Ergonomics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/terg20

Task exposures in an office environment: a comparison of methods

Dwayne Van Eerd [a b], Sheilah Hogg-Johnson [a b c], Anjali Mazumder [a d], Donald Cole [a b], Richard Wells [e] & Anne Moore [f]

[a] Institute for Work & Health, Toronto, Canada

[b] Dalla Lana School of Public Health, University of Toronto, Toronto, Canada

[c] Department of Health Policy, Management and Evaluation, University of Toronto, Toronto, Canada

[d] Department of Statistics, University of Oxford, Oxford, UK

[e] Department of Kinesiology, University of Waterloo, Waterloo, Canada

[f] Department of Kinesiology, York University, Toronto, Canada

Version of record first published: 21 Oct 2010.

To cite this article: Dwayne Van Eerd , Sheilah Hogg-Johnson , Anjali Mazumder , Donald Cole , Richard Wells & Anne Moore (2009): Task exposures in an office environment: a comparison of methods, Ergonomics, 52:10, 1248-1258

To link to this article: http://dx.doi.org/10.1080/00140130903023683

Ergonomics
Vol. 52, No. 10, October 2009, 1248–1258

Taylor & Francis
Taylor & Francis Group

Task exposures in an office environment: a comparison of methods

Dwayne Van Eerd[a,b]*, Sheilah Hogg-Johnson[a,b,c], Anjali Mazumder[a,d], Donald Cole[a,b], Richard Wells[e] and Anne Moore[f]

[a]*Institute for Work & Health, Toronto, Canada;* [b]*Dalla Lana School of Public Health, University of Toronto, Toronto, Canada;* [c]*Department of Health Policy, Management and Evaluation, University of Toronto, Toronto, Canada;* [d]*Department of Statistics, University of Oxford, Oxford, UK;* [e]*Department of Kinesiology, University of Waterloo, Waterloo, Canada;* [f]*Department of Kinesiology, York University, Toronto, Canada*

Task-related factors such as frequency and duration are associated with musculoskeletal disorders in office settings. The primary objective was to compare various task recording methods as measures of exposure in an office workplace. A total of 41 workers from different jobs were recruited from a large urban newspaper (71% female, mean age 41 years SD 9.6). Questionnaire, task diaries, direct observation and video methods were used to record tasks. A common set of task codes was used across methods. Different estimates of task duration, number of tasks and task transitions arose from the different methods. Self-report methods did not consistently result in longer task duration estimates. Methodological issues could explain some of the differences in estimates seen between methods observed. It was concluded that different task recording methods result in different estimates of exposure likely due to different exposure constructs. This work addresses issues of exposure measurement in office environments. It is of relevance to ergonomists/researchers interested in how to best assess the risk of injury among office workers. The paper discusses the trade-offs between precision, accuracy and burden in the collection of computer task-based exposure measures and different underlying constructs captures in each method.

Keywords: ergonomic tools and methods; injury risks; office ergonomics; computer workstations; upper limb disorders

1. Introduction

Musculoskeletal disorders are often associated with physical and psychosocial factors among computer users in office settings. These factors include task duration, repetition or frequency, awkward (or static) postures, monotonous work, work pace and lack of control over aspects of the job (or tasks) performed (Polanyi *et al*. 1997, Punnett and Bergqvist 1997, National Research Council 2001, Village *et al*. 2005, IJmker *et al*. 2007, de Kracker *et al*. 2008). Measuring these factors depends on clear identification and consistent measurement of tasks as key observables relevant to exposures (Wells *et al*. 2004, Dennerlein and Johnson 2006). Computer users in office environments may perform a wide variety of tasks during a workday. Many of these tasks are very similar across various job titles. Conversely, simply determining the amount of time working at a computer or mouse vs. non- computer work may not adequately quantify exposure (Gerr *et al*. 1996). Measuring properties of the tasks performed by computer users in office settings may provide a better understanding of the full range of relevant exposures. For example, Dennerlein and Johnson (2006) reported that different computer tasks have different levels of biomechanical risk.

Different methods have been used to define and record the tasks performed by workers. An inexpensive, relatively low burden method for gathering task information on large numbers of workers has been through self-report questionnaires but this may over-estimate task durations when compared to other measurement methods (Faucett and Rempel 1996, Homan and Armstrong 2003, Mathiassen *et al*. 2003, Balogh *et al*. 2004, Heinrich *et al*. 2004, Lassen *et al*. 2005, Douwes *et al*. 2007, Mikkelsen *et al*. 2007, IJmker *et al*. 2008). In contrast, in a systematic review, Stock *et al*. (2005) demonstrated that worker self-reports of the presence and duration of sitting and standing postures as well as the use and duration of use of visual display terminals can be valid and reliable. Also recently, Barrero *et al*. (2009) reported that subjects consistently underestimated computer use as compared to lifting and filing tasks.

*Corresponding author. Email: dvaneerd@iwh.on.ca

ISSN 0014-0139 print/ISSN 1366-5847 online

DOI: 10.1080/00140130903023683
http://www.informaworld.com

Another self-report method involves participants keeping a diary, completing it at regular intervals (Balogh *et al*. 2004, Unge *et al*. 2005). Extensively used to measure other kinds of exposure either daily (e.g. dietary intake; Witschi 1990) or hourly (e.g. airborne contaminant excursions; Wegman *et al*. 1992), there are, however, potential challenges including cost and the effect upon those observed (including changing work activities and interruptions).

Observation, with or without the use of video recording and playback, is also frequently used in defining tasks at work (Hagberg 1992, Spielholz *et al*. 2001, Homan and Armstrong 2003, David 2005). Directly recording from equipment used in the completion of the tasks is another option, for example, measuring keyboard activity directly from the keyboard (Hansson *et al*. 2001, Homan and Armstrong 2003) or through specially designed software (Mathiassen *et al*. 2003, Blangsted *et al*. 2004, Mikkelsen *et al*. 2007, Douwes *et al*. 2007, IJmker *et al*. 2008). These methods can allow for great precision in task measurement but require consistent technical definitions to differentiate between task completion and breaks and may or may not match with the perception of workers. Direct technical recordings using electromyography, goniometry, inclinometry or motion capture are also possible but these typically cannot distinguish tasks (e.g. Balogh *et al*. 2004, Dennerlein and Johnson 2006).

As part of a larger study among computer users in an office environment (Polanyi *et al*. 1997), the present study sought to better describe office task exposures (Cole *et al*. 2002). The objective in this paper is to describe and compare methods of task recording as measures of exposure in an office setting. Four different methods were used (questionnaire, task diary, direct observation and observation from video recording) and compared across common metrics.

2. Methods

2.1. Worker sample

A total of 41 workers (71% female) were recruited from a large urban newspaper as a sub-sample of workers participating in a larger study (Cole *et al*. 2006). The workers performed clerical, administrative, sales, customer accounts and call centre jobs from advertising, circulation and finance departments. The mean age of the workers was 41 years (SD 9.6). Their mean height and weight were 168 cm (SD 10.3) and 74 kg (SD 19), respectively. All participants provided written informed consent in keeping with approval by the Research Ethics Boards of McMaster University and the University of Waterloo.

2.2. Defining office tasks

Through consultation with workplace parties (union and management), a set of 21 tasks was generated, representing those considered common to office settings (e.g. keyboarding, mousing, phone, deskwork, in meetings, photocopying). Each task was assigned a simple number/letter code. Workers and trained observers started with this list but could add to the list if they felt the existing codes did not represent the tasks performed. Any additional codes were examined and those considered to be adequately represented by the original 21 task codes were reassigned. For example, one worker entered a code for 'keyboarding/mousing', which was reassigned using the original keyboarding and mousing codes (the worker clearly indicated doing both keyboarding and mousing at the same time). Two authors (D.V.E. and S.H.J.) came to consensus on the reassignment of the task codes with input and agreement from the rest of the team. In this manner, a single expanded task list of 32 codes was created to represent the tasks from both the task diary and the direct observation methods (Appendix A).

The expanded list of 32 codes was used to create a shorter list of tasks (Appendix A) for the video observation method. This shorter list of codes was created with input from one of the trained observers, to ensure comparability of codes across methods. The video task code list included a task called 'other' to capture times when workers were clearly not engaged in any of the specific office tasks.

2.3. Data collection

2.3.1. Questionnaire

Design of the questionnaire pre-dated consultation with workplace parties. It included questions on demographics, workstation set-up and the nature of work. The workers were asked whether they performed tasks of keyboarding, mousing or using a phone during a normal working day and how long they spent at each in a normal day. A normal day was considered to be 8 h (480 min) long.

2.3.2. Task diary

The workers used up to 32 codes to record the tasks they performed every 15 min during the course of a workday in a diary. If a single task was performed within a 15 min block, then the single code corresponding to that task was recorded. If two or more tasks were performed sequentially in a block, then the codes recorded for each task were separated

by commas. If two or more tasks were performed concurrently, then the codes were recorded with a plus sign. For example, a recording of 'A + B, C + D' for a block indicated that first A and B were performed simultaneously, then C and D were performed simultaneously within a 15 min period. The task diary was to be completed for three consecutive complete workdays. The self-reported length of a workday varied little among workers across days with means from 469 to 478 min (range 150 to 700 min).

2.3.3. *Direct observation*

Each worker was observed at her/his own workstation for a 2 h period by a trained observer. The observation of the workers was not done at the same time as the self-report task diary, but the observation covered at least one of the same days of the week. It was felt that observing the worker at the same time as task diary reports could influence the self-report behaviour. The observer used the same set of 21 codes to record the tasks performed by a worker every minute of the observation. Sequential and concurrent tasks were recorded by the observer as per the task diaries. Observers added tasks if they felt that the list did not represent what a worker was doing, resulting in the same set of 32 codes as for the task diary. The direct observation was to cover 2 h of the workday on two workdays. The mean direct observation recording time reflected somewhat less than 2 h with means of 113 to 114 min (range 64 to 138 min).

2.3.4. *Video*

A VHS video recording was taken of the worker at her/his own workstation on two workdays. The video was taken at the same time as the direct observation. The video camera with a wide-angle lens was focused on the worker and included the keyboard, mouse, monitor and as much desk space as possible. A 30 min segment of the video recording, maximising worker presence at the workstation, was later coded by a trained analyst, who captured start and stop times for a subset of six video codes. To ensure consistent estimation of task start and stop times the six video codes were explicitly defined with input from one of the trained observers. Task coding was done with Observer Pro 4.0, (Noldus Information Technology, P.O. Box 268, 6700 AG Wageningen, Netherlands), which allowed the analyst to slow down or rewind the video and estimate the task start and end times to the nearest tenth of a second. The video method was to capture 30 min of video, which was accomplished with means of 30 to 31 min (range 22 to 48 min).

2.4. *Data analyses*

Data from the task diary, direct observation and video were entered into spreadsheets and imported into SAS for data preparation and analysis (SAS Institute Inc., Cary, NC, USA). Task duration, number of tasks in an observation period and number of task transitions in an hour were calculated for task diary, direct observation and video methods. The questionnaire data yielded only task durations measures.

Comparisons across all methods were based on the shorter list of video task codes. Comparisons were also made between task diary and direct observation methods using the expanded task list (32 codes) that they shared.

2.4.1. *Number of workers reporting tasks*

Each of the tables presents the overall number of workers with task data for each method (N) and the number of workers reporting each specific task within each method (n), with ranking of the tasks based on task diary frequencies.

2.4.2. *Number of tasks and transitions*

Comparisons were made across methods for mean number of tasks and mean number of task transitions. Mean values calculated for each method used all workers with data available for that method.

2.4.3. *Task duration*

Task duration measures for keyboarding, mousing and phone tasks from the questionnaire were converted from hours to a percentage of a normal 8 h day. An additional task duration value for handset phone was calculated from questionnaire data by using time entered for phone use from only those workers who indicated that they used a handset phone. This could be compared to the phone duration from the video analysis, where only handset phone was observed. In addition to handset phones, the workers reported using hands-free phones.

Task duration measures from the task diary, direct observation and video methods were converted into a percentage of the total data collection time for each method. SAS (SAS Institute Inc.) was used to calculate the values for each measure. To calculate task durations, tasks done simultaneously were considered to have durations equal to the total time available within a time period. Consecutive tasks were considered to split the total time available in a time period. In the example above, a recording of 'A + B, C + D' indicated that first A and B were performed

simultaneously, then C and D were performed simultaneously within a 15 min period. This meant that task A + B had 7.5 min and C + D also had 7.5 min of the time period as consecutive tasks split the time period. Therefore, each of tasks A B C D was performed for 7.5 min in this example. The video task code 'other' was taken into account when calculating the number of tasks and task transitions but duration statistics for it are not included given its lack of specificity.

Further comparisons were made by calculating the Spearman correlation coefficient between specific office tasks from the video list task duration measures across methods as one could reasonably expect these methods to capture similar proportional task durations of common tasks. 'Other' or 'away from desk' tasks were not included for these comparisons given their lack of specificity.

3. Results

3.1. Questionnaire

Since one participant indicated on the questionnaire that they did not use the keyboard, mouse or phone during a normal workday, data were available on 40 of 41 participants (Table 1). A total of 38 (95%) workers reported using a phone, (22 (55%) of which used a hand-held phone), 38 (95%) workers reported using a mouse and 39 (98%) workers reported using a keyboard during a normal workday.

3.1.1. Task duration

Average task durations indicated a perception of spending somewhat more time keyboarding (mean 42% of a workday) and on the phone (mean 37% of a workday) than mousing (mean 31% of a workday). There was a fairly high level of variability in the task duration estimates for each of the three tasks from the questionnaire as reflected in the relatively large standard deviations in relation to the means.

Table 1. Mean task durations from questionnaires as a percent of an average 8 h day for workers who reported using each piece of equipment.

Task	% time: mean (SD), N = 40
Keyboarding	42.0 (26.2), n = 39
Phone*	37.0 (28.5), n = 38
Mousing	31.3 (24.6), n = 38

*Hand-held phone results were also calculated, in order to compare with video task codes, by using only responses from subjects who indicated that they used hand-held phones on a separate question in the survey (n = 22). The mean percent time for hand-held phone was 20.5 (SD 17.6).

3.2. Task diary

A total of 36 workers completed the task diaries but one worker completed only the first day. In total, 12 of 32 (38%) tasks (expanded list) were reported by 50% or more of the workers for at least one of the 3 d that the diary was used (see Table 2).

Exploring the six video task codes, all workers reported being away from their desk over the 3-d period of the task diary. In addition, the tasks of keyboarding, deskwork and phone were often reported (number of observations). However, mousing was reported by relatively few workers (Table 3).

3.2.1. Number of tasks and transitions

The mean number of expanded list tasks recorded by individual workers across days was 10.2 (SD 2.9) with a range of two to 18 tasks. The mean number of task transitions per hour across days was 6.8 (SD 6.6). However, the range of task transitions varied from less than one transition per hour (some workers making as little as two transitions over the entire day) to 31 transitions per hour.

The mean number of video list tasks recorded by individual workers across days was 4.7 (SD 0.7), with the range varying from two to 18 per day. The mean number of task transitions per hour was 5.2 (SD 4.5) with a range of one to 23 transitions per hour.

3.2.2. Task duration

Concerning the expanded list tasks performed by more than one or two workers, the tasks with the longest durations were on phone with customers (22%), keyboarding-data entry (18%) and mousing (14%) (Table 2). However, it is important to point out that there is considerable inter-worker variability in these task durations.

Exploring the video list tasks (not including the 'other' task), the 'away from desk' task (a diverse combination of expanded list codes – see Appendix A) had the longest mean duration (38%) of all tasks recorded (Table 3). Keyboarding was reported to have the next longest mean duration (25%). Tasks with shorter durations were on the phone (22%) and deskwork (21%) and mousing (14%). Once again, there is substantial variability in the task durations using the video list of codes (Table 3).

3.3. Direct observation

A total of 41 workers were observed with one worker not available for a second day of observation. In total,

Table 2. Mean task durations as percent of recording time from task diaries and direct observation, using 32 task codes, and ranked according to task diary frequencies.

Task	Task Diary Means (SD) N = 36, over 3 d	Direct Observation Means (SD) N = 41, over 2 d
Meal break	11.6 (2.9), n = 35	15.0, n = 1
Walking more than five paces	13.2 (8.4), n = 33	19.1 (11.4), n = 39
Keyboarding data entry	18.3 (20.9), n = 32	23.8 (17.8), n = 41
Consultation co-worker	9.1 (5.9), n = 28	15.5 (10.8), n = 41
Photocopying	5.3 (4.1), n = 28	2.4 (1.7), n = 5
Phone customer	21.6 (24.1), n = 27	16.0 (15.7), n = 38
Phone co-worker	6.6 (6.1), n = 27	6.0 (6.1), n = 22
Short break	6.2 (2.1), n = 27	13.8 (8.0), n = 22
Deskwork reviewing documents	7.8 (8.9), n = 25	8.7 (6.8), n = 40
Meetings away from desk	13.0 (11.4), n = 24	22.9 (19.7), n = 7
Deskwork filing	9.4 (9.4), n = 24	9.3 (7.2), n = 41
Deskwork document creation	8.6 (8.9), n = 24	4.8 (6.2), n = 14
Deskwork data entry	11.8 (15.7), n = 23	10.6 (5.7), n = 40
Keyboarding text edit	9.8 (8.6), n = 23	6.2 (5.9), n = 10
Keyboarding document creation	11.3 (8.9), n = 21	8.9 (7.0), n = 13
Faxing	5.9 (4.5), n = 19	1.9 (1.7), n = 6
Consultation customer	6.2 (3.7), n = 16	2.2 (2.7), n = 4
Mousing	14.3 (12.5), n = 14	14.8 (11.4), n = 35
Phone co-worker off-site	3.3 (2.3), n = 12	0.8 (0.3), n = 4
Phone customer off-site	2.5 (0.9), n = 4	16.0 (26.1), n = 11
Off-site travel	15.9 (2.6), n = 3	n = 0
Read monitor	27.1 (25.0), n = 2	5.6 (7.0), n = 31
Craftwork*	27.1, n = 1	4.0 (2.7), n = 32
Lifting	6.1, n = 1	0.9, n = 1
Calculator use	n = 0	2.0 (1.9), n = 20
Opening mail	n = 0	1.1 (1.0), n = 5
Printing/printer	n = 0	2.6 (2.2), n = 3
Washing hands	n = 0	6.2 (3.8), n = 2
Stuffing envelopes	n = 0	5.6, n = 1
Paper entry	n = 0	0.3, n = 1
Stretching	n = 0	n = 0
Unknown	12.1, n = 1	n = 0

*Using tape, scissors, stapler, etc.

Table 3. Mean task durations as percent of total recording time from task diaries, direct observation and video, using video list tasks.

Task	Task diary Means (SD), N = 36	Direct observation Means (SD), N = 41	Video Means (SD), N = 32
Away from desk	37.7 (13.2), n = 36	27.2 (13.4), n = 41	15.6 (11.9), n = 28
Deskwork	21.4 (15.3), n = 36	28.2 (10.9), n = 41	38.1 (20.2), n = 32
Keyboarding	24.7 (18.9), n = 35	25.4 (16.7), n = 41	25.8 (17.1), n = 30
Phone	21.6 (21.9), n = 34	18.2 (17.0), n = 40	15.1 (14.3), n = 22
Mousing	14.3 (12.5), n = 14	14.8 (12.0), n = 35	12.8 (11.7), n = 27

10 of 32 tasks were performed by 50% or more of the workers on at least one of the observation days (Table 2). The expanded list tasks most often observed were consultation with co-worker, walking, deskwork-data entry and keyboard-data entry. For the video tasks, all workers were observed doing deskwork and most were observed away from the desk, keyboarding and on the phone (Table 3).

3.3.1. *Number of tasks and transitions*

The mean number of expanded list tasks recorded for individual workers by the direct observation method across days was 10.5 (SD 1.9), with a range from four to 18 tasks per day. The mean number of tasks was similar to that of the task diary. The mean number of task transitions was 45.2 (SD 17.3), much greater than those

of the task diaries. The range of task transitions varied from 12 transitions per hour to 145 transitions per hour.

The mean number of video list tasks for all workers observed by the direct observation method showed slightly higher mean number of tasks than the task diary, with a mean of 5.6 (SD 0.5) tasks. The range of task transitions varied from 10 transitions per hour to 99 transitions per hour, with a mean numbers of task transitions of 39.3 (SD 14.6) much greater than those noted in the task diaries.

3.3.2. Task duration

Similar to that of the task diary method, observed tasks showed great variability across subjects using both the expanded and video list of tasks (Table 2). The most often observed expanded list tasks with the longest durations were keyboarding-data entry (24%), consultation with co-worker (16%), on phone with customers (on-site) (17%) and mousing (15%). However, the tasks of walking more than five paces (20%) and consulting with co-workers (16%) are also among the tasks with the longest durations reported (Table 2). The video list tasks of away from desk (a combination of direct observation codes) and deskwork were reported to have the longest durations (27 and 28% respectively) followed by keyboarding (25%). Video list tasks with the shorter durations were on phone (18%) and mousing (15%) (Table 3).

3.4. Video

A total of 32 workers were observed with the video method. All tasks were performed by at least 50% of the workers in this sample (Table 3).

3.4.1. Number of tasks and transitions

The mean number of tasks observed for individual workers across days was 5.1 (SD 0.9). This is similar to the mean number of tasks of both the task diary and direct observation methods. The mean number of task transitions was 273.1 (SD 99.6), much greater than that observed through task diaries and direct observation.

3.4.2. Task duration

The video results showed similar wide variability in task duration but, overall, deskwork had the longest mean duration (38%), with keyboarding (26%) having the next longest duration (Table 3). The phone task (using handset phones only) was next (15%) while the mousing task was shortest (13%). The task recorded as away from desk shows relatively short duration (16%) because the video analysis focused on the recorded segment that minimised the time that workers were away from their desks.

3.5. Comparing across methods

There were similar percentages of workers reporting tasks across the different methods using the video list tasks. The percentage of workers reporting phone use ranged from 69 (video) to 94 (task diary). The percentage of workers reporting mouse use varied the most, from 39 (task diary) to 95 (questionnaire). Interestingly, the greatest difference existed between these two self-report methods. All workers reported or were observed doing deskwork. The range of workers keyboarding varied little, 89% (task diary) to 98% (questionnaire). A similar percentage of workers was away from desk as well, 88 (video) to 100 (task diary). The difference between video and other methods was in part because the 30 min segment of video analysed was chosen to minimise workers being away from their desks.

3.5.1. Number of tasks and transitions

Comparison of number of tasks between methods using the six video list tasks showed that the mean number of tasks was quite similar across methods, varying from 4.7 for task diary to 5.6 for direct observation. Comparison of the task transitions reveals a great difference between methods, with 5.2 task diary task transitions, 39.3 direct observation task transitions and 273 video task transitions.

3.5.2. Task duration

A comparison of task duration using the six video list tasks showed similar mean durations across methods for mousing and keyboarding tasks (Table 3). For the mousing task, the range was from 13 to 15% of recording time, for keyboarding the range of duration was from 25 to 26% of recording time. For the tasks of deskwork there were differences between methods, with video showing longer durations (38%) than direct observation (28%) than task diary (21%). For the task of phone use and being away from the desk an opposite trend was noted, where task diary revealed longer durations (22% and 38% respectively) than direct observation (18% and 27% respectively) and video (15% and 16% respectively). However, it is noted that there are methodological reasons beyond the exposure methods employed that may be responsible for the differences in phone use and away from desk.

A comparison of task diary and direct observation with the expanded list tasks with the tasks were

recorded most frequently by workers with both the task diary and direct observation (Table 3): phone customer; phone co-worker; consultation with co-worker; keyboarding data entry; deskwork data entry; deskwork filing; deskwork reviewing documents; walking; short breaks. There were similar durations between methods for deskwork filing and deskwork reviewing documents tasks (8–12% for task diary and 9–11% for the direct observation). Task diary and direct observation methods do not show similar task durations for the remaining tasks. The differences in estimates between methods were not consistent in magnitude or direction of difference. Sometimes the task diary recorded shorter task times, e.g. consultation with co-worker, keyboard data entry and walking more than five paces, and sometimes the direct observation recorded shorter task times, e.g. 'on phone co-worker'.

3.6. Correlations of percent task duration

Table 4 shows the Spearman rank order correlations for each pair of methods, using four video task codes by day. Correlations for phone duration ranged from low to high and were all positive. The highest correlations were between questionnaire and task diary, questionnaire and direct observation, task diary and direct observation.

For mousing duration, there were fewer workers to compare and lower correlations as compared to the phone task. Moderate correlations existed between questionnaire and task diary and questionnaire and direct observation. The remaining comparisons resulted in low correlations.

For keyboarding duration, consistent positive signs were observed and at least moderate correlations were observed for each pair of methods. The highest correlations were between the direct observation and video methods. Similarly, deskwork duration showed moderate to high correlations for direct observation and video methods. There were lower correlations between task diary and both direct observation and video methods.

4. Discussion

The present results show that the four different methods of task recording lead to different estimates of the exposures measured. Task duration is a commonly identified risk factor in many aetiological studies of musculoskeletal disorders (e.g. Marcus *et al*. 2002, Jensen 2003, Mathiassen *et al*. 2005, Dempsey and Mathiassen 2006, Mikkelsen *et al*. 2007, IJmker *et al*. 2008, Douwes *et al*. 2007). The number of tasks and the number of task transitions are other aspects of exposure that may capture the variety and nature of the work (e.g. monotony). Understanding the differences among task recording methods is important to allow for comparison across studies and exposure measures. In general, differences may result from differences in underlying constructs, measurement characteristics or sampling issues. Measurement issues include the number of categories or the time between recorded events. Sampling issues include variation in the times and frequencies of measurement.

4.1. Number of tasks performed/reported by workers

The number of tasks performed and the number of task transitions estimated are different across methods. Both the task diary and direct observation methods

Table 4. Spearman rank-order correlations, across the task diary, direct observation and video method measures of percent task duration over total observation time for selected video task codes.

Task Method	Task Diary	Direct Observation	Video
Phone			
Questionnaire	0.72**, n = 33	0.68**, n = 39	0.15, n = 21
Task diary		0.76**, n = 34	0.25, n = 20
Direct observation			0.36, n = 22
Mousing			
Questionnaire	0.43, n = 14	0.40*, n = 34	0.28, n = 26
Task diary		0.13, n = 13	0.18, n = 9
Direct observation			0.24, n = 25
Keyboarding			
Questionnaire	0.43*, n = 34	0.51**, n = 40	0.54**, n = 29
Task diary		0.63**, n = 35	0.66**, n = 27
Direct observation			0.73**, n = 30
Deskwork†			
Task diary		0.35*, n = 36	0.25, n = 30
Direct observation			0.77**, n = 32

*Significant at $p < 0.05$; **Significant at $p < 0.01$.
†Deskwork task not reported in questionnaire.

recorded a mean of 10 tasks performed in each observation period. However, the direct observation method resulted in more task transitions per hour than the task diary. Comparing the task diary, direct observation and video methods with the video list tasks common to these methods showed that the task diary estimate was consistently less than the direct observation, which was, in turn, consistently less than the video method. This may in part be a result of the shorter duration of the recording interval in the video method (0.1 s) vs. direct observation (1 min) vs. the task diary (15 min). Another potential reason for the difference between the task diary and the other methods could be variation in how well workers can recall the tasks performed in a 15 min block. It is possible that workers do not remember brief or less important tasks completed during a period of time, especially if some tasks are not considered to be as important as others. This memory burden is not an issue with the observation methods.

4.2. Task duration

When considering task duration, the questionnaire method showed the highest estimates of duration for the tasks of phone, keyboarding and mousing when compared to other methods, as previously reported (Homan and Armstrong 2003, Balogh *et al*. 2004, Mikkelsen *et al*. 2007, IJmker *et al*. 2008, Douwes *et al*. 2007). Specifically comparing the task durations between questionnaire and task diaries showed that different methods of self-report may lead to different estimates of task durations. This seems to support the suggestion by Barrero *et al*. (2009) that task diaries with short intervals may be superior to questionnaire approaches.

Comparing task diaries and direct observation using expanded list tasks, there did not appear to be a consistent difference between the two methods. For some tasks, the task diary durations were less than the direct observation and for others the opposite was true. Also, for some tasks the task diary and direct observation estimates were quite different between days of recording.

Looking at video list tasks across task diary, direct observation and video methods, a different pattern was seen. For the task of phone use, the task diary method showed longer durations than did the direct observation and video methods. For keyboarding and mousing, the estimates of task duration were quite similar across methods. However, for deskwork, the task diary showed shorter durations than the other methods. This is not consistent with the suggestion that self-report methods tend to over-estimate task durations (Homan and Armstrong 2003, Balogh *et al*. 2004, Mikkelsen *et al*. 2007, IJmker *et al*. 2008, Douwes *et al*. 2007).

Spearman correlation (rank order association) results suggested some consistency for task duration between methods. There were some moderate to strong correlations observed between pairs of methods when considering the tasks comparable across all available methods. There were generally higher correlations for the direct observation and video methods than other pairs of methods, probably due to both observations being taken within the same period of time. There tended to be weaker correlations between task diary and video than for other method pairs. Based on correlation results, the methods cannot be considered interchangeable for measuring task duration exposure. The different task recording methods may be capturing different information regarding exposure (task duration).

A comparison across all methods for task duration determined that the various methods capture the tasks performed (reported) by workers in different ways. The questionnaire method asks about the time spent doing three tasks during a 'typical day'. The task diary and direct observations methods make it possible to capture a much greater range of tasks. The video method is similar to the direct observation method but is limited by the camera angle and can be prone to equipment malfunctions; however, the benefits are the precision with which the task start/stop times can be estimated. Given these different 'lenses' on task duration, different results are perhaps understandable.

4.3. Methodological comparison

Within the same construct, there are two main dimensions of variability in exposure measures: workers and time (Loomis and Kromhout 2004). In this study, the workers may perform different tasks because their jobs are different. In situations where workers have the same job title, they may be working on different projects or may approach the work in different ways. Differences in job requirements, deadlines and workers' decisions can lead to variability in the tasks performed and therefore the exposures. In addition, there may also be variability in self-reporting of tasks based on how the workers perceive the tasks they complete. Reasonable exposure methods should be able to capture the variability adequately.

Time is a key aspect of exposure measures (Loomis and Kromhout 2004). The sampling frame of the measure provides limits on the precision with which number of tasks, task transitions and task duration can be measured (or estimated). The present study compared four methods of measuring task exposures, each with different sampling frames. The questionnaire asked workers to consider an entire day and a limited set of tasks. Task diaries also reflected an entire day

but required task recording every 15 min for a large number of tasks. Direct observation allowed for monitoring a large number of tasks sampled every minute for a 2 h sample of the day. Finally, the video method could sample to within 1 s but for a reduced number of tasks, limiting the number of tasks, limiting phone use to handset rather than the full range of phones and purposely sampled segments of the video with participants at their desk, resulting in lower durations away from desk. In addition, the observer of the video must be able to record changes in tasks with great precision; therefore, a larger number of tasks would require slowing down the video (or repeated stops), resulting in a potentially inordinate amount of time to code tasks from even a short video sample.

The main trade-off between these methods is precision of task identification (number of task or sub-tasks) vs. precision of time (day, minutes, seconds). The precision differences come with increased burden for workers (task diaries, questionnaires) or observers/researchers (observation, video). There is the potential for decreased accuracy in recordings from observation with increased burden. Therefore, the method chosen must consider where precision is most important (task or time), the amount of precision required as well as the burden and potential accuracy challenges.

Finally, when considering exposure methods, it is necessary to consider the level of precision required and the nature of constructs involved among exposures that lead to musculoskeletal disorders, symptoms and lost productivity. Exposure to office tasks has been linked to these outcomes (Polanyi *et al*. 1997, Punnett *et al*. 1997, National Research Council 2001, Village et. al. 2005, Hagberg *et al*. 2007, IJmker *et al*. 2007, de Kracker *et al*. 2008). However, which method best captures the most pertinent constructs of task exposure in the most precise ways has not been established for office work.

4.4. Strengths and limitations

The present study was part of a larger study examining changes in exposure and musculoskeletal disorder health outcomes in an office workplace during a period of change (Cole *et al*. 2006). The results of four exposure measurement methods reported herein were studied on a small sub-sample of workers. The study was not designed to explore measurement error or compare the measurement properties of the task recording methods. Instead, the use of each recording method was explored as an independent manner of quantifying tasks in this broader study of office exposures.

Strengths of the study include comparing task recording methods on the same day (or in the case of the task diaries, the same day of the week) and that workplace parties (workers and management) were involved with researchers in determining the tasks that are relevant to office-based computer work. Task diaries were completed 1 to 2 weeks prior to the direct observation and video. The direct observation and video were done simultaneously and incorporated the same day of the week of at least one of the task diary days. To have direct observation ongoing while workers completed task diaries may have influenced how the diaries were completed, thereby reducing the opportunity to compare these field methods independently. Ethics was not sought for surreptitious observation in this study.

A limitation of the study was that the questionnaire was administered at a separate time than the other exposure methods and required workers to consider what they did on a usual day. It is possible that the tasks that a worker usually performed could have changed between the time of the questionnaire and the time that the remaining task exposures were collected. Second, the remaining three exposure measures were sampled using different time periods. Differences in exposures between methods could be attributed to different patterns of tasks being captured in the specific time sampled.

There are additional methodological issues to consider when comparing these task recording methods. To reduce respondent burden, there were only three tasks listed on the questionnaire. This may have resulted in the workers estimating each task as a proportion of a complete day leading to an over-estimation effect for each of the tasks. This may have affected the tasks differentially with some tasks being over-estimated more than others.

The task diaries were the most demanding of the workers' time (burdensome) and were not well liked by workers. The diaries were to be completed every 15 min, but at times it was noted that they were completed only at the end of a day, limiting the benefits of the method. It was also possible to complete the diary by indicating a group of tasks that did not vary through the entire day. It is possible that workers felt that this was representative of their work but it may also have been done to decrease the time burden of completing the diaries.

The methodological issues highlighted do not diminish the importance of these comparisons; rather, they inform why different estimates of exposure may result from the different methods. It cannot be determined from these comparisons which method is the most accurate indicator of exposure as there is currently no criterion measure for a variable such as keyboarding time. Even measurement methods based upon direct measures of key strokes and mouse movement depend on the outcomes of algorithms processing these discrete events. A person may

consider holding their hands over the keyboard to be 'keyboard use', whereas a particular algorithm may not be sensitive to such activity.

4.5. Summary

The four task recording methods used do not result in similar estimates of exposure in this group of office workers. There were some moderate to strong correlations observed between percent durations of the various methods for the video list tasks. Keyboarding and phone tasks tended to have higher levels of inter-method correlation as compared to mousing and deskwork tasks. In this study, self-report methods did not consistently lead to higher levels of mechanical exposure-related variables. However, further attention to methodological differences (both conceptual and measurement) in task exposure methods should be addressed to better understand these potential risk factors.

Acknowledgements

The authors acknowledge other members of the Worksite Upper Extremity Group at the Institute for Work & Health, members of the RSI (Repetitive Strain Injury) Watch Steering Committee, and participants in the study. This project was sponsored by the Institute for Work & Health. The Institute, an independent not-for-profit research organisation, receives support from the Ontario Workplace Safety & Insurance Board. Funding was provided by the US NIOSH/NIH and the Center for VDT & Health.

References

Balogh, I., *et al*., 2004. Self-assessed and directly measured occupational physical activities – influence of musculoskeletal complaints, age and gender. *Applied Ergonomics*, 35 (1), 49–56.

Barrero, L.H., *et al*., 2009. Work pattern causes bias in self-reported activity duration: a randomised study of mechanisms and implications for exposure assessment and epidemiology. *Occupational and Environmental Medicine*, 66, 38–44.

Blangsted, A.K., Hansen, K., and Jensen, C., 2004. Validation of a commercial software package for quantification of computer use. *International Journal of Industrial Ergonomics*, 34, 237–241.

Cole, D.C., Wells, R.P., and the Worksite Upper Extremity Research Group, 2002. Interventions for musculoskeletal disorders in computer-intense office work: A framework for evaluation. *Work and Stress*, 16 (2), 95–106.

Cole, D., *et al*., 2006. Reducing musculoskeletal burden through ergonomic program implementation in a large newspaper. *International Archives of Occupational and Environmental Health*, 80, 98–108.

David, G.C., 2005. Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occupational Medicine (London)*, 55 (3), 190–199.

de Kracker, H., *et al*., 2008. The effect of a feedback signal in a computer mouse on hovering behaviour, productivity, comfort and usability in a field study. *Ergonomics*, 51 (2), 140–155.

Dempsey, P.G. and Mathiassen, S.E., 2006. On the evolution of task-based analysis of manual materials handling, and its applicability in contemporary ergonomics. *Applied Ergonomics*, 37, 33–43.

Dennerlein, J.T. and Johnson, P.W., 2006. Different computer tasks affect the exposure of the upper extremity to biomechanical risk factors. *Ergonomics*, 49 (1), 45–61.

Douwes, M., de Kracker, H., and Blatter, B.M., 2007. Validity of two methods to assess computer use: Self-report by questionnaire and computer use software. *International Journal of Industrial Ergonomics*, 37, 425–431.

Faucett, J. and Rempel, D., 1996. Musculoskeletal symptoms related to video display terminal use: an analysis of objective and subjective exposure estimates. *AAOHN Journal*, 44 (1), 33–39.

Gerr, F., Marcus, M., and Ortiz, D.J., 1996. Methodological limitations in the study of video display terminal use and upper extremity musculoskeletal disorders. *American Journal of Industrial Medicine*, 29 (6), 649–656.

Hagberg, M., 1992. Exposure variables in ergonomic epidemiology. *American Journal of Industrial Medicine*, 21, 91–110.

Hagberg, M., *et al*., 2007. Incidence of self-reported reduced productivity owing to musculoskeletal symptoms: associations with workplace and individual factors among computer users. *Ergonomics*, 50 (11), 1820–1834.

Hansson, G.-Å., *et al*., 2001. Questionnaire versus direct technical measurements in assessing postures and movements of the head, upper back, arms and hands. *Scandinavian Journal of Work Environment and Health*, 27 (1), 30–40.

Heinrich, J., Blatter, B.M., and Bongers, P.M., 2004. A comparison of methods for the assessment of postural load and duration of computer use. *Occupational and Environmental Medicine*, 61, 1027–1031.

Homan, M.M. and Armstrong, T.J., 2003. Evaluation of three methodologies for assessing work activity during computer use. *American Industrial Hygiene Association Journal*, 64, 48s–55s.

IJmker, S., *et al*., 2007. Should office workers spend fewer hours at their computer? A systematic review of the literature. *Occupational and Environmental Medicine*, 64, 211–222.

IJmker, S., *et al*., 2008. Test-retest reliability and validity of self-reported duration of computer use at work. *Scandinavian Journal of Work Environment and Health*, 34 (2), 113–119.

Jensen, C., 2003. Development of neck and hand-wrist symptoms in relation to duration of computer use at work. *Scandinavian Journal of Work Environment and Health*, 29 (3), 197–205.

Lassen, C.F., *et al*., 2005. Risk factors for persistent elbow, forearm and hand pain among computer workers. *Scandinavian Journal of Work Environment and Health*, 31 (2), 122–131.

Loomis, D. and Kromhout, H., 2004. Exposure variability: concepts and applications in occupational epidemiology. *American Journal of Industrial Medicine*, 45 (1), 113–122.

Marcus, M., *et al*., 2002. A prospective study of computer users: I.I. Postural risk factors for musculoskeletal symptoms and disorders. *American Journal of Industrial Medicine*, 41 (4), 236–249.

Mathiassen, S.E., *et al*., 2003. Efficient one-day sampling of mechanical job exposure data–a study based on upper trapezius activity in cleaners and office workers. *AIHA Journal*, 64 (2), 196–211.

Mathiassen, S.E., *et al*., 2005. Task-based estimation of mechanical job exposure in occupational groups. *Scand Journal of Work Environment and Health*, 31 (2), 138–151.

Mikkelsen, S., *et al*., 2007. Validity of questionnaire self-reports on computer, mouse and keyboard usage during a four-week period. *Occupational and Environmental Medicine*, 64, 541–547.

National Research Council, 2001. *Musculoskeletal disorders and the workplace*. Washington, DC: National Academy Press.

Polanyi, M.F.D., *et al*., 1997. Upper limb work-related musculoskeletal disorders among newspaper employees: cross-sectional survey results. *American Journal of Industrial Medicine*, 32, 620–628.

Punnett, L. and Bergqvist, U., 1997. *Visual display unit work and upper extremity musculoskeletal disorders: a review of epidemiological findings*. Solna, Sweden: National Institute for Working Life.

Spielholz, P., *et al*., 2001. Comparison of self-report, video observation and direct measurement methods for upper extremity and musculoskeletal disorder physical risk factors. *Ergonomics*, 44 (6), 588–613.

Stock, S.R., *et al*., 2005. Reproducibility and validity of worker's self-reports of physical work demands. *Scandinavian Journal of Work Environment and Health*, 31 (6), 409–437.

Unge, J., *et al*., 2005. Validity of self-assessed reports of occurrence and duration of occupational tasks. *Ergonomics*, 48, 12–24.

Village, J., Rempel, D., and Teschke, K., 2005. Musculoskeletal disorders of the upper extremity associated with computer work: A systematic review. *Occupational Ergonomics*, 5, 205–218.

Wegman, D.H., *et al*., 1992. Measuring exposure for the epidemiologic study of acute effects. *American Journal of Industrial Medicine*, 21 (1), 77–89.

Wells, R., Van Eerd, D., and Hagg, G., 2004. Mechanical exposure concepts using force as the agent. *Scandinavian Journal of Work Environment and Health*, 30, 179–190.

Witschi, J.C., 1990. Short-term dietary recall and recording methods. *In*: W. Willet, ed. *Nutritional epidemiology*. Oxford: Oxford University Press, 52–68.

Appendix A. Tasks recorded and methods of recording.*

No.	Task description	Task Diary	Direct Obs	Video
Original				
1	Meal break	X	X	X (A)
2	Short (coffee) break	X	X	
3	On phone with customer	X	X	X (P)
4	On phone with supervisor or co-worker	X	X	
5	On phone with customer (off-site)	X	X	
6	On phone with supervisor or co-worker (off-site)	X	X	
7	Consultation with customer	X	X	X (O)
8	Consultation with supervisor or co-worker	X	X	
9	Graphic editing with mouse (mousing)	X	X	X (M)
10	Document creation with keyboard	X	X	X (K)
11	Text editing with keyboard	X	X	
12	Data entry with keyboard	X	X	
13	Deskwork (by hand) document creation	X	X	X (D)
14	Deskwork (by hand) data entry	X	X	
15	Deskwork (by hand) filing/retrieving/sorting documents	X	X	
16	Deskwork (by hand) reviewing documents	X	X	
17	Off-site travel	X	X	X (A)
18	In meetings (away from desk)	X	X	
19	Walking (more than five paces)	X	X	
20	Photocopying	X	X	
21	Faxing	X	X	
Expanded				
22	Calculator or adding machine		X	X (D)
23	Washing hands (including applying bandaid)		X	X (A)
24	Craft work (using tape, scissors, stapler, etc.)		X	X (D)
25	Read from monitor	X	X	X (A)
26	Lifting	X	X	
27	Paper entry		X	X (D)
28	Opening mail		X	
29	Stuffing envelopes		X	
30	Printing or putting paper in printer (or copier)		X	
31	Stretching		X	X (A)
32	Unknown†	X		

*Tasks 22 to 32 were added by participants or observers if they felt that the original 21 tasks did not represent what they were doing.
†In one case a task diary was returned with no task label entered.
A = away from desk; P = phone; O = other (not captured by any existing codes); M = mousing; K = keyboarding; D = deskwork.