Scand J Work Environ Health 1992;18 Suppl 2:123—6

Ergonomic analysis to characterize task constraint and repetitiveness as risk factors for musculoskeletal disorders in telecommunication office work

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Despite improvements in the equipment and fit of office tools and workstations, workers in many clerical job categories continue to experience significant levels of musculoskeletal discomfort and pain. To identify the sources of pain and discomfort, investigators must examine complex combinations of task functions in the modern office environment. Traditional motion analysis techniques fail, however, to capture the ergonomic stresses associated with modern office work. Consequently, we developed an expanded activity analysis to characterize the task functions of clerical workers in telecommunications (1). The analysis focuses on task repetitiveness and task constraint as risk factors since both attributes have been identified as contributing to the development of cumulative trauma disorders (2—4).

Methods

Job categories. On the basis of an initial walk-through survey and an analysis of job descriptions in a telecommunication industry, the following five clerical job categories were selected for inclusion in the study: (i) directory assistance operators (DAO), (ii) centralized mail remittance employees (CMR), (iii) service representatives (SR), (iv) employees of a recent change memory administration center (RCMAC), and (v) employees of a loop provisioning center (LPC). Figure 1 shows the approximate skill level for each job.[3] In general, the employees in the five job categories sat at individual workstations equipped with modern adjustable computer displays and keyboards.

Data collection. Where possible, four or more workers, from each of the five job categories at three job sites (P, D, M), were randomly selected to be taped with a videotape recorder. To ensure enough samples of job cycles, we attempted to video tape at least 20 consecutive cycles of jobs with short cycles (ie, <1-min duration), and at least 7—15 consecutive cycles of jobs with longer cycles (ie, >1-min duration). Given this restriction, our final sample consisted of 66 workers, with a minimum of three workers per job category at each worksite.

Activity analysis. The analysts reviewed each of the 66 samples of work using a video recorder-editor system (Sony model EVO720) as an electronic marker to number and record the duration of tasks, cycles within tasks, and events within cycles. To assess the attributes of task constraint and task repetition in telecommunication jobs, the following four measures of task function were collected:

1. Measures of essential worktime (EWT) for a job cycle, defined as the duration of an employee's time engaged in computer or telephone work or both.
2. Measures of total worktime (TWT) for a job cycle. Total worktime is the sum of the essential worktime and a measure of auxiliary worktime (AWT). In this study, auxiliary worktime provided a measure of the duration of noncomputer or nontelephone work or both. Auxiliary

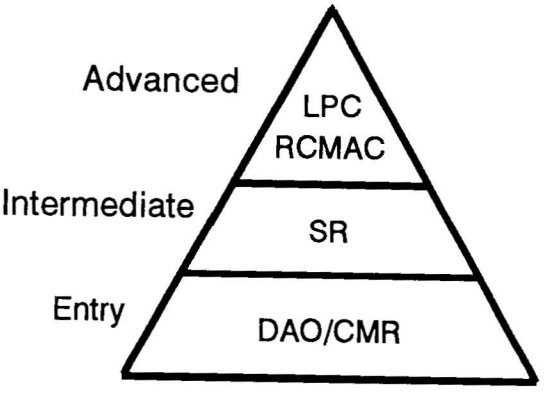

Figure 1. Relative skill levels for jobs. (LPC = loop provisioning center, RCMAC = recent change memory administration center, SR = service representatives, DAO = directory assistance operators, CMR = centralized mail remittance)

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worktime could be a form of "light work," providing an opportunity for recovery.

3. Measures of the cycle time for the primary task (CY), defined as the task performed more than 50% of the time.
4. The number of unique tasks in each job category (# task). A job cycle could also contain a nonwork component or workflow pause with a duration defined as nonworktime (NWT). Examples of nonworktime in this study included computer malfunctions, telephone busy signals, waiting for work or information, or certain personal work pauses. Nonworktime was computed by subtracting the total worktime from the cycle time. Generally, nonworktime and auxiliary worktime served to reduce job demands, but they could increase mental stress if the work was monitored or incentive-driven (5).

Each of the preceding measures is depicted in figure 2a—b as a component of an activity analysis that illustrates two extreme variations in job design. The job shown in figure 2a required the worker to perform a variety of different tasks (A, B, C, D, etc). Each task provided diversity, requiring only a few repetitive cycles. Each cycle provided a balance of total worktime and nonworktime, and each episode of total worktime consisted of a balance between essential worktime and auxiliary worktime. By contrast, the job in figure 2b consisted of a single task (A) with highly repetitive short cycles. The task cycle consisted almost entirely of work events resulting in large values for total worktime and relatively low values for nonworktime (ie, high work focus). Moreover, the total work time for this job (figure 2b) was almost solely dedicated to essential work events with minimal requirements for auxiliary work activities. As a result, the durations of essential worktime were substantially longer than the durations of auxiliary worktime and therefore added to task constraint.

Exposure determination. To categorize the job demands for each of the 66 job samples, two classification rules were established. According to rule 1, a job was classified as high constraint if the worker spent more than 80% of his or her time using a computer plus telephone (ie, EWT/TWT >0.80). This rule was based on recommendations for minimizing mental and physical fatigue by alternating work with a video display terminal (VDT) with non-VDT work in a ratio between 4:1 and 5:1 (6, 7). With rule 2, a job was classified as high task repetitive (as distinct from "motion repetitive") if the worker repeated the primary task more than once per minute (ie, #task/CY >1.0) (8, 9). By applying the two classification rules to each of our job samples from the 66 workers, we formed four exposure categories consisting of "high" and "low" combinations of the attributes of task constraint and repetitiveness.

Results and discussion

Table 1 summarizes, by job category, the results of the activity analysis. Three of the five constraint ratios (column 4) for the job categories of directory assistant operators, service representatives, and centralized mail remittance employees had task constraint ratios above 0.80. Since the ratio was based on the proportion of employee time allocated to essential work events (ie, computer plus telephone usage) the data indicate that three of the jobs exceeded the 80% value for VDT-related work. The sample of 26 directory assistance employees produced the highest levels of VDT-related constraint, averaging 97.3 (SD 11) %, followed by the service representatives and centralized

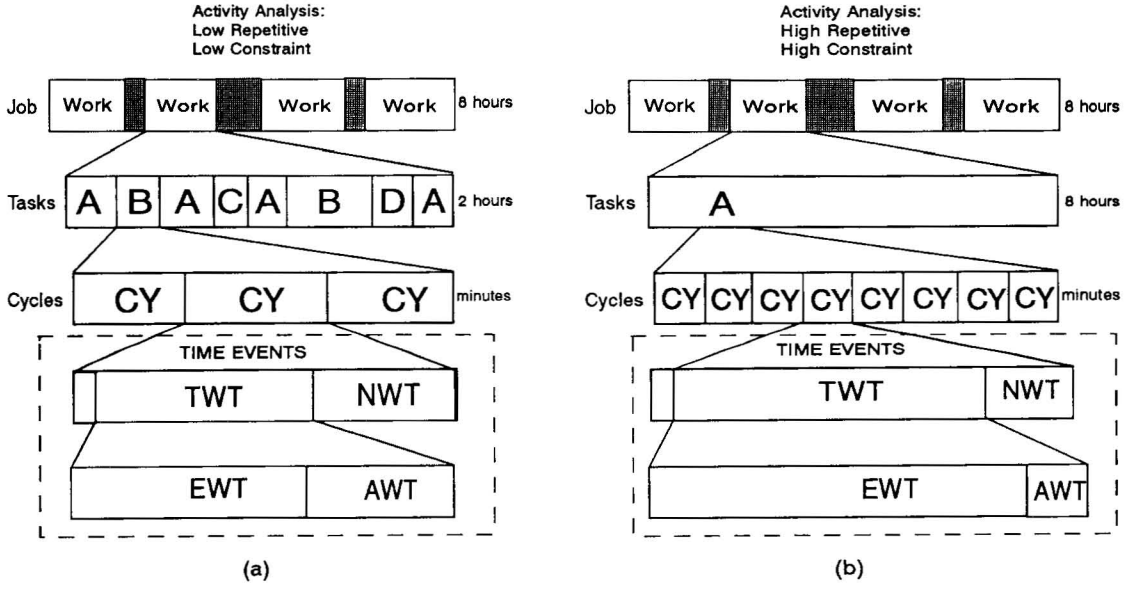

Figure 2. Components of activity analysis for (a) a low-constraint and low-repetitive job, and (b) a high-constraint and high-repetitive job. (TWT = total worktime, NWT = nonworktime, EWT = essential worktime, AWT = auxiliary worktime)

Table 1. Data values for the activity analysis.

	Constraint				Repetitive		
	N	Essential worktime (s)	Total worktime (s)	Ratio	Tasks	Cycle time (min)	Ratio
Directory assistance operators	26	22.8	23.4	0.97	1	0.40	2.50
Service representatives	12	381	400	0.95	2	7.0	0.29
Centralized mail remittance employees	8	694	783	0.88	1	23.9	0.04
Employees of a recent change memory administration center	11	801	1128	0.71	5	24.8	0.20
Employees of a loop provisioning center	9	811	1276	0.63	4	23.3	0.17

mail remittance employees, with averages of 95 and 88%, respectively. The directory assistance employees also had the shortest average durations of auxiliary worktime (AWT = 0.6 s) and nonworktime (NWT = 0.6 s) of the five job categories, a finding indicating little opportunity for alternate work or work pauses. The repetitive nature of the task of the directory assistance employees was also evident from the duration of the average cycle time for each call (20—23 s), the repetition rates being three per minute.

Although employees with jobs as service representatives and centralized mail remittance workers also engaged in extensive computer or telephone usage, the cycle times for the primary tasks of these two jobs averaged 7 (SD 5) min and 23.9 (SD 9) min, respectively. The primary task of the centralized mail remittance employees consisted of processing batches of billing items. For each billing batch, these employees averaged about 694 s (11 min) for their essential worktime measures, while their total worktime averaged 783 s (13 min). Therefore, about 2 min during the processing of a batch was available for auxiliary work, such as note taking, organizing, separating items, cleaning optical reader heads, etc. The primary cycle time exceeded the total worktime by about 10 min, a finding which indicated that the centralized mail remittance employees experienced almost as much nonworktime (10 min) as worktime (13 min). Both the job categories of recent change memory administration center employees and loop provisioning center employees registered similar levels of essential worktime values, averaging 801 s of essential worktime for the recent change memory administration center employees and 811 s of essential worktime for the loop provisioning center employees (about 13 min each). Measures of total worktime for the job tasks were also similar (about 20 min of total worktime) which allowed about 7 min for noncomputer- and nontelephone-related work. In other words, almost 20 min of every hour were unencumbered by telephone or computer usage. The cycle time for the primary task of the employees in the recent change memory administration and loop provisioning centers averaged about 24 min. The amount

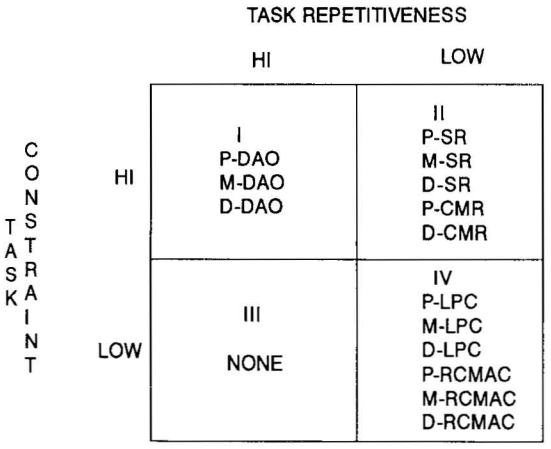

Figure 3. Predicted exposure classification for five job categories in a telecommunication industry according to the results of a customized activity analysis to assess two job design factors. (P, M, and D = worksite locations, DAO = directory assistance operators, SR = service representatives, CMR = centralized mail remittance, LPC = loop provisioning center, RCMAC = recent change memory administration center)

of nonworktime for the workers in the recent change memory administration center averaged about 6 min, whereas the nonworktime for the employees in the loop provisioning center averaged about 2 min per job cycle.

According to our classification rules for exposure determination and the data values summarized in table 1, each of the 66 work samples was classified into one of the four exposure groups shown in figure 3. All 26 work samples from the directory assistance employees were assigned to the high-risk exposure group (quadrant I), whereas the 12 work samples of the service representatives and the eight work samples of the centralized mail remittance employees were assigned to a moderate risk group (ie, high constraint and low repetitive exposure) (quadrant II). The work samples of the employees from the recent change memory administration and the loop provisioning centers were found to be compatible with the criteria for the low-risk exposure group (quadrant IV). None

of the 66 worker samples met the criteria for quadrant III.

Summary

A modified activity analysis procedure was devised to quantify the presence of two task attributes identified in previous research as contributing to an increase in work demands and ergonomic hazards. The purpose of this study was to develop an exposure index based on the presence of two task attributes. The utility of this job activity analysis will, of course, be determined by the extent to which workers with varying degrees of muscular pain and discomfort correspond to the risk exposure group we have described. The results of both the medical and psychological assessments of the workers — contained in the final HETA report — will be used to assess the utility of our method and determine whether the task attributes of constraint and repetitiveness contribute to the onset of cumulative trauma disorders among clerical workers.

Acknowledgments

Appreciation is extended to Ms LL Steward and Dr KA Grant for their assistance in the job analysis.

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