions, occupational health and safety representatives and general staff) was held to inform management and other organizational stakeholders about the study's broad aims and discuss the feasibility of the study from a management and team perspective. At this workshop, a range of organizational-level strategies appropriate for the various intervention sites were brainstormed. These strategies, as well as the baseline feedback, were then subsequently discussed with all participants at each intervention worksite to identify those strategies most suitable to their work context, with the site-specific strategies finalized using a participatory approach. Team champions (typically the worksite team leader) were recruited and encouraged to be role models and to promote the organizational-level strategies. This included sending six e-mails, which the champion could tailor to include messages relevant for their team, at weeks 2, 4, 6, 8, 10, and 12. Research staff were copied in on the e-mails for monitoring of intervention fidelity.

Environmental strategies. A dual-screen sit–stand workstation (Ergotron WorkFit-S; www.ergotron.com) with a work surface accessory was installed for the duration of the study (12 months). Participants received written and verbal instructions and tips on the appropriate ergonomic posture for both sitting and standing, as recommended by the product manufacturer (www.ergotron.com/tabid/305/language/en-AU/Default.aspx), as well as adhesive stickers applied by research staff to indicate the recommended configuration tailored for each individual (i.e., appropriate desk height when standing/sitting).

Individual strategies. These were implemented for 3 months by study-trained health coaches. These consisted of an individual face-to-face coaching session (0–3 d after workstation installation) at the participants' workplace and four telephone calls at weeks 2, 4, 8, and 12. The coaching was used to explain the "Stand Up, Sit Less, Move More" intervention targets, to indicate the extent to which participants were meeting these targets according to their baseline assessment results, and to identify specific goals and individual-level behavior change strategies relating to each of these key intervention messages. Participants recorded their goals and strategies on their personal tracker (example provided in the protocol article [9]), which was affixed to their workstation. During the face-to-face coaching session, participants also received specific instructions to "listen to their body" and to regularly change posture (i.e., to neither sit nor stand for too long). After the consultation, a personalized e-mail summary of the session was sent to participants. The telephone calls were used to support goal attainment. The calls involved assessment of participant progress toward previously set goals, problem-solving as necessary, and adjustment/progression of goals and related behavior change strategies. The telephone call at week 8 focused on sitting and activity outside the workplace. Intervention fidelity was maintained through the health coach's use of detailed intervention scripts and checklists and quarterly meetings with senior study investigators.

Data Collection and Measures

Assessments included activity monitoring, an onsite assessment, and an online questionnaire. They occurred at baseline, after 3 months of intervention (at completion of the tailored e-mails and individual-level health coaching), then at 12 months postbaseline. After the onsite assessment (which included the body composition measures and instructions on how to wear the activity monitor), participants were e-mailed a link to the self-administered online questionnaire (LimeService: www.limeservice.com), through which sociodemographic, work-related, and other health-related data were collected. Demographic and work-related data were collected only at baseline.

Activity outcomes. Activity outcomes were as follows: time per 8-h day at work spent sitting, sitting for ≥30 min continuously (prolonged sitting), standing, stepping, stepping at a light intensity (<3 METs) and moderate–vigorous intensity (MVPA stepping; ≥3 METs), usual workplace sitting bout duration (min), and overall time per 16-h waking day spent sitting, standing, and stepping. The primary outcome was workplace sitting time. The activity outcomes were measured by the highly accurate and responsive activPAL3™ activity monitor (PAL Technologies Limited, Glasgow, UK; minimum version 6.3.0). The monitor was initialized, waterproofed, and then secured onto the right anterior thigh with a hypoallergenic patch. Participants were asked to wear the monitor continuously (24 $h \cdot d^{-1}$) for 7 d after the onsite assessment and to record daily in a diary their wake up, sleep ("lights out"), and monitor removal times (if any). They were also asked to report their work hours, the location from which they worked, and periods spent in non-DHS paid employment (if any). Missing sleep/wake times were estimated from monitor movement data by study staff. For this manuscript, "sitting" is sitting/lying bouts recorded by the activPAL, and "work" and "workplace" interchangeably refer to all DHS work from any location. At every assessment, almost all work time reported (≥98%) was for DHS, and very little (<5%) of the DHS work time reportedly occurred in locations other than primary DHS workplace.

Monitor data (activPAL events files) were processed in SAS 9.4 (SAS Institute Inc., Cary, NC). Bouts that were mostly (≥50%) within the diary-reported times for waking hours, naps, removals, and work hours were classed as such. Initially identified sleeping periods (not naps) were then adjusted to begin/end with the first/last sitting bout of ≥20-min duration within the initial period. Only periods awake and wearing the monitor were examined. For each participant,

time in each of the relevant activities while wearing the monitor was totaled for each day for all waking hours and all work hours. It was then averaged across valid workdays (monitor worn for ≥80% of work hours) and valid days (monitor worn for ≥80% of waking hours and for ≥10 h when waking hours were inferred from movement). To account for variation in work or waking time wearing the monitor, time spent in each activity was normalized to an 8-h workday or a 16-h waking day. For each individual, usual bout duration (also known as w50 or x50) for workplace sitting time was calculated across all relevant valid data using nonlinear regression (the Levenberg–Marquardt algorithm), fitting the cumulative distribution function for a power-law distribution (5). Each participant accumulates half of all workplace sitting time in bouts longer than his or her usual bout duration.

Adverse events. Data on adverse events related to the study (participant reported) were recorded for the intervention group only via the online questionnaire (3 and 12 months). Participants were asked if they had experienced any health problems that they believed were related to their participation in the study; if yes, they were asked to list the health problem(s), whether treatment was sought, and, if so, from whom and how often (number of visits). Physical symptoms potentially attributable to the intervention that were mentioned as reasons for withdrawal from the study and/or sit–stand workstation component of the intervention were also counted as adverse events.

Potential confounders. At baseline, data on numerous participant characteristics were collected for consideration as potential confounders (see Table, Supplemental Digital Content 1, potential confounders adjusted for in models, http://links.lww.com/MSS/A700). Weight (nearest 0.1 kg) was measured using foot-to-foot bioelectrical impedance analysis scales (Model TISC-330S, Tanita Inc., Tokyo, Japan) in the fasted and voided state. Standing height was measured in duplicate to the nearest 0.1 cm, with body mass index (BMI; $kg \cdot m^{-2}$) calculated using the average height and weight. Musculoskeletal health was assessed using the 27-item Nordic Musculoskeletal Questionnaire (7) over the last 3 months (instead of the usual 12 months) and the last 7 d. Problems were considered separately for the lower back, lower extremities, and upper extremities and, if present, were also categorized depending on whether the problem interfered with usual activities. Quality of life was assessed as the physical and mental domains of the validated Australian Quality of Life Survey (AQoL-8D) (31). Job control and productivity were assessed using the Health and Work Questionnaire (34), and an indicator of mental demands was derived from the Work Limitation Questionnaire (19). Dietary behaviors were assessed using the Fat and Fiber Behavior Questionnaire (30); measures of fatigue, headaches, and sleep quality were also collected.

Sample Size

Sample size details are reported elsewhere (9). Briefly, minimum differences of interest (MDI) for activity outcomes were 45 $min \cdot d^{-1}$ of sitting, standing, and prolonged sitting; 15 $min \cdot d^{-1}$ for all forms of stepping; and 5 min for usual sitting bout duration. Based on prior pilot data, we expected 30% attrition and strong clustering for activity (intracluster correlation, $\rho = 0.1$), with an assumed average n per cluster ($\bar{m}$) of 20 (design effect = 2.9, estimated as $1 + (\bar{m} - 1)\rho$) (10). We estimated each arm required 160 participants spread across eight clusters to achieve ≥90% power (5% two-tailed significance) to detect MDI for activity outcomes.

Statistical Analyses

Analyses were performed in STATA version 13 (STATACorp LP) with statistical significance set at $P < 0.05$, two-tailed, and reporting any interactions at $P < 0.1$. For continuous outcomes, intervention effects and changes within groups were estimated using linear mixed models. Outcomes were transformed (log transformations) as required to improve normality and/or to reduce heteroscedasticity. Models included fixed terms for group (intervention/control), time (3 or 12 months), and group–time interaction; baseline values of the outcome and potential confounders; and random intercepts for workplace (restricted maximum likelihood estimation). The models used unstructured within-participant covariance to deal with the repeated measures (3 and 12 months). A list of all potential confounders was first identified *a priori* (Table, Supplemental Digital Content 1, potential confounders adjusted for in models, http://links.lww.com/MSS/A700), and those displaying an association with the outcome at $P < 0.2$ in backward elimination were included in models. Estimates of changes within groups, and differences between groups, were obtained using marginal means and pairwise comparisons of marginal means of either the outcome or the predicted values of the outcome back-transformed to the original scale (for transformed outcomes). Overall results across both 3 and 12 months combined were presented only if intervention effects did not differ between these time points at $P < 0.1$. Effects are only described as "small" if they are less than the MDI.

To evaluate the sensitivity of results to missing data assumptions, analyses were also performed using multiple imputation by chained equations. Imputation models (m = 20 imputations) included all variables used in the analysis, a fixed effect for cluster (10), and any variables that showed an association with the odds of missing data at $P < 0.2$ (Table, Supplemental Digital Content 2, odds of missing data, http://links.lww.com/MSS/A701). The degree of clustering (intracluster correlation, ρ) in each outcome variable at baseline (unadjusted) was assessed using random intercept models. For the primary outcome, workplace effects were reported as both ρ and best linear unbiased predictions (BLUP), using separate models for the short-and long-term outcomes, with a random intercept for workplace and fixed effects for randomization, baseline values, and confounders. The significance of workplace effects was tested by comparing models with and without a random intercept.

RESULTS

Recruitment Outcomes

Of the 17 potential sites identified by the host organization liaison, 14 were approached (recruitment was limited to the project funding period) and 14 consented to randomization, with 7 sites allocated to receive the intervention and seven to the control condition (Fig. 1). Five of the sites could be considered large (>200 employees), six medium (50–200 employees), and three small (<50 employees). Four of the sites did predominantly telephone-based work (customer service tasks), seven non-telephone-based work (administrative/clerical tasks), and three sites had a mix of telephone and nontelephone tasks (13). A total of 278 employees across the sites initially expressed interest in the study, with 231 participants (between 5 and 39 per site) ultimately enrolled and ascertained to be eligible upon completing baseline assessment.

Participant Characteristics

The baseline characteristics of the participants (Table 1) in terms of age (24–65 yr with n = 70 [30.3%] age 35 to <45 yr and n = 83 [35.9%] age 45 to <55 yr), sex (68.4% female), full-time working status (79.2%), and job role

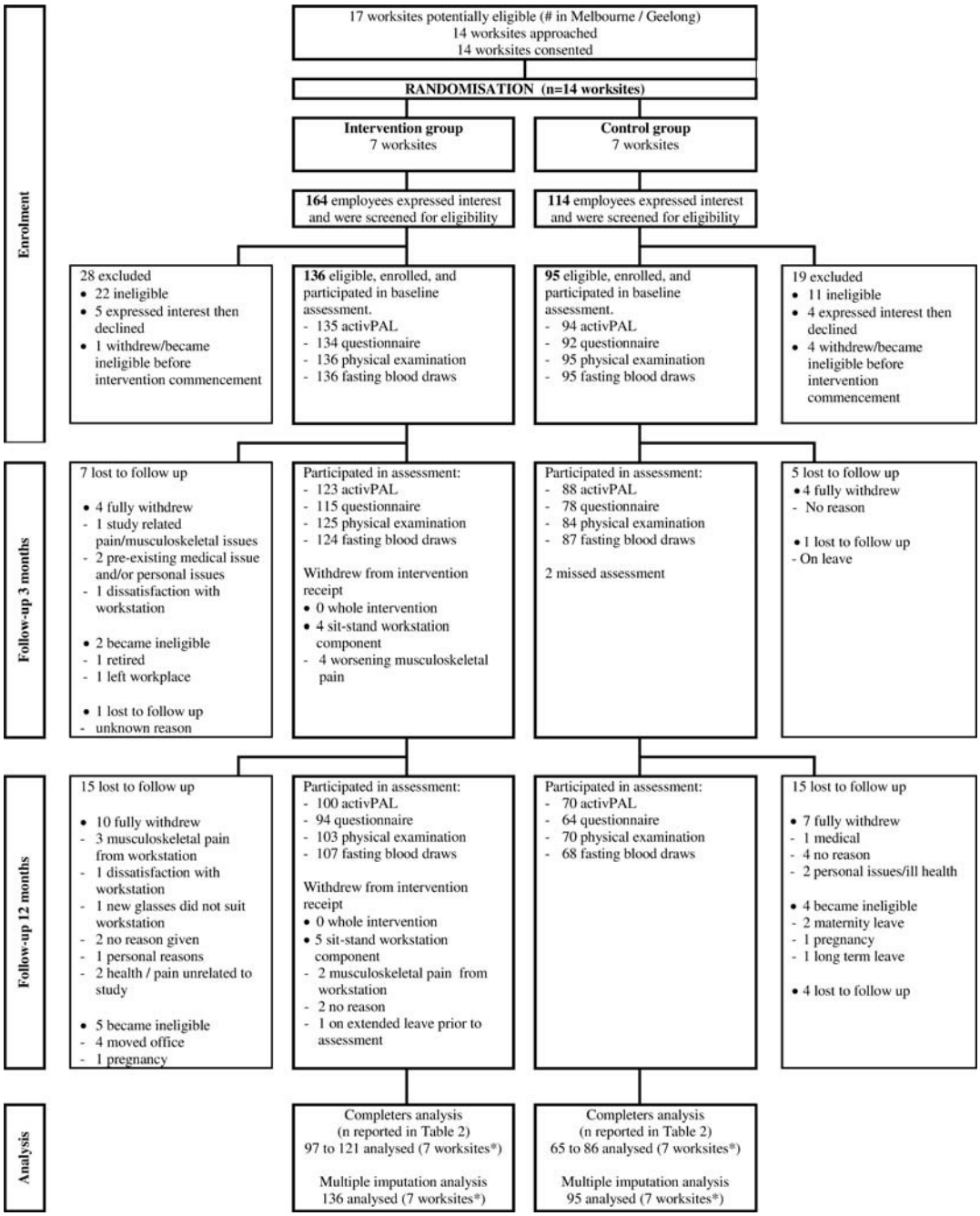

FIGURE 1—Flow diagram of enrolment, participation, and analyses.

TABLE 1. Baseline characteristics of the Stand Up Victoria study participants (n = 231, 14 teams), intervention (n = 136, 7 teams), and control (n = 95, 7 teams) groups.

	Intervention (n = 136, 7 Teams)[a]	Control (n = 95, 7 Teams)[a]	All (n = 231, 14 Teams)[a]
Age, yr	44.6 ± 9.1	47.0 ± 9.7	45.6 ± 9.4
Female	89 (65.4%)	69 (72.6%)	158 (68.4%)
Caucasian	109 (81.3%)	71 (77.2%)	180 (79.7%)
Married/living together	86 (64.2%)	62 (67.4%)	148 (65.5%)
Postschool education	90 (67.2%)	61 (66.3%)	151 (66.8%)
1.0 full-time equivalent, DHS	107 (79.9%)	72 (78.3%)	179 (79.2%)
Job category			
Manager/administrator	6 (4.5%)	10 (10.9%)	16 (7.1%)
Professional/associate	19 (14.2%)	12 (13%)	31 (13.7%)
Clerical/sales/service	109 (81.3%)	70 (76.1%)	179 (79.2%)
Current smoker	25 (18.7%)	17 (18.5%)	42 (18.6%)
BMI, $kg \cdot m^{-2}$	28.61 ± 6.46	28.61 ± 5.48	28.61 ± 6.08
Lower back problems[b]			
No	45 (33.6%)	28 (30.4%)	73 (32.3%)
Yes, does not affect activity	64 (47.8%)	49 (53.3%)	113 (50%)
Yes, affects activity	25 (18.7%)	15 (16.3%)	40 (17.7%)
Upper extremity problems[b]			
No	21 (15.7%)	15 (16.3%)	36 (15.9%)
Yes, does not affect activity	81 (60.5%)	63 (68.5%)	144 (63.7%)
Yes, affects activity	32 (23.9%)	14 (15.2%)	46 (20.4%)
Lower extremity problems [b]			
No	39 (29.1%)	30 (32.6%)	69 (30.5%)
Yes, does not affect activity	72 (53.7%)	46 (50%)	118 (52.2%)
Yes, affects activity	23 (17.2%)	16 (17.4%)	39 (17.3%)
Activity outcomes			
Workplace			
Sitting, minutes per 8-h	381.1 ± 49.0	374.3 ± 39.9	378.3 ± 45.6
Standing, minutes per 8-h	67.8 ± 44.1	70.1 ± 31.8	68.7 ± 39.5
Stepping, minutes per 8-h	31.1 ± 13.8	35.6 ± 13.8	32.9 ± 14.0
Sitting in ≥30 min bouts, minutes per 8-h	206.7 ± 95.5	195.9 ± 89.8	202.3 ± 93.4
Usual sitting bout duration, min	33.2 ± 14.9	31.8 ± 14.5	32.6 ± 14.8
Overall			
Sitting, minutes per 16-h day	625.2 ± 90	614.1 ± 64.4	620.6 ± 80.7
Standing, minutes per 16-h day	234.6 ± 74.7	237.9 ± 48.6	235.9 ± 65.3
Stepping, minutes per 16-h day	100.3 ± 31.1	108 ± 26.2	103.4 ± 29.4

Table presents n (%) or mean ± SD, with linearized variance estimation.
[a]All n = 136 intervention, n = 95 controls (age and gender); n = 134 intervention, n = 92 controls (other questionnaire data); n = 135 intervention, 94 controls (activity data).
[b]Problems in the lower back, upper extremities (neck, shoulders, elbows, and wrists/hands) and lower extremities (hips, knees, ankles) were assessed over the "last 3 months" before baseline and were classed as no/yes/affects activity. No = no problem in last 3 months. Yes = problem in last 3 months but that does not interfere with daily activities. Affects activity = problem present that interferes with performing regular activities.

(79.2% as clerical, service or sales) was comparable with the broader DHS employee population. Nationally, the majority of DHS staff are female (72%), employed full time (70%), and in the age brackets of 35 to <45 yr (30%) or 45 to <55 yr (29%). In Victoria, 71% of DHS staff are employed in Australian public service bands 3 and 4 (general administrative and service positions) (2). Most participants (n = 163, 70.6%) had a BMI in the overweight or obese categories (≥25 $kg \cdot m^{-2}$). On average, most work time was spent sitting (78.8% ± 9.5%; 53% of which was accrued in prolonged bouts), with limited time spent standing (14.3% ± 8.2%) or stepping (6.9% ± 2.9%). The corresponding values for all waking hours were 64.6% ± 8.4%, 24.6% ± 6.8%, and 10.8% ± 3.1%, respectively. Further details of participant characteristics by worksite are provided elsewhere (13).

The intracluster correlations (ρ) in baseline values of the outcomes are shown in Supplement Digital Content 3 (Table, Supplemental Digital Content 3, ICCs for worksite clustering at baseline, http://links.lww.com/MSS/A702). Here, ρ ranged from 0.021 (95% confidence interval [CI] = <0.001–0.580) for sitting per 16-h day to 0.265 (0.116–0.497) for MVPA stepping per 8 h-workday, with a mean of 0.151 (specifically, 0.181 for the workplace activity outcomes and 0.090 for the activities per 16-h waking day). There was no significant difference between intervention and control groups in missing data from loss to follow-up, skipped assessments, and/or missing items (Table, Supplemental Digital Content 2, odds of missing data, http://links.lww.com/MSS/A701). During the 12-month intervention, 31 participants (13.4%) formally withdrew from the study (no intervention and no assessment) or were otherwise lost to follow-up (n = 16, 16.8% controls, and n = 15, 11.0% intervention) and 11 became ineligible (n = 4, 4.2% controls, n = 7, 5.1% intervention; Fig. 1). Data on changes in workplace sitting (primary outcome) were obtained from 121 intervention and 87 control participants (89.0% vs 91.6%, P = 0.656) in all 14 worksites (7–32 per intervention site and 5–32 per control site) at the 3-month follow-up, and from 97 intervention and 70 control participants (71.3% vs 73.7%, P = 0.766) in all 14 worksites (5–27 per intervention site and 2–23 per control site) at the 12-month follow-up.

Intervention Implementation

All worksites completed the initial (feedback and brainstorming) consultation, and all team champions complied with the tailored e-mail protocol (6/6 e-mails sent). All intervention participants (n = 136) received their face-to-face

coaching session and the associated e-mail from the health coach and at least one telephone health coaching call with 77 participants (57%) receiving all four calls (41 received three calls, 12 received two calls, and 4 received one call). The median (min, max) duration was 35 (25, 45) min for the face-to-face coaching session (n = 136 sessions) and 8 (5, 12) min for the telephone coaching calls (n = 459 calls).

Activity Outcomes

Table 2 shows the results for changes within groups and for differences between intervention and control groups (intervention effects) for the activity outcomes, adjusted for baseline values and confounders. Significant intervention effects, favoring the intervention group, at one or both of the follow-up assessments, were observed for all of the activity outcomes except for stepping, light stepping, and MVPA stepping (Table, Supplemental Digital Content 4, light and MVPA stepping, http://links.lww.com/MSS/A703) for which no significant or meaningful intervention effects were observed. The intervention effects for sitting and standing, respectively, showed that the intervention group sat less and stood more than controls (all $P < 0.001$) by a large amount at the workplace, both at 3 months (−99.1 and +95.2 min per 8-h day) and 12 months (−45.4 and +42.8 min per 8-h day), and overall across the waking day at both 3 months (−77.7 and +75.8 min per 16-h day) and 12 months (−36.3 and +41.1 min per 16-h day). At 3 months, participants sat for significantly shorter periods at a time than controls at work (−4.4 min), with the amount of prolonged sitting time at work being also lower (−72.6 min per 8-h day). All of the significant intervention effects occurred through significant intervention group improvements that exceeded any control changes.

All of the significant intervention effects were also stronger at 3 months than at 12 months (all $P < 0.001$). Mostly, significant intervention effects were seen for both initial and long-term outcomes. The exceptions were prolonged sitting time and usual bout duration, for which only significant short-term intervention effects were seen. Here, although these outcomes remained improved over baseline within intervention participants, they also improved within controls between baseline and the 12-month assessment.

Substantial workplace variation was observed in baseline workplace sitting (ICC = 0.201, 95% CI = 0.075–0.438, $P <$ 0.001). At 3 months, workplace variation (after adjusting for randomization condition, baseline values, and confounders) was nonsignificant (P = 0.374), weak (ρ = 0.010, 95% CI = <0.001–0.899), and estimated with a wide margin of error. The BLUP showed <5 min per 8-h day differences for each worksite from the average (Fig. 2). Workplace variation for long-term change was significant (P = 0.006) and strong (ρ = 0.175, 95% CI = 0.048–0.468). Accounting for randomization condition, baseline values, and confounders, two sites (both receiving the intervention) differed significantly from the average, with one site doing significantly better (−62.0, 95% CI = −110.7 to −13.4; site M) and one significantly worse (43.6, 95% CI = 1.4–85.8 min per 8-h, site K) than average.

Sensitivity analyses. The conclusions concerning intervention effects for the activity outcomes were unchanged

TABLE 2. Intervention effects (intervention–control) on changes from baseline in activity outcomes at the workplace and overall, adjusting for baseline values of the outcome and confounders (completers analysis).[a]

		Intervention (n = 136)		Control (n = 95)		Intervention–Control		P
Outcome	**Time**	n	**Adjusted Mean Change (95% CI)[b]**	n	**Adjusted Mean Change (95% CI)[b]**	**Difference (95% CI)[c]**	P	**3 M v12M**
Workplace								
Sitting[d], minutes per 8 h	3 M	117	−107.8 (−122.5 to −93.2)***	84	−8.8 (−17.6 to 0.0)^	**−99.1 (−116.3 to −81.8)**	**<0.001**	**<0.001**
Baseline = 387.3	12 M	96	−58.3 (−72.9 to −43.7)***	65	−13.0 (−25.3 to −0.63)*	**−45.4 (−64.6 to −26.2)**	**<0.001**	
Standing[d], minutes per 8 h	3 M	119	102.2 (88.5 to 115.9)***	85	7.0 (0.3 to 13.7)*	**95.2 (79.8 to 110.5)**	**<0.001**	**<0.001**
Baseline = 59.6	12 M	97	55.2 (41.7 to 68.8)***	67	12.4 (2.2 to 22.7)*	**42.8 (25.8 to 59.8)**	**<0.001**	
Stepping[d], minutes per 8 h	3 M	117	2.2 (−0.8 to 5.2)	83	1.7 (−1.4 to 4.9)	0.5 (−3.9 to 4.9)	0.829	0.674
Baseline = 30.3	12 M	96	−0.3 (−3.3 to 2.7)	65	−0.1 (−3.5 to 3.3)	−0.2 (−4.8 to 4.3)	0.926	
Sitting accumulation								
Sitting ≥30 min bouts, minutes per 8 h	3 M	117	−88.8 (−102.5 to −75.0)***	84	−16.2 (−32.2 to −0.1)*	**−72.6 (−93.8 to −51.4)**	**<0.001**	**<0.001**
Baseline = 204.2	12 M	96	−50.1 (−68.1 to −32.1)***	65	−32.3 (−53.9 to −10.8)**	−17.7 (−45.8 to 10.3)	0.216	
Usual bout duration	3 M	120	−7.4 (−9.2 to −5.6)***	85	−3.0 (−5.1 to −1.0)**	**−4.4 (−7.0 to −1.8)**	**0.001**	**<0.001**
Baseline = 33.0	12 M	96	−3.7 (−6.1 to −1.4)**	67	−5.5 (−8.2 to −2.8)***	1.7 (−1.8 to 5.3)	0.329	
Overall								
Sitting, minutes per 16 h	3 M	119	−77.9 (−92.5 to −63.3)***	83	−0.2 (−17.3 to 16.9)	**−77.7 (−100.3 to −55.2)**	**<0.001**	**<0.001**
Baseline = 617.8	12 M	97	−40.1 (−56.9 to −23.2)***	65	−3.8 (−23.9 to 16.4)	**−36.3 (−62.6 to −10.0)**	**0.007**	
Standing, minutes per 16 h	3 M	119	75.5 (63.6 to 87.4)***	83	−0.3 (−14.5 to 13.9)	**75.8 (57.1 to 94.6)**	**<0.001**	**<0.001**
Baseline = 238.1	12 M	97	46.1 (31.7 to 60.4)***	65	4.9 (−12.5 to 22.4)	**41.1 (18.3 to 63.9)**	**<0.001**	
Stepping, minutes per 16 h	3 M	121	1.5 (−3.7 to 6.8)	86	0.6 (−5.3 to 6.4)	1.0 (−6.9 to 8.8)	0.810	**0.042**
Baseline = 103.9	12 M	98	−6.6 (−12.0 to −1.1)*	67	−0.6 (−6.7 to 5.5)	−6.0 (−14.2 to 2.2)	0.154	

Bolded text indicates a statistically significant ($P < 0.05$) intervention effect.
^$P < 0.1$ (change from baseline).
*$P < 0.05$ change from baseline.
**$P < 0.01$ change from baseline.
***$P < 0.001$ change from baseline.
[a]All adjusted means are estimated from marginal means, with baseline values of the outcome and all confounders set to the overall mean, with the means backtransformed to original units for transformed outcomes.
[b]Changes are estimated from marginal means for predicted mean – mean baseline value; differences between groups are estimated from marginal means at 3 months and 12 months.
[c]Estimated from pairwise comparisons and contrasts of marginal means at mean values of baseline levels and all covariates (at 3 months and at 12 months).
[d]Outcome modeled as log of outcome or as log of 480 for sitting; results in tables are presented back-transformed to original unit.

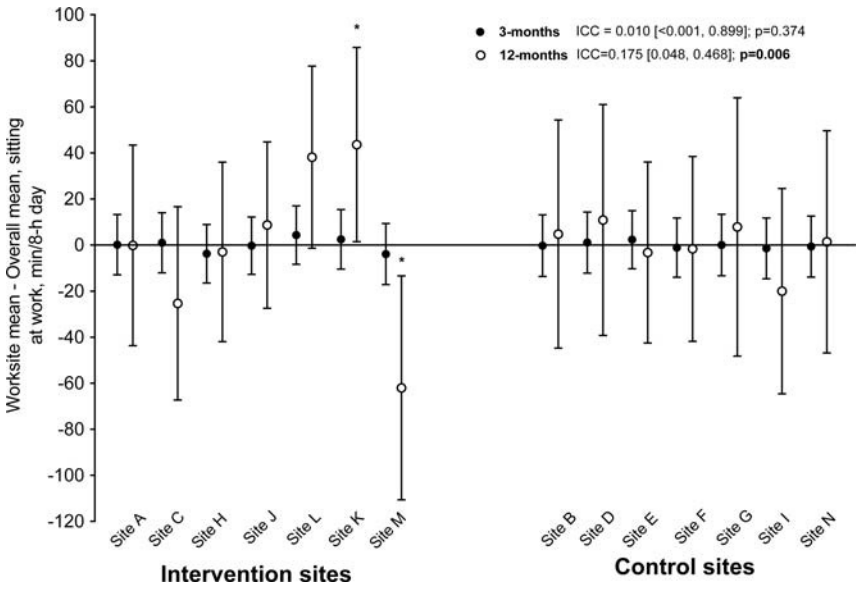

FIGURE 2—Worksite variation in short- and long- term changes in workplace sitting at intervention and control sites, adjusted for baseline values, randomization condition, and confounders. Data are BLUP (95% CI) at 3 and 12 months with the order of the site letter (A to N) based on order of unadjusted total sitting time from BLUP at baseline.

in the multiple imputation analyses as per the completers' analyses (Table, Supplemental Digital Content 5, multiple imputation analysis, http://links.lww.com/MSS/A704). The differences between multiple imputation and completers analysis estimates of intervention effects for activity outcomes were all less than 5 min with many (including those for stepping and usual bout duration) less than 1 min.

Adverse Events

Adverse events in the intervention group that may have arisen from study participation are reported in Table 3. A total of 29 intervention participants (21.3%) reported an adverse event across the entire study, either in the questionnaire, as a withdrawal reason, or both. Of the 31 events reported in the questionnaire (from both 3 and 12 months), 26 were related to musculoskeletal problems in the upper body (n = 16), back/lower back/bottom (n = 4), or lower limb (n = 6). Of the 23 participants who withdrew from the study, or from the sit–stand intervention component of the study (i.e., they asked for the workstation to be removed), 11 (48%) did so because of an adverse event they attributed to study participation (all musculoskeletal related). A plausible mechanism for some of the adverse musculoskeletal events is via prolonged static standing (37). Intervention group participants accumulated half of their workplace standing

TABLE 3. Adverse events related to study participation reported by the intervention group.

Time	Intervention Participants	Participants with Adverse Events	Specific Adverse Event Reported in Questionnaire	Treatment Sought for Adverse Event	Withdrew Due to an Adverse Event[a]
Baseline to 12 months	n = 136 (baseline)	All: 29 (21.3%)	31 events reported in questionnaire • Upper body: neck/shoulder/arm (11), wrist (4) • Back/lower-back/bottom (4) • Lower limb: leg/knee/thigh (4), ankle (1), varicose vein (1) • Other: headache (1), eye strain/sore eyes (3), stress/tiredness (1).	76 visits to health provider	From study: 5 From intervention receipt only: 6
Baseline to 3 months	n = 136 (baseline)	All: 12 (8.8%) Questionnaire: 114 No, 7 Yes (5.8% of responses)	13 events (from 7 participants) reported in questionnaire • Upper body: neck/shoulder (6), wrist (2) • Lower-back/bottom (2) • Lower limb: thigh (2), ankle (1)	Questionnaire: 117 No, 6 Yes (5.0% of responses) 36 visits to health provider	From study: 1 From intervention receipt only: 4
Three months to 12 months	n = 129 (not already withdrawn from study/lost to follow-up/ineligible)	All: 17 (13.1%) Questionnaire: 82 No, 11 Yes (11.8% of responses)	18 events (from 11 participants) reported in questionnaire • Upper body: neck/shoulder/arm (6), wrist (2) • Back (2) • Lower limb: leg/knee pain (2), varicose vein (1) • Other: eye strain/sore eyes (3), headache (1), stress/tiredness (1)	Questionnaire: 88 No, 13 Yes (13.9% of responses) 40 visits to health provider	From study: 4 From intervention receipt only: 2

[a]Adverse events potentially attributable to the intervention, all of which transpired to be musculoskeletal pain. Withdrawal from intervention receipt only = withdrawal from one or more intervention components while remaining in the study for assessments; in every case, the intervention component the participant did not want to receive was the sit–stand workstation only.

time in bouts longer than a median (minimum, maximum) of 1.4 (0.4, 12.9) min at baseline, 5.5 (0.7, 24.3) min at 3 months, and 3.6 (0.7, 19.3) min at 12 months. Although most standing occurred in short bouts, continuous periods of ≥30 min of standing were seen during the monitoring period in 5.1% (7/136) of intervention participants at baseline, in 48.8% (59/121) at 3 months, and in 29.9% (29/97) at 12 months.

DISCUSSION

The Stand Up Victoria study evaluated a multicomponent intervention incorporating organizational-, environmental-, and individual-level change strategies aimed at reducing workplace sitting time in a cluster-randomized trial of 14 worksites of office workers from the one large organization. Significant reductions in both workplace and overall sitting time, exceeding any control improvements, were observed in both the short term (3 months) and the long term (12 months). These corresponded with approximately equivalent intervention effects for standing time, with small and nonsignificant effects for stepping. These novel findings suggest that a workplace-delivered intervention can elicit relatively large improvements in sitting time over a sustained period. Although issues of compensation and generalization (20) are yet to be examined in detail, we did not observe evidence that reducing sitting time and targeting primarily the workplace led to a detrimental intervention effect for the total time spent in other activities (standing and stepping) because of compensation.

The short-term intervention effect on workplace sitting (>1.5 h per 8-h workday) was comparable in magnitude to previous studies that have evaluated this type of multicomponent intervention (14,24) and with other interventions that have included an activity-permissive workstations component (23). Notably, the individual health coaching component of the intervention ceased after 3 months, as did support from the researcher team to promote organizational-level change via the tailored e-mails. Nevertheless, the long-term intervention effects were still large, at approximately 45 min per 8-h workday or half an hour per 16-h waking day on average. In line with the focus of the intervention, most of the intervention effects on workplace sitting, especially in the short term, occurred through reductions in sitting accrued in prolonged unbroken bouts. Consistent with previous studies that used this type of intervention approach (14,24), sitting was primarily replaced with standing, suggesting that the sit–stand workstations were major contributors to behavior change. The collection of context-specific data, such as through wireless technology, may be of benefit to understand where the changes are happening and which strategies are being implemented.

The effect of this workplace-delivered intervention on overall sitting (both in and out of the workplace setting) was significant, substantial, and compared favorably against interventions that have been conducted outside the workplace setting (1,12). Our intervention targeted all sitting but focused on workplace behaviors primarily; adding further emphasis on settings outside the workplace might increase the reductions in overall sitting over what we achieved. Notably, the control group also improved in several workplace activity outcomes. These may have been random findings (multiple testing), observer effects, and response to the feedback provided, or these may reflect general trends within the workplace. Work teams from different buildings were chosen and randomized, but we cannot be certain there was no interaction between teams or that the intervention messages did not disseminate through the organization. During the intervention, there was also significant media attention on the health risks of too much sitting, globally and particularly in Australia, and sedentary behavior public health guidelines that promote regularly breaking up prolonged sitting have emerged (3).

Adverse events plausibly attributable to the intervention were observed in approximately one-fifth of intervention participants during the 12 months of observation. Nearly all were related to musculoskeletal pain (primarily neck/shoulder pain), and participants attributed these to the use of the sit–stand workstation. Both job tasks and workstation design (retrofitted to the existing desk, up and down movements only) are likely to contribute to the symptoms observed. It may also be that additional training and/or information on workstation use may be required. Some of the other symptoms (lower limb and back) may relate to the manner in which standing was increased in long periods at a time. However, it is worth noting that musculoskeletal complaints were common in the sample: most participants had some form of musculoskeletal problem before the intervention, and many had problems at a level that interfered with their daily activities. The collection of additional data on the level of pain may provide further insights into these symptoms and the extent to which they were exacerbated or relieved by the intervention. Employees, especially those with preexisting musculoskeletal complaints, may need more than instructions on ergonomic positioning of the monitors when given a sit–stand workstation, such as condition-specific advice and instructions in pain-relief exercises.

Strengths of the study, which address several of the limitations noted in previous studies (21,23,35,38), include the cluster randomized controlled design, the evaluation of the short- and long-term effects of the intervention both at the workplace and overall, and the use of high-quality objective measures of the activity outcomes. Although data on long-term change in the primary outcome (workplace sitting) were unavailable for approximately 30% of participants, there was very little evidence of bias, with multiple imputation analyses and completers' analyses showing near identical findings. Evaluating multiple work teams across different sites would offer more generalizable evidence than the single-site studies mostly evaluated to date; however, using multiple sites from one organization helps to control for organizational-level effects. Despite not using probabilistic recruitment methods, participants were fairly characteristic of staff within the organization in terms of age, gender, and full-time status.

However, generalizability to other organizations and workers is limited as there was significant workplace variation, and only work teams and sites from a single organization (with fairly homogenous job tasks) were studied. Many potential confounders were considered, but residual confounding is still possible from unmeasured characteristics. Several key research questions remain to be addressed within this trial, including evaluation of the intervention effect on health outcomes (including cardiometabolic biomarkers), work outcomes (including productivity), when activity changes occurred, intervention acceptability (including qualitative data), cost-effectiveness, mediators and moderators of change (including worksite and team characteristics), and long-term changes on policy and practice within the organization.

In conclusion, these primary outcome findings from the Stand Up Victoria intervention clearly demonstrate that large shifts in sitting time can be achieved with this multicomponent approach, which included strong buy-in from the organization. Critically, the intervention elements, including tailoring, flexibility, and a participatory approach, were designed with consideration for scale-up and wider dissemination. The challenge now is to understand the uptake, implementation, and effectiveness when adapted for this next phase.

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