Rapid Communication

The use of turnover rate as a passive surveillance indicator for potential low back disorders

STEVEN A. LAVENDER

Rush-Presbyterian–St Luke's Medical Center,
1653 West Congress Parkway, Chicago, IL 60612-3833, USA

and WILLIAM S. MARRAS

Biodynamics Laboratory, Ohio State University,
Columbus, Ohio, USA

Passive surveillance techniques which rely only on injury reporting to locate ergonomic problems within a facility may not be sensitive enough to identify all jobs that place a worker at risk of low back disorder. The current study examines whether turnover rate data provide useful input to a passive surveillance approach. It is hypothesized that the turnover of employees through individual jobs, when not attributable to differential pay scales within a facility, is likely to indicate the presence of ergonomic hazards associated with low back cumulative trauma disorders. This study used the database and multiple logistic regression model developed by Marras *et al.* (1993) to evaluate this hypothesis. Two data sets were evaluated with the model to determine whether jobs with turnover resemble those with a high historical risk of LB-CTD. The first data set contained trunk motion and workplace data from jobs in which there had been turnover but there were no incidents of LB-CTD. When comparing these data to truly low risk jobs (no LB-CTD incidents or turnover), the model yielded an odds ratio of 5·2. This moderate odds ratio indicates that many of the jobs with turnover have characteristics similar to those found in high LB-CTD risk jobs. The second data set included jobs with turnover and moderate LB-CTD incident rates. The model's resulting odds ratio of 11·0 indicates that jobs with moderate incident rates and turnover are very similar to jobs with a high LB-CTD risk. These results suggest that passive surveillance programs would be more sensitive if turnover rates were determined for each job within a facility and were used to supplement incident rate data.

1. Introduction

The occupational factors prevalent in low-back pain cases have been extensively reported in epidemiological studies (Andersson 1991, Damkot *et al.* 1984, Frymoyer *et al.* 1983, Magora 1973). Punnett *et al.* (1991) recently reported a logistic regression model predicting low-back injury which, while including trunk postures and the loads handled, also included age and back injury history.

Passive surveillance techniques have been advocated to locate jobs with an increased potential for injury within a particular facility (Silverstein 1990). The most commonly used data sources for a surveillance programme include the OSHA 200

logbooks, workman's compensation records, and accident report forms. For example, by determining where within a facility the low back cumulative trauma disorders (LB-CTDs) cluster, the passive surveillance programme can isolate areas which need further attention from an ergonomics team. However, passive surveillance programmes which rely only on reported low back injuries cannot detect problems before they become severe enough to be reported. In addition, the reporting of injuries is affected by several psychosocial parameters of the workplace (Bigos et al. 1991).

The present authors have observed several instances in which the occupational risk factors associated with LB-CTDs were present at the worksite, although no injuries have been reported. When asked about these worksites, the representatives from the organization frequently related that these were high turnover positions. This suggested the possibility of considering the turnover rate as an index of LB-CTD risk. The turnover rate is defined as the percentage of employees in a given job which are replaced during a one-year period.

The primary advantage of using the turnover rate as an additional index of LB-CTD risk is that it may be a more sensitive measure with which high-risk jobs can be identified prior to injuries being reported. As such it may be advantageous to use the turnover rate to circumvent the errors in prevalence rates due to the 'healthy worker effect' (Andersson 1991). In essence, this means that healthy workers may stay in a particular job, but those who find themselves straining are likely to move on to other jobs. As a result the prevalence rates of those in the less taxing jobs may be inflated while the true prevalence rate of the taxing job is under-represented.

It should be noted that turnover can occur for a variety of reasons other than the LB-CTD risk. The compensation in a particular job may be less than in other jobs within the facility or within the community. Injury and lay-offs also affect turnover. And seniority frequently dictates the movement between jobs within a facility. However, jobs deemed desirable by the more senior employees are possibly less likely to result in injury or chronic pain.

A recent cross-sectional study quantitatively described the trunk motions and several workplace variables in 403 highly repetitive manual material handling jobs (Marras et al. 1993). Based on these data, these authors developed a multiple logistic regression model that quantifies the relationship between the trunk motion factors and the LB-CTD injury rates. They found that the incorporation of trunk motion and workplace data resulted in a model that was ten times more likely to predict LB-CTD risk group membership than estimates based on chance alone (odds ratio 10·7) and more than three times more predictive than the current NIOSH (1981) guidelines.

The factors identified by Marras et al. (1993) were successful in accounting for the data groupings based on injury. In this study the correlation between the normalized incidence rate (IR200K) and the turnover for the entire database was only 0·22. Therefore, the incidence rate and the turnover data may be sensitive to different aspects of the work environment, or it may be that the turnover is affected by the same factors as LB-CTD, and the fact that the turnover occurs, prevents the injury occurrence. The latter hypothesis would be supported if jobs having turnover are viewed by the model as having a high LB-CTD risk. Such a finding would allow passive surveillance programmes to locate potential sources of LB-CTD even without reported incidents. Therefore, this paper will evaluate the hypothesis that jobs identified via their turnover rates are representative of jobs with a high LB-CTD risk due to the trunk motions and the workplace factors involved.

2. Methods

2.1. *Approach*

This study comprises an analysis of jobs classified according to turnover rates using the LB-CTD model developed by Marras *et al.* (1993). The data used in this study were from a database in which 403 jobs were sampled with regard to the trunk motions, workplace parameters, and employee anthropometry. The jobs in the current sample, while measured during the initial survey, were not used in developing the original model. The following section provides a brief description of the experimental protocol employed in building the database. A complete description is contained in the above referenced paper.

2.2. *Database construction*

Forty-eight companies agreed to participate in a study in which the trunk motions in repetitive manual material handling jobs would be measured. For each job the normalized historical back injury rate and the turnover rate were determined. The former were based on the Occupational Safety and Health Administrations forms available at each facility (OSHA 200). The latter were determined by interviewing supervisors within each section of a given facility. The turnover data were expressed as the percentage of individuals performing a given job which had to be replaced within a year's time. Where possible, these data were averaged over multiple years.

The trunk motions in each job were determined using a triaxial electro-goniometer fitted via a harness system over the lower thoracic and lumbar spine. This unit, called the lumbar motion monitor (LMM), was designed to measure the instantaneous trunk position, velocity, and acceleration in the sagittal, frontal, and transverse planes.

LMM data were obtained from each job for approximately 10 cycles . With more variable tasks, more cycles were monitored to provide a representative sample of the work activities. In addition to the trunk motions several workplace variables were measured which included: the magnitude of the load handled, the maximum horizontal distance between the handled load and the spine (moment arm), the work heights, and the lift rate per hour. Anthropometric measures were obtained for each employee sampled. These included the employee's height, weight, segment lengths, the trunk breadth, trunk depth, and trunk circumference.

The data from the jobs classified as high risk (greater than 12 incidents per 200 000 h of exposure) and jobs classified as low risk (no turnover and no incidents) were used to develop the multiple logistic regression model. The model, shown in figure 1, is composed of five factors: the lift rate, the peak moment placed on the lumbar spine due to the load handled, the average twisting velocity, the peak lateral bending velocity, and the maximum sagittal flexion (forward bending). Together these factors can be used to estimate the probability that a job has characteristics which resemble those found in the high-risk group. The coefficients used in the model and the mathematical formulation are provided in table 1.

2.3. *Current data analysis*

The model described above was used to evaluate the relationship between jobs showing turnover and LB-CTD risk. The jobs in which the turnover rates were elevated and where the incidence rate per 200 000 h of exposure (IR200K) was greater than 0 but less than 12 were not tested in the original model. It is these data that were the subject of the current analyses.

79	119	145	167	187	207	229	255	295	Liftrate (lifts/hour)
3.4	5.2	6.3	7.2	8.1	8.9	9.9	11.1	12.8	Average Twisting Velocity (deg/sec)
21.9	32.9	40.3	46.3	51.9	57.4	63.4	70.8	81.8	Maxium Moment (Nm)
6.0	9.1	11.1	12.8	14.3	15.8	17.5	19.5	22.5	Maximum Sagittal Flexion (deg)
17.6	26.4	32.4	37.2	41.6	46.1	50.9	56.8	65.7	Maximum Lateral Velocity deg/sec)

Average Probability

10%   20%   30%   40%   50%   60%   70%   80%   90%

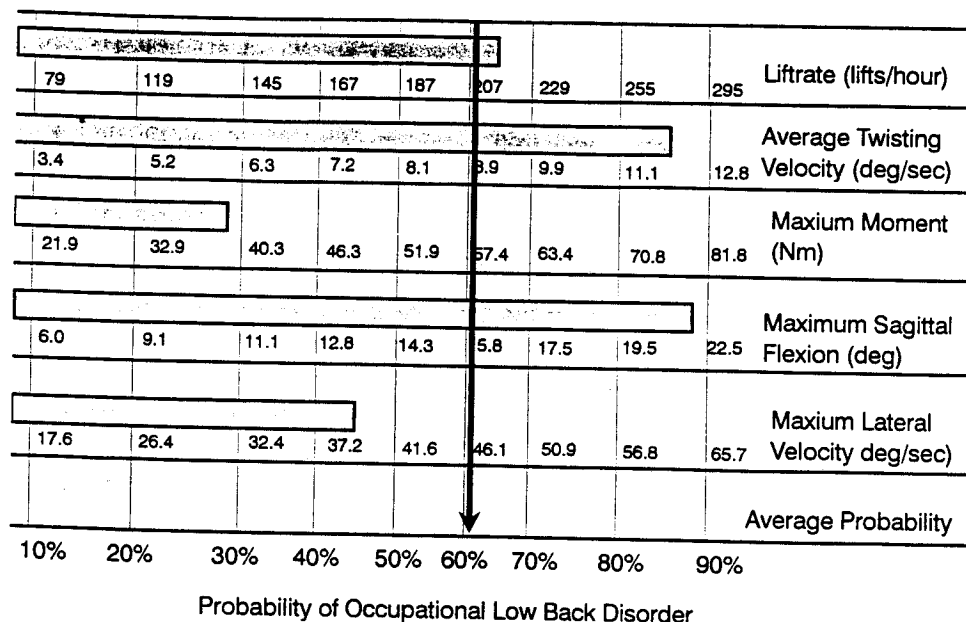Probability of Occupational Low Back Disorder

Figure 1.   The multivariate logistic regression model developed by Marras *et al.* (1993). The overall probability that a job resembles a high-risk job is determined as follows. First, the value of the variable for a given task is located on the variable's respective scale. Second, the probability value for each scale is then determined by dropping a vertical line to the probability scale at the bottom of the figure. These two steps are repeated for each of the five variables in the model. Third, the overall probability is obtained by averaging the individual probabilities obtained from each scale.

Table 1.   The coefficients of the multiple logistic regression model developed by Marras *et al.* (1993) to predict the probability (*p*) of high-risk group membership. The model has an odds ratio of 10.7 (computed with weighted means) and a confidence interval between 4.9 and 23.6.

Variable	Coefficient	SE
Constant (C)	−3.80	0.67
Lift rate (LR)	0.0014	0.0006
Average twisting velocity (TV)	0.061	0.041
Maximum moment owing to load (M)	0.024	0.004
Maximum sagittal flexion (SF)	0.020	0.012
Maximum lateral velocity (LV)	0.036	0.014

$$p = 1/\{1 + \exp[-(-3.80 + 0.0014(LR) + 0.061(TV) + 0.024(M) + 0.020(SF) + 0.036(LV))]\}.$$

Two analyses were performed. The first analysis included jobs from the database in which the IR200K was equal to zero and the turnover rate was greater than zero. In this analysis 51 jobs formed the first 'high'-risk group. The second analysis expanded the high-risk group by including jobs which, in addition to having turnover, had an IR200K which was greater than 0 but less than 12. This revised definition resulted in 124 jobs being included in the second high-risk group. In both analyses the 'low'-risk group contained jobs in which the IR200K and the turnover rate were zero. Data were

tested with the model to establish whether high- and low-risk LB-CTD groups were discernible in these data sets. The modelling results are reported in terms of the resulting odds ratios.

3. Results

The means and standard errors for the five variables used in the modelling are shown in table 2 as a function of the risk groupings. The frequency distribution of the turnover data used in the first analysis is shown in figure 2. Where the IR200K was constrained to zero, the multiple logistic regression model yielded an odds ratio of 5·2 with a confidence interval of 3·3 to 8·2. This indicates that jobs showing turnover, even in the

Table 2. Means (M) and standard error of the mean (SE) for variables used in the Marras *et al.* (1993) model for the low-risk group (no turnover and no LB-CTD incidence), $n = 124$, and the turnover groups used in the first and second analysis, $n = 51$ and 130, respectively.

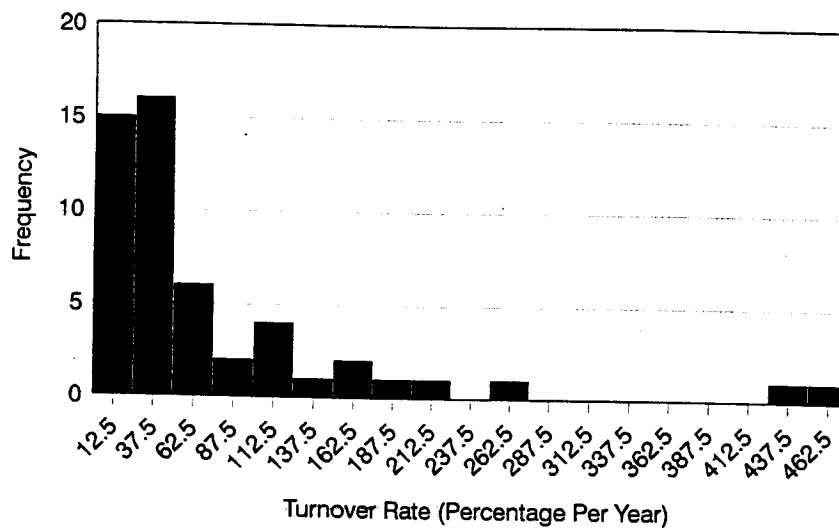| Variable	Statistic	Low-risk group	High-risk group 1	High-risk group 2
Lifts/h	M	183	118	266
	SE	16	15	28
Twisting velocity (°/s)	M	6·5	8·4	10·5
	SE	0·28	0·72	0·65
Moment (N–m)	M	22·2	94·7	74·6
	SE	3·3	14·8	7·3
Forward flexion (°)	M	8·7	17·1	18·6
	SE	1·5	1·9	1·5
Lateral bending velocity (°/s)	M	36·7	40·4	43·8
	SE	1·2	1·6	1·7

Figure 2. A frequency distribution of annual turnover rates for the jobs used in the first analysis in which there was turnover but no LB-CTD history.
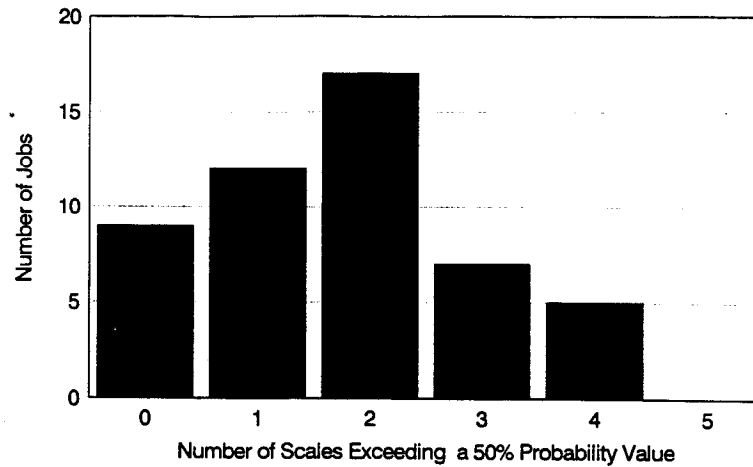
Figure 3.   A frequency distribution of the 51 jobs in which there was turnover and no LB-CTD history according to the number of scales in Marras *et al.* (1993) model which exceeded the 50% probability value. This figure shows that most of the jobs with turnover had one or more risk factors above the 50% probability level based on the scales in the Marras *et al.* (1993) model.

absence of any injury, are likely to possess many of the characteristics associated with LB-CTD. For each of the 51 jobs used in this analysis the probability of high risk group membership was computed based on the model. The distribution of these probabilities ranged from 4·6% to 80·7% with a mean value of 38%. However, the correlation between a job's turnover rate and its probability of high-risk group membership was near zero ($r = -0.21$). This indicates that there is no simple monotonic relationship between these two quantities.

A further analysis with the Marras *et al.* (1993) model showed a number of jobs in this sample containing risk factors which individually yielded probability values greater than or equal to 50%. Figure 3 shows the distribution of these jobs according to the number of scales at or above the fiftieth percentile mark.

The second analysis of the expanded data set which included jobs with moderate IR200K values yielded an odds ratio of 11·0 with a confidence interval of 4·3 to 29·0. This indicates that when turnover is present in jobs with a moderate incident rate it is even more likely that these jobs contain characteristics indicative of a high LB-CTD risk.

4.   Discussion

The analysis in this paper showed that jobs with turnover likely will contain components similar to those found in high LB-CTD risk jobs. It is clear from figure 3 that many of these jobs contain high risk components. While turnover is not a redundant measure of incident rate it may serve as a forecasting tool, thus making it useful for surveillance programmes. For example, this analysis suggest that if turnover was prevented from occurring owing to a change in policy or the presence of a more senior and stable work force in the facility, the low back injury problem would quickly surface in several instances.

The above view is supported by an analysis that compared the model's ability to discriminate jobs based on a composite risk measure composed of the incidence rate,

the days lost, and the restricted time (Marras *et al.* 1994). These researchers classified the jobs that had composite risk measures within the central 50% of the resulting distribution as 'medium' risk jobs. When these data were compared with the low-risk jobs from this distribution, the logistic regression model resulted in an odds ratio of 6·3. Note the similarity in odds ratios between jobs which have turnover but no reported incidence and those which have a moderate composite risk measure. Likewise, the jobs classified as high risk with the composite risk measure showed similar odds ratios (10·6 and 11·0) to those jobs used in the second analysis for the current paper, where turnover and moderate incidence rates were encountered. Thus, these comparisons suggest there is a trade-off between turnover and LB-CTD incidence.

Turnover is clearly affected by numerous factors beyond the biomechanical considerations raised in this paper. For example, it is likely that turnover is sensitive to the same psycho-social factors as is the reporting of back injury (Bigos *et al.* 1991). This may in part explain why there is no simple monotonic relationship between turnover rate and low-back disorder risk. Another factor perhaps preventing the emergence of such a relationship is the noisy source for the turnover data. It is likely that the supervisors would be more accurate when turnover rates were low, thereby creating inconsistencies in the data when turnover rates were high. However, it should be noted that these individuals identified the turnover well enough for the current model to discriminate between jobs with and without risk factors for LB-CTD. Had turnover records been available, it is anticipated that the model's performance would have been further enhanced.

Passive surveillance programmes are typically based only on reported incidents. Such programmes are often plagued by the so-called 'healthy worker effect' (Andersson 1991). This effect is where individuals change jobs or occupations prior to reporting injury. As a result injury rates are lower than expected in the more strenuous jobs and higher than expected in the less strenuous jobs. If only injury data are used in the surveillance programme at such a facility, the jobs which are responsible for the back injuries may not be correctly identified. Once again, the use of turnover rates as a risk variable provides the surveillance programme with the supplemental information necessary to correctly identify hazardous jobs. Perhaps more importantly, it would prevent these jobs from being considered as light duty for those returning to work following injury rehabillitation.

It is interesting to note that most managers frequently knew which jobs had high turnover. The same was not true for injury statistics, especially if there was no lost time associated with the reported incident. This may in part be due to the costs and problems facing management when there are unskilled employees performing the jobs in which there is substantial turnover. These costs include reduced product quality, repeated training, reduced production in job shop environment or the slowing of an assembly line operation, increased waste, and time spent reworking products.

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