Associations of device-measured sitting, standing, and stepping time with informal face-to-face interactions at work

Sugiyama, Takemi, Winkler, Elisabeth A. H., LaMontagne, Anthony D., Healy, Genevieve N., Hadgraft, Nyssa T., Dunstan, David W. and Owen, Neville

Journal of Occupational and Environmental Medicine, Publish Ahead of Print

DOI : 10.1097/JOM.0000000000001586

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Running Title: Sitting Time and Face-to-Face Interactions at Work

Authors: Takemi Sugiyama, PhD,[1,2,3] Elisabeth A. H. Winkler, PhD,[4] Anthony D. LaMontagne, PhD,[5,6] Genevieve N. Healy, PhD,[3,4,7] Nyssa Hadgraft, PhD,[2,3] David W. Dunstan, PhD,[1,3,4,8,9,10] Neville Owen, PhD [2,3,4,6]

Affiliations

[1] Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Australia

[2] Centre for Urban Transitions, Swinburne University of Technology, Melbourne, Australia

[3] Baker Heart & Diabetes Institute, Melbourne, Australia

[4] School of Public Health, The University of Queensland, Brisbane, Australia

[5] Centre for Population Health Research, Deakin University, Geelong, Australia

[6] School of Population and Global Health, The University of Melbourne, Victoria, Australia

[7] School of Physiotherapy, Faculty of Health Sciences, Curtin University, Perth, Australia

[8] School of Sport Science, Exercise and Health, University of Western Australia, Perth, Australia

[9] School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia

[10] Faculty of Medicine, Nursing and Health Sciences, Monash University, Melbourne, Australia

Corresponding Author

Takemi Sugiyama, *PhD, MArch*

Mary MacKillop Institute for Health Research, Australian Catholic University

215 Spring Street, Melbourne, Victoria 3000, Australia

Tel: +61 (3) 9230 8262

Email: takemi.sugiyama@acu.edu.au

Conflicts of Interest: Non declared

Author Contributions: TS conceived the idea, developed hypotheses with help from EW, AL and NO, and conducted statistical analyses with help from EW. GH, NH, and DD conducted the SUV study. All authors contributed to the manuscript writing.

Acknowledgements

Stand Up Victoria (SUV) was funded by a National Health and Medical Research Council (NHMRC) Project Grant [#1002706], project funding from the Victorian Health Promotion Foundation's Creating Healthy Workplaces Program, and the Victorian Government's Operational Infrastructure Support Program. Healy was supported by an NHMRC Career Development Fellowship [#1086029]. Hadgraft was supported by an Australian Government Research Training Program Scholarship and a Baker Institute Bright Sparks top up scholarship. Dunstan was supported by an NHMRC Senior Research Fellowship [#1078360] and the Victorian Government's Operational Infrastructure Support Program. Owen was supported by an NHMRC Program Grant [#569940], a Senior Principal Research Fellowship [#1003960], and the Victorian Government's Operational Infrastructure Support Program.

We acknowledge and thank Dr. Brianna Fjeldsoe for her contribution to SUV questionnaire development, and the following project staff: Glen Wiesner, Lisa Willenberg, Mary Sandilands, Kirsten Marks, Cameron Johnson, Bethany Howard, Stephanie Fletcher, and Michael Wheeler. We also acknowledge the assistance of the Australian Government Department of Human Services liaison officers Sevasti Athiniotis and Valerie McRorie.

ABSTRACT

Objective: This cross-sectional study examined the interrelationships between workplace movement (sitting, standing, and stepping), availability of discussion space, and face-to-face (FTF) interactions between workers.

Methods: Desk-based workers (n=221) wore an activity monitor for seven days and self-reported their weekly frequency of FTF interactions and discussion space availability. Negative binomial regression models examined behavioral and spatial factors associated with the frequency of FTF interactions.

Results: Adjusted for potential confounders, each one SD increment in time spent sitting, standing, stepping, and discussion space availability was associated with 20% lower (p=0.004), 19% higher (p=0.003), 6% higher (p=0.16), and 11% higher (p=0.26) frequency of FTF interactions, respectively

Conclusions: Lower workplace sitting was often linked to reduced risk of chronic diseases. Our findings suggest that less sitting at work may have additional benefits of increasing informal interactions between office workers.

Keywords: sedentary behavior; social interaction; office spaces

Knowledge sharing in the workplace is increasingly important, with changes in technology and increasing levels of job specialization.[1] Face-to-face (FTF) interactions, which involve communication between individuals co-present in the same physical space, are recognized to be a valuable element in contemporary knowledge-based workplaces.[2] FTF interactions at work are considered to be efficient for sharing "tacit" knowledge, which cannot be easily codified (unlike "explicit" knowledge that can be standardized and shared in written documents) yet can enhance group's competence.[3] Tacit knowledge, which is based on individual's experience, provides insights, schemata, and skills that are helpful in performing a work task.[3] Socialization is a key step to share tacit knowledge and transfer it into explicit knowledge.[4] Research has shown multiple productivity-related benefits of FTF interactions. For instance, the frequency of such interactions between team members is associated with the quality of the team's output.[5] Research examining more than 500 workplaces in the U.K. found that teams in which FTF interactions were prioritized recorded higher productivity levels (measured as sales value added per employee) than did those without such priorities.[6] The recent phenomenon of coworking, where those from different disciplines share workspace, aims to encourage "collision" between workers to accelerate knowledge sharing.[2]

Informal FTF interactions, which can happen outside formal settings (e.g., scheduled meetings), may provide additional benefits for social and mental wellbeing at work. For instance, more frequent FTF interactions have been found to be associated with improved mood states,[7] higher levels of trust between team members,[5] and a better chance of receiving support from colleagues.[8] By contrast, digital communication could be a source of stress, as it is asychronous and can involve normative pressure to react.[9] A recent study found that office workers tended to associate digital communication as a source of demand, involving the need to cope with its increasing volume and expectations of being responsive.[10] Social contact and support at work can be protective against the impact of job stress,[11,12] while social support has

a strong positive relationship with workplace mental well-being.[13] As occupational mental health is recognized as a global concern,[14,15] informal FTF interactions at work may play an important role in mitigating the impact of job stress and promoting positive mental health.

Co-location or coworking is considered as as a typical strategy to increase informal FTF interactions. However, sitting and movement patterns at work may be also relevant to levels of FTF interactions with colleagues. For example, co-location may not promote FTF interactions if workers are deskbound for prolonged periods. Desk-based workers can spend, on average, 70–80% of working hours sitting.[16,17] It has been also shown that sitting at work can frequently be accrued through prolonged, unbroken bouts,[18,19] which may be a barrier to FTF interactions. Regular breaks from prolonged sitting may facilitate more frequent FTF interactions. Although recent studies have shown associations of lower sitting time with work-related outcomes (work engagement, vitality, and efficiency),[20,21] no research appears to have examined associations of workplace movement-related behaviors (sitting, standing, and walking) with informal FTF interactions.

Informal FTF interactions may also be influenced by office spatial layout. It can be argued that having more suitable places for informal conversation may facilitate more FTF interactions. There are a few studies examining the link between office spatial design and FTF interactions. One study examined associations of overall office layouts (how spaces are connected to each other) with FTF interactions and found no clear relationships.[22] A more recent study has shown that visibility and proximity between work spaces are related to the frequency of unplanned FTF meetings.[23] In addition, it is possible that less sitting and more movement may be more conducive to having a conversation with colleagues if the workplace has adequate space for informal discussion. In other words, associations of workplace

movement with FTF interactions may be more pronounced in workplaces with sufficient/suitable space for informal interactions. However, research does not seem to have investigated the roles of discussion space in workers' FTF interactions.

To address these evidence gaps, this study examined the interrelationships between workplace movement, interactions, and spatial factors, as depicted in Figure 1. Specifically, the following three hypotheses, which correspond to paths *a*, *b*, and *c* in Figure 1, were tested.

Hypothesis 1: Workplace movement (i.e., sitting, standing, and stepping) will be associated with the frequency of informal FTF interactions. We expect those with less sitting and more standing and stepping will have more frequent interactions than their counterparts (path *a*).

Hypothesis 2: Availability of space for informal discussion will be associated with the frequency informal FTF interactions. We expect those with sufficient space for informal discussion will have more frequent interactions than those with insufficient space (path *b*).

Hypothesis 3: The relationships between workplace movement and informal FTF interactions (as per Hypothesis 1) will be modified by availability of informal discussion space. We expect the relationships will be more pronounced among those with sufficient space for informal discussion than those with insufficient space (path *c*).

METHODS

Data Source and Participants

This cross-sectional study used baseline data collected within the Stand Up Victoria (SUV) study, a cluster randomized controlled trial of a multicomponent workplace intervention that successfully achieved its primary aim of reducing sitting time at work.[24,25] SUV recruited 14 geographically separate offices (worksites) from a single government department in Victoria, Australia between April 2012 and October 2013. One work team, a distinct group with

dedicated team leader(s), was recruited per worksite. Eligibility criteria for participation were: aged 18 to 65 years, English-speaking, working at least 0.6 full time equivalent, and having designated desk, telephone, and internet. Of the 278 participants who originally expressed interest, 33 were ineligible and 14 were no longer eligible or were unwilling to participate at the intervention commencement, leaving 231 participants. Ethics approval was granted by the Alfred Health Human Ethics Committee (Melbourne, Australia).

Data Collection

The current study reports on baseline data, collected before the intervention commenced. No participants had access to height-adjustable workstations at that time. Trained staff provided participants with instructions, activity monitors, and logbooks. Thereafter, participants completed a self-administered online questionnaire, containing questions relating to demographic, organizational, work, and health characteristics.

Measures and Instruments

Workplace interactions. A single-item measure, not previously validated, assessed the frequency of informal FTF interactions at work. Participants were asked to report the number of times in the last week they interacted with colleagues in "ad hoc meeting/conversation, not necessarily related to work, taking place away from desk". Since no survey questionnaire aiming to identify the frequency of interactions at work appeared to exist, a new set of questions was produced using the format of a physical activity questionnaire in which the frequency and duration are asked.[26] We used the frequency measure only due to potential misunderstanding of the duration item by some participants. For the nine participants who reported more than 35 FTF interactions per week (equivalent to having more than one FTF interaction per workhour), their frequency of interactions was truncated at 35 times/week.

Workplace movement. The primary exposure variables of this study were movement-related behaviors at work —time spent sitting, standing, and stepping— as measured via the activPAL3 activity monitor (PAL Technologies Limited, Glasgow, UK). The monitor provides highly accurate measures of these behaviors based on the wearer's posture and movement.[27] Full details regarding the protocol and data reduction have been reported.[28] Briefly, participants were asked to wear the monitor 24 hours per day for seven consecutive days, with the monitor waterproofed and attached in the standard wear position (the anterior mid-line of the right thigh) using hypoallergenic adhesive material. They were also asked to complete a paper-based log of their work times and locations (workplace/elsewhere), sleep/wake times, and monitor removal times. Activities were summarized during self-reported work hours (not excluding breaks) at the workplace. Time in which the monitor was not worn or the participant was asleep was excluded (ascertained via a combination of movement and the self-report data) along with invalid days (device worn for <80% of work hours). In addition to time spent sitting, standing, and stepping, the number of transitions from sitting to upright (including standing and stepping) was examined. Sitting time can be accrued either with shorter frequent bouts or with longer uninterrupted bouts. It was therefore further postulated that those with more sit-upright transitions will have more informal FTF interactions than those with less transitions.

Workplace discussion space. The secondary exposure variable was availability of space for informal discussion. This was also used as a potential moderator of the associations of FTF interactions with workplace movement. We used participants' response to the following statement: "There is a sufficient amount of space for informal discussion in my workplace (e.g., lounge, printer/copier areas, kitchen, tea room)". The response option ranged from 1 (strongly disagree) to 5 (strongly agree). This item was developed based on the Workplace Collaborative Environment Questionnaire, a survey instrument aiming to assess the perceived

availability and quality of the workplace environment that support collaboration.[29]

Individual- and worksite-level characteristics. The individual-level characteristics were collected via self-report: age; gender; education; occupational category; ethnicity; tenure at the workplace; and smoking at work. The worksite characteristics reported by the team leader were: workplace size (small: ≤ 50 workers, large: > 50 workers) and predominant work type (phone-based; non-phone-based; mixed).

Statistical Analyses

Data were analyzed in Stata 14 (StataCorp LP, College Station, TX). In view of the multilevel design, mixed models were used, with a random intercept for worksite. Since the outcome was a count variable (frequency of FTF interactions), a negative binomial distribution (and log link) was assumed. All models adjusted for total work time, as workplace interactions and sitting time are directly related to how long participants worked. To assess Hypotheses 1 and 2, three models were fitted for each exposure variable. In Model 1, each movement variable and spatial factor was examined separately, adjusting only for work time. Model 2 further adjusted for potential confounders (age, gender, education, job category, and smoking at work). The other individual- and worksite-level characteristics (ethnicity, tenure at work, workplace size, and predominant work type) were not adjusted because they did not meet the entry criteria of bivariate association of $p < 0.2$ with FTF interactions. Model 3 further adjusted for the availability of space for informal discussion, to investigate to what extent the space availability accounts for the association of workplace movement with FTF interactions. To assess Hypothesis 3 concerning effect modification, the interaction of each workplace movement variable with the spatial factor was examined (both continuous), adjusting for total work time and the covariates used in Model 2. The significance level was set at $p < 0.05$ (two-tailed). Complete case analysis was used.

RESULTS

After excluding those lacking data on the outcome, exposures, or covariates (*n*=10, 4.3%), 221 participants were retained for analysis. Table 1 shows the characteristics of study participants. The majority of participants were women and undertook clerical work. On average, participants spent 8.5 h/workday at the workplace, of which almost 80% (6.7 h) was spent sitting. The median frequency of informal FTF interactions was 5 times/week (25th–75th percentile: 2–10). Correlation coefficients between movement variables were -0.58 between sitting and standing, -0.25 between sitting and stepping, and 0.31 between standing and stepping (all at $p < 0.001$). The median number of participants for the 14 participating worksites was 16 (range: 5 to 34). Nine of them were small (≤ 50 workers) and 5 were large (> 50) in size. In terms of predominant work type, four of them were categorized as phone-based, seven were not-phone-based, and three were mixed.

Table 2 shows the associations of workplace movement and spatial factor with weekly frequency of FTF interactions. The results partially supported Hypothesis 1. Spending more time sitting at work was significantly associated with fewer informal FTF interactions, with 20% fewer interactions per week for each additional hour per day spent sitting (Model 1). This remained significant after adjustment for potential confounders in Models 2 and 3. Conversely, greater standing time at work was associated with more FTF interactions in all models, with each additional hour per day of standing being associated with around 30% more interactions. Stepping time was significantly associated with the outcome in Model 1, where one additional hour of stepping was associated with almost 50% more interactions. But, the association became non-significant after adjustment. The number of transitions from sitting to upright was associated with FTF interactions in Model 2 (marginally associated in Models 1 and 3), with about 10% more FTF interactions per 10 daily transitions. When the exposure measures were standardized, one SD increment in sitting and standing time had a

similar effect size, about 20% less and 20% more FTF interactions, respectively. The effect size for stepping was 10% for Model 1, but it was halved after adjustment. The effect size for transitions was constant in all models: one SD increment was associated with 13% more interactions. The results did not support Hypothesis 2 for the spatial factor, with no significant association between the spatial factor and FTF interactions. However, the test was somewhat inconclusive. The estimated effect size was 7–11% more FTF interactions per one-unit (and per one SD) increment, with confidence intervals that contained potentially substantial effect sizes (-8 to 35% per unit or SD increment in Model 2).

As shown in Table 3, the results did not support Hypothesis 3. None of the interaction terms between availability of discussion space and workplace movement were statistically significant. The effect sizes indicated almost no modification of associations of sitting time and transitions with FTF interactions by space availability.

DISCUSSION

This study examined the interrelations of workplace sitting, standing, and stepping (measured by activity monitors), availability of space for informal discussion, and weekly frequency of informal FTF interactions at work. Supporting Hypothesis 1, our results showed that FTF interactions were more frequent among those who sat less and stood more than their counterparts. A similar but weaker association was found for those who transitioned postures more frequently than their counterparts, while no significant association was seen in workplace stepping time. The associations observed were independent of potential confounders and the perceived availability of space for informal discussion. Lower amounts of sitting time are known to be associated with lower risk of major chronic diseases such as type 2 diabetes, cardiovascular disease, and musculoskeletal disorders.[30,31] It is possible that lower levels of sitting at work may not only confer health benefits to workers but also

increase informal interactions with colleagues, which may benefit their mental health (through mitigating work stress) and potentially enhance their productivity (through facilitating knowledge sharing). However, the reverse interpretation is also plausible: FTF interactions, which tend to be performed in a standing rather than sitting posture, impact workplace movement. Although it can be argued that moving around in an office can increase the chance of encountering a colleague, future experimental studies are needed to examine causal relationships.

The findings did not support Hypotheses 2 and 3. A lack of variability in the spatial factor may be a reason for the findings, especially since the large majority of participants had agreed that space provision was sufficient. All worksites were from a single government organization and may have been quite homogenous both in terms of spatial arrangement and cultural norms regarding when and where informal discussion is acceptable. Another possible explanation for the inconclusive findings on space availability is that informal interactions may take place in smaller spaces (such as those along the corridor, around the printer, or near the cabinet), even if these spaces may not fit participants' idea of an "adequate" space for informal interactions. Measurement error is also a possibility: the FTF interaction frequency and space availability were measured by self-report, with an unknown degree of reliability and validity.

Previous studies examining spatial factors relevant to interactions at work focused more on spatial relationships between workers or workspaces.[22,23] However, providing a space for informal discussion may be a feasible way to encourage social interactions at work. A recent study found that the availability of sufficient space for informal discussion was associated with lower levels of sitting in a subgroup who reported more-supportive organizational norms,[32] suggesting the relevance of such a space to worker's movement behaviors. It is thus important to identify characteristics of space where workers are more likely to gather and

engage in conversation. To better assess the possible role of space for informal discussion in FTF interactions, future research should investigate offices with diverse spatial characteristics, ideally using objective measures of space and interactions.

A strength of the study was the use of activity monitors to measure participants' workplace movement behaviors. Limitations included the cross-sectional design, which limited inferences about causal direction, a smaller than desirable sample size (the study was not powered a priori on these questions), and the generalizability of the findings (participants recruited from a single government department). The use of non-validated self-report measures for FTF interactions was another limitation. Contemporary wearable devices may be used to assess how often people engage in interaction, albeit with some limitations to what is defined as an interaction. For instance, Bluetooth technology has been used as a proximity sensor to identify colocation of workers or to detect wearer's location within an office setting.[33,34] An RFID (radio frequency identification) system, which captures unique information stored in a tag when it is within a certain proximity of a reader, has also been used to identify FTF interactions.[35] Collecting speech data along with proximity may help better gauge the nature of interactions taking place.[36] Another level of information that can contribute to research on this topic is where people interact at the workplace. No research appears to have investigated the locations of FTF interactions at work. However, identifying the characteristics of places where people engage in conversation will be informative for office designers and facility managers in designing and modifying office space layout. Proximity sensors may be employed in future research to locate where people interact in the workplace.

In conclusion, this study expands upon the health-related rationales supporting efforts to reduce sitting at work. Sitting has been mainly captured as health risk, and lower levels of sitting at work are encouraged to reduce risk of developing chronic diseases.[37] In the context

of knowledge-based work, our cross-sectional evidence showed some promise that less sitting may increase workers' FTF interactions, which may have positive implications for their mental health and productivity, thereby potentially benefitting not only employees but also employers. Future workplace trials examining the prospective impact of sitting reduction on workers' interactions and other work-related indicators (e.g., job satisfaction, stress from work, mental health) would assist in better assessing potential business case for reducing sitting at work.

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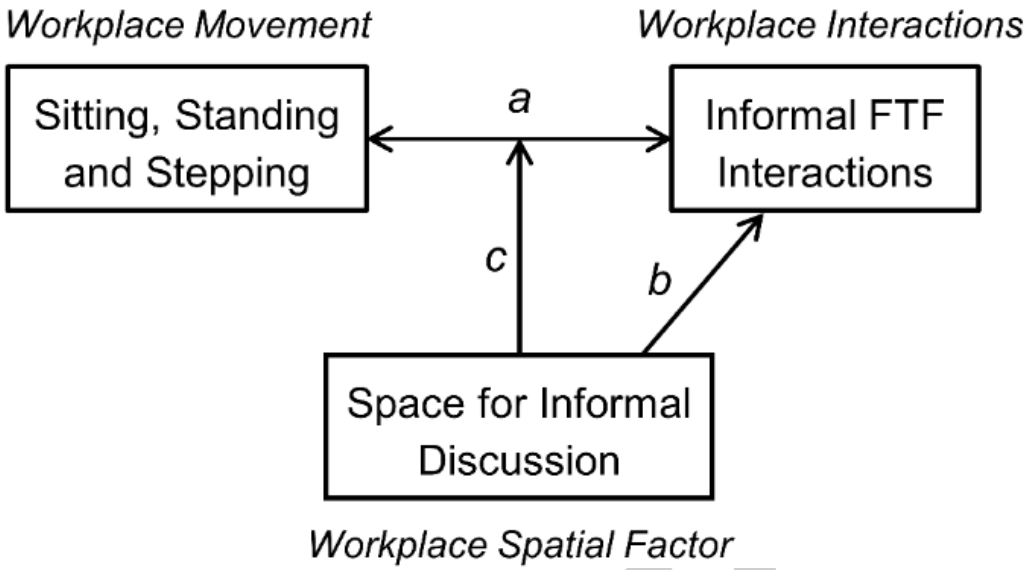
FIGURE CAPTION

Figure 1. Hypothesized relationships examined in the study



TABLES

Table 1. Characteristics of study participants (N = 221)

	Mean ± SD, n (%)
Gender, women	151 (68%)
Age, years	45.5 ± 9.4
Education	
High school or less	73 (33%)
Vocational	62 (28%)
Bachelor's degree or higher	86 (39%)
Occupational category	
Managerial	16 (7%)
Professional	31 (14%)
Clerical	174 (79%)
Ethnicity, Caucasian	177 (80%)
Tenure at work, >5 years	166 (75%)
Smoking at work, yes	30 (14%)
Weekly frequency of FTF interactions	8.8 ± 9.6
Workplace movement	
Time at workplace, min/workday	510 ± 56
Total sitting, min/workday	402 ± 67
Standing, min/workday	73 ± 43
Stepping, min/workday	35 ± 15
Transitions [a], n/workday	29 ± 12
Availability of space for informal discussion [b]	3.8 ± 1.0

[a] Count of posture change from sitting to upright (including standing and stepping)

[b] Scores range from 1 to 5 with higher scores indicating higher perceived availability of space for informal discussion.

Table 2. Associations of workplace movement and spatial factor with weekly frequency of informal FTF interactions (N=221)

Exposure	Unit	Model 1		Model 2		Model 3	
		RR (95% CI)	*p*	RR (95% CI)	*p*	RR (95% CI)	*p*
Workplace movement							
Sitting	1 h/workday	0.80 (0.73, 0.89)	<0.001	0.82 (0.72, 0.94)	0.004	0.81 (0.72, 0.92)	0.001
	1 SD	0.78 (0.70, 0.88)		0.80 (0.69, 0.93)		0.79 (0.70, 0.91)	
Standing	1 h/workday	1.29 (1.15, 1.45)	<0.001	1.28 (1.09, 1.51)	0.003	1.31 (1.13, 1.52)	<0.001
	1 SD	1.20 (1.11, 1.31)		1.19 (1.06, 1.34)		1.21 (1.09, 1.35)	
Stepping	1 h/workday	1.47 (1.05, 2.04)	0.023	1.26 (0.91, 1.73)	0.163	1.21 (0.90, 1.62)	0.212
	1 SD	1.10 (1.01, 1.20)		1.06 (0.98, 1.15)		1.05 (0.97, 1.13)	
Transitions	10 times/workday	1.11 (0.99, 1.25)	0.064	1.12 (1.00, 1.24)	0.042	1.11 (1.00, 1.24)	0.050
	1 SD	1.13 (0.99, 1.29)		1.13 (1.00, 1.28)		1.13 (1.00, 1.28)	
Availability of space for informal discussion [a]	1 unit/1 SD [b]	1.07 (0.87, 1.33)	0.515	1.11 (0.92, 1.35)	0.262	–	–

[a] Scores range from 1 to 5 with higher scores indicating higher perceived availability of space for informal discussion.

[b] Coefficients for these units were the same as the SD for this variable was 1.0.

RR: Relative Rate (exponentiated regression coefficient from multilevel negative binomial regression)

Model 1: adjusted for total time at work

Model 2: further adjusted for age (years), gender (male; female), education (≤high school; vocational; ≥Bachelor's degree), occupational category (managerial; professional; clerical), and smoking at work (yes; no)

Model 3: further adjusted for the availability of space for informal discussion

Table 3. Statistical interaction of workplace movement with the spatial factor in their associations with weekly frequency of informal FTF interactions

Workplace movement	Unit	Interaction term with the spatial factor: RR (95%CI)	*p*
Sitting	1 h/workday	0.97 (0.88, 1.07)	0.508
Standing	1 h/workday	0.93 (0.78, 1.12)	0.463
Stepping	1 h/workday	1.28 (0.76, 2.13)	0.352
Transitions	10 times/workday	0.98 (0.88, 1.09)	0.671

RR: Relative Rate (exponentiated regression coefficient from multilevel negative binomial regression)

All models adjusted for total time at work, age, gender, education, occupational category, and smoking at work.