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Low Back Pain Recurrence in Occupational Environments

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Study Design. Prospective assessment of return to work after low back pain.

Objective. To determine which factors or combination of factors best predict recurrence of low back pain (defined 4 different ways) when returning to full-duty work.

Summary of Background Data. Recurrent back pain is one of the more costly health problems facing industry today. Few systematic evaluations of the various factors suspected of exacerbating low back pain have been reported in the literature.

Methods. A total of 206 workers who reported low back pain were evaluated as they returned to full-duty work. Five types of assessments were performed including: 1) a low back kinematic functional assessments, 2) evaluation of job physical demands, 3) psychosocial assessment of the job environment, 4) self-reported impairment including perception of symptoms and psychological measures, and 5) personal (individual) factors. One year after return to full duty workers were interviewed to assess who had a recurrence of low back pain according to 4 different definitions of low back pain (symptom reports, medical visits, self-reported lost days, and employer-reported lost days due to back pain). Multiple logistic regression models were developed to assess the best combinations of predictors.

Results. The most liberal definition of recurrence, recurrent symptoms, had a significantly greater recurrence rate at 58% than all other outcome measures ($P = 0.0001$). The medical visit recurrence rate of 36% was significantly greater than the more conservative lost time measures ($P = 0.0001$). The recurrence rate for self-reported lost time was 15%, whereas the more conservative employer confirmed lost time measure was significantly lower at 10% ($P = 0.0077$). Multivariate predictive models associated with the various recurrence definitions yielded sensitivities varying between 78% and 80% and specificity between 73% and 80%.

Conclusion. Recurrence is greatly dependent on how one defines recurrence with symptom reporting yielding 5.5 times as many recurrences compared with employer confirmed lost time. In general, more quantitative measures of worker musculoskeletal function yielded the best predictions of recurrence when predicting the more restrictive definitions of recurrence (employer confirmed lost time).

Key words: low back pain, recurrence, functional assessment, prospective evaluation, secondary back pain.
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Recurrent low back pain (LBP) represents a major challenge for both the medical community as well as for the industrial sector. Recurrence is common with rates as great as 78% within a year of the original documentation of pain.[1] However, more modest recurrence rates are typically reported in most industrial settings.[2–12] Recurrence is also associated with substantial monetary costs. MacDonald *et al* report that the median disability costs associated with recurrent back pain episodes were greater than those for nonrecurrent LBP.[7] A recent analysis of the Washington State Workers' Compensation data indicated that "gradual onset" (chronic) back injuries represent two thirds of the award claims and 60% of lost workdays attributed to back injuries.[13] In addition, analysis of low back related workers' compensation claims in Ohio indicate that 16% of the back injuries accounted for 80% of back injury costs. In-depth evaluations revealed that "these high cost back injuries typically result from reinjury (exacerbation) of an existing condition."[14] Hence, recurrent LBP represents a large and costly problem.

One of the significant problems with interpreting recurrence rates concerns the lack of a standardized definition for recurrence. Some have proposed additional lost work time as a standard definition of recurrence.[15–17] Others have defined recurrence as reports of an additional claim within a given period of time.[7] Still others report recurrence as a function of pain symptom reports.[17] Hence, the definition of LBP recurrence should play a pivotal role in assessing predictors of recurrent LBP.

The causal mechanisms behind LBPs are thought to be multidimensional, complex, and most likely, interactive, with contributing factors associated with the genetics and physiologic characteristics of the individual,[18–22] individual conditioning,[23,24] physical work requirement,[13,25–27] psychosocial factors,[28–32] and biochemical factors.[33–37] Few LBP reports can be associated with a specific anatomic problem. LBP causality ranges from muscular problems, to structural problems within the

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spine, to up-regulation of cytokines at a specific site, and often is unknown. Each of these mechanisms may or may not initiate pain and each may have a very different potential for recurrence. Because of the complexity and many potential sources or initiators of pain, it has been difficult to assess predictors of recurrence.

Given the spectrum of factors that might potentially influence LBP recurrence, we are faced with a void in that we do not understand how the mixture of exposures to various factors might influence the risk of LBP recurrence. It is hypothesized that the factors influencing the risk of LBP recurrence may change as a function of the definition of recurrence. Furthermore, we would expect that as the definition of recurrence becomes more restrictive the predictors of recurrence may become more objective. Thus, the goal of the current study was to prospectively monitor workers who had reported a LBP episode as they returned to full duty work and determine, quantitatively, which factors and how much exposure to the contributing factors play a role in predicting LBP recurrence as a function of 4 common definitions of LBP (symptoms, medical visits, lost time, and confirmed lost time) over the course of a 1-year period.

■ Methods

Approach. A prospective study was designed to monitor industrial workers over the course of a 1-year period after returning to their full duty jobs following a LBP report. When workers returned to full duty, 5 types of baseline assessments were performed including: 1) a low back kinematic functional assessment, 2) evaluation of the job physical demands, 3) psychosocial assessment of the job environment, 4) self-reported impairment, including perception of symptoms and psychological measures, and 5) personal factors, including anthropometry and LBP history. Workers were monitored for 1-year after their return to full duty work in order to assess recurrence according to 4 different definitions of LBP recurrence consisting of recurrence of symptoms, medical visits, self-reported lost time, and confirmed lost time with company records.

Industry Participation. Forty-one industrial facilities in the Midwestern United States participated in the study. The population of workers represented both manufacturing and service industry jobs. Industries represented in this sample included auto manufacturing, truck manufacturing, metal stamping, material processing, food processing, pharmaceutical processing, printing, health care, construction, appliance manufacturing, lawn equipment manufacturing, and distribution.

Company records were examined in order to identify work-related LBP cases. A company representative approached the worker with LBP regarding participation in the study. If the worker agreed to participate, a time was scheduled for the research team to visit the plant and collect data about the job, worker, and the work environment.

Subjects. A total of 206 workers with documented LBP participated in the study. The inclusion criteria consisted of: 1) the worker sought medical care for work-related LBP at the plant medical department or associated medical provider, 2) the worker had experienced time away from their regular duty job due to the LBP, and 3) worker returned to full-duty work. The exclusion criteria were: 1) worker was still on job restrictions or 2) multiple injury sites were in the pain complaint. The average number of lost days for the reported episodes of back pain, within this population, was 12.7 (SD = 43.4).

The NASS questionnaire was used to assess back and leg pain frequency of the subject population over the past week before participating in the study. The baseline questionnaire results indicate that 92% of participants reported at least a little LBP in the past week, 69% experienced at least a little leg pain in the past week, 59% had at least a little numbness in the leg or foot, and 56% reported at least a little weakness in the leg. All participants had been treated with conservative care management (no surgical patients) for their back pain. Baseline summaries of job and other health status measures collected at the time of return to full duty work are reported in Table 1.

Experimental Design. A prospective study design was used to assess which baseline variables collected at the time workers returned to full-duty work best predicted LBP recurrence. Baselines measures consisted of 5 categories of measures representing individual (personal) factors, self-reported perceptions of impairments and symptoms, quantitative assessments of their kinematic abilities, psychosocial impressions of the workplace, and physical requirements of the workplace. Workers and their employers were contacted a year after they had returned to the workplace to determine who had a recurrence of LBP according to 4 different definitions of LBP.

Baselines Measures. Among the 5 categories of baseline measures assessed in this study, 168 variables were measured. All measures were assessed at the time the worker returned to work full-duty.

Kinematic Functional Assessment. A kinematic assessment of the lumbar spine was performed using a methodology that compared lumbar range of motion, velocity, and acceleration performance while moving in the 3 cardinal planes as well 5 controlled motions in the sagittal plane. These responses were compared with a normative database of performance controlled for age and gender. This method has been described and validated in the literature.[38–42]

Workplace Physical Demands. The physical demands of the job to which the worker returned were documented *via* a risk model that included load magnitude and frequency exposure as well as the kinematic demands of the job.[43,44] The risk model has been also been previously described and validated.[45]

Table 1. Baseline Measures

Baseline Measure	Mean	SD
Job risk	0.51	0.18
Probability of normal	0.21	0.25
McGill pain present pain intensity	1.46	1.04
Million Visual Analog Score	50.0	27.2
SF-36		
Physical Function	66%	27%
Role Physical	52%	43%
Bodily Pain	51%	21%
General Health	68%	25%
Vitality	51%	22%
Social Functioning	76%	25%
Role Emotional	72%	39%
Mental Health	80%	14%

Personal Characteristics. A variety of personal attributes were recorded based on assessments of the literature relative to causality.[13] These attributes included gender, age, marital status, race, education, smoking, hours worked, history of previous LBP, overtime, restricted time, lost days, and a host of anthropometric variables.

Self-reported Impairment Scales. Three questionnaires were used to understand the workers perceptions of their impairment and health status. The McGill pain questionnaire[46] was used to measure pain symptoms. Next, the Million Visual Analog Scales (MVAS)[47] was used to measure impairment of activities of daily living. Finally, the SF-36 health survey was used to collect individual factors.[48]

Psychosocial Factors. Psychosocial factors were evaluated with 3 questionnaires: the Job Content Questionnaire,[49] the NIOSH Generic Job Stress Questionnaire,[50] and the Perceived Stress Scale.[54]

Procedure. As workers recovering from LBP returned to their full-duty jobs, they were enrolled into the study. The research study was explained to the worker, and they agreed to participate in the study by signing a consent form approved by the University Institutional Review Board. Questionnaires were administered in a quiet environment and the workers were allowed to ask questions of clarification. Kinematic functional assessments were performed in the same environment and required the subject to interact with a computer while wearing a back monitor per procedures that have been described in the literature previously.[41] Finally, job assessments were performed at the work site using the risk model also previously described and validated.[43–45] In order to ensure that the job risk measures were not influenced by the kinematic abilities of the worker who had recently experienced LBP, another worker (without a history of LBP) was also used as a test subject in assessing physical job risk.

The average age, height and weight for the healthy controls was 40.7 (11.2) years, 175.8 (8.5) cm, 83.8 (16.7) kg, and for the returning workers 41.8 (10.3) years, 174.4 (8.1) cm, and 84.6 (19.4) kg, respectively. The healthy control group had 78% males, whereas the recently injured workers had 74% males. Table 2 lists the mean and standard deviation of anthropometric characteristics for both groups as well as *P*-values indicating significant differences. Previously reported analyses indicated that the worker kinematic status had no influence on the estimate of job risk.[51] Workers were given a T-shirt for participating in the study.

Table 2. Anthropometric Measures for Healthy Controls and Workers Returning to Full Duty After Low Back Pain

Anthropometric Measures	Low Back Pain	Healthy Controls	Paired *t* Test (*P*)
Age	41.8 (10.3)	40.8 (11.3)	0.1084
Weight (kg)	84.6 (19.4)	83.8 (16.8)	0.5155
Standing height (cm)	174.4 (8.1)	175.8 (8.6)	0.0684
Shoulder height (cm)	145.0 (7.3)	145.8 (7.7)	0.2665
Elbow height (cm)	109.1 (5.5)	109.2 (6.0)	0.8693
Trunk length (cm)	51.6 (4.5)	52.6 (5.1)	0.0156*
Trunk breadth (cm)	33.2 (3.8)	32.7 (3.6)	0.1368
Trunk depth (cm)	26.9 (5.2)	26.5 (4.9)	0.3647
Trunk circumference (cm)	98.5 (17.2)	96.8 (17.0)	0.2062
Gender	73% males	78% males	0.1661

Values are mean (SD).
*Significant difference at $P = 0.05$.

LBP Recurrence Definitions. The outcome measures in this study consisted of 4 different definitions of LBP recurrence. All recurrence definitions were specific to the 1-year follow-up period and related to LBP. These definitions consisted of:

1. LBP symptoms reported by self-reports (most liberal definitions of LBP recurrence).
2. Self-reported visit to a medical facility for LBP (slightly more stringent definition of recurrence).
3. Self-reported lost workdays due to LBP (the next most stringent definition of recurrence).
4. Lost workdays confirmed by the employer and associated with LBP (the most restrictive definition of recurrence).

Statistical Analysis. Several analyses were performed to assess the significance of the variables in identifying recurrence. First, univariate *t*-tests compared the potential predictor variables between subjects who had a recurrence and those who did not (*t*-tests for continuous variables, z-test comparison of 2 proportions for 0–1 [recurrence] variables). Second, Classification using Regression Trees (CART)[52] was used to develop various combinations of variables to predict each recurrence measure. CART is unique and powerful in that it provides a "threshold" or "cut-point" for each continuous variable in the combination variables that best distinguished between recurrence and nonrecurrence cases based on each definition of recurrence. The cut-points from CART were used to dichotomize the continuous predictor variables to use in logistic regression. The third analysis technique used was logistic regression with dichotomous predictors. Univariate logistic regression was performed on variables that were selected by CART. Finally, a multivariate logistic regression model was chosen based on interpretability (variables and direction of effect) and maximum sensitivity and specificity. Sensitivity and specificity were estimated using the n-fold cross-validation procedure in SAS PROC LOGISTIC.

■ Results

A total of 196 of the original 206 (95%) workers were available for the 1-year follow-up. Recurrent symptoms, the most liberal definition of recurrence, had the highest recurrence rate at 58%, medical visits, the second most liberal definition, had a recurrence rate of 36%. Self-reported lost time, a somewhat restrictive measure of recurrence, had a 15% recurrence rate, and confirmed lost time, the most restrictive measure of recurrence, had a recurrence rate of 10%. χ^2 pairwise comparison indicated that all recurrence rates were significantly different from one another. Table 3 lists the recurrence rates and illustrates the monotonic decrease in recurrence that occurred as the definition of recurrence became more conservative.

Univariate statistically significant differences between the workers experiencing a recurrence and those who did not experience a recurrence over the 1-year follow-up period are reported in Tables 4 through 8 for measures of personal/anthropometric attributes, symptom and psy-

Table 3. Recurrence as a Function of Low Back Pain Definition

Definition of Recurrence	Yes	%
Have you had back pain symptoms?	114	58
Have you visited a medical provider for back pain?	71	36
Have you taken a day off due to back pain?	29	15
Workplace confirmation of lost day due to back pain for the worker	20	10

chologic measures, kinematic functional assessments, psychosocial measures, and physical workplace measures, respectively. Several general observations are worthy of mention. First, Table 4 indicates that marital status and education are the only statistically significant personal factors that distinguished between recurrence and nonrecurrence for confirmed lost time, whereas overtime, restricted days, and lost days (with *P*-values of 0.0136, 0.0019, and 0.0020, respectively) were also significant factors for more liberal definitions of recurrence. Second, Table 5 indicates that 10 of 18 subjective symptom questionnaire measures were significantly different for all definitions of recurrence. Third, *P*-values reported in Table 6 illustrate that confirmed lost time had the highest number (26) of significantly different objective functional assessment measures, whereas the most liberal definition of symptoms had the least.[11] Fourth, Table 7 shows that none of the psychosocial workplace measures yielded statistically significant differences for any of the LBP recurrence definitions. Finally, Table 8 showed that none of the physical workplace measures was significantly different for the most restrictive definition of recurrence (confirmed lost time), whereas 18 of the physical workplace measures were significantly different for the most liberal definition of recurrence (symptoms).

Table 4. Significance (*P*-values) for Each Personal and Anthropometric Measure Shown as a Function of the Definition of Recurrence

Personal/Anthropometric Measures	Pain	Medical Visit	Lost Time	Confirmed Lost Time
Gender	0.3157	0.3200	0.3291	0.3311
Age	0.2922	0.1175	0.6799	0.3504
Marital status	0.4696	0.6180	0.0436*	0.0446*
Race	0.3177	0.3215	0.3250	0.3254
Education	0.7423	0.6147	0.0450*	0.0436*
Smoking	0.4679	0.5954	0.5635	0.5254
Hours worked	0.0145*	0.0197*	0.7645	0.2191
History of previous LBP	0.2367	0.1101	0.2938	0.1443
Overtime	0.0136*	0.018*	0.7694	0.2116
Restricted days	0.0019*	0.0201*	0.0386*	0.0502
Lost days	0.002*	0.0156*	0.0311*	0.0593
Weight of person	0.6133	0.8641	0.3421	0.3407
Standing height	0.8500	0.8248	0.1563	0.6102
Shoulder height	0.5290	0.2167	0.3018	0.8124
Elbow height	0.4754	0.6017	0.2014	0.7808
Upper leg	0.8861	0.2175	0.3602	0.5818
Lower leg	0.9400	0.4110	0.5092	0.6478
Upper arm	0.2939	0.1023	0.2852	0.5875
Lower arm	0.4663	0.4760	0.7387	0.9763
Trunk length	0.2115	0.6208	0.7163	0.5339
Trunk breadth	0.3005	0.9489	0.3176	0.3862
Trunk depth	0.3751	0.9736	0.8400	0.4581
Trunk circumference	0.2312	0.6145	0.9126	0.7571

A statistically significant difference indicates the variable is associated with a difference between recurrence and nonrecurrence.
*Significance at $P = 0.05$.

Table 5. Significance (*P*-values) for Each Symptom and Personality Measure Shown as a Function of the Definition of Recurrence

Subject Symptoms and Psychological Measures	Pain	Medical Visit	Lost Time	Confirmed Lost Time
Million Visual Analog Score	0.0001*	0.0001*	0.0004*	0.0001*
NASS	0.0001*	0.0001*	0.0054*	0.0148*
SF-36 Physical Function	0.0001*	0.0008*	0.0069*	0.0056*
SF-36 Role Physical	0.0007*	0.0208*	0.0394*	0.0403*
SF-36 Bodily Pain	0.0021*	0.0032*	0.0113*	0.0021*
SF-36 General Health	0.0092*	0.0032*	0.0561	0.2602
SF-36 Social Functioning	0.0852	0.1043	0.1327	0.0992
SF-36 Role-Emotional	0.0028*	0.4910	0.3399	0.1607
SF-36 Mental Health	0.1821	0.5148	0.6738	0.4405
SF-36 Reported health transition	0.2104	0.3561	0.0018*	0.0084*
SF-36 Vitality	0.0255*	0.0194*	0.0026*	0.0118*
SCL-90 Depression	0.0112*	0.0775	0.2896	0.9900
MPQ Present Pain Intensity	0.0001*	0.0005*	0.0021*	0.002*
MPQ Sensory	0.0147*	0.0452*	0.0097*	0.0107*
MPQ Affective	0.0286*	0.0828	0.0803	0.0351*
MPQ Evaluative	0.0086*	0.0335*	0.0239*	0.0027*
MPQ Supplemental	0.0263*	0.0979	0.0007*	0.0014*
MPQ Total	0.0077*	0.0332*	0.0029*	0.0038*

A statistically significant difference indicates the variable is associated with a difference between recurrence and nonrecurrence.
*Significance at $P = 0.05$.

The multiple logistic regression models predicting LBP recurrence based on the various recurrence definitions are shown in Table 9. This table shows the combination of variables that best distinguish between those patients who experience a LBP recurrence as a function of 4 definitions of LBP recurrence. The values in the table represent the cut-off values for each outcome variable (in combination with other outcome measures), which provides the best distinction between recurrent and nonrecurrent groups. Figure 1 shows an example of how CART was used to identify the combination of variables that distinguishes between LBP recurrences as defined by self-reported lost time. The multiple logistic regression models described in Table 9 were selected based on the best sensitivity and specificity and not on the statistical significance of each factor in the model; thus, some individual factors may not be statically significant but were found to improve sensitivity and specificity.[52]

Table 9 indicates that recurrence can be estimated with surprisingly good sensitivity and specificity. In addition, the multivariate models indicate that different variables are important for predicting LBP recurrence as a function of the different definitions. Pain symptoms can be predicted with a sensitivity of 79% and specificity of 73% using a model with 2 self-reported perception of impairment variables, 1 variable from the kinematic functional assessment, physical workplace measures,

Table 6. Significance (*P*-values) for Each Objective Functional Assessment Measure Shown as a Function of the Definition of Recurrence

Objective Functional Assessment Measures	Pain	Medical Visit	Lost Time	Confirmed Lost Time
Probability of normal	0.2140	0.0930	0.1573	0.0112*
Streamline probability of normal	0.0793	0.0181*	0.0065*	0.0001*
Probability of sincerity	0.0532	0.0021*	0.0112*	0.0008*
Sagittal minimum	0.1775	0.3085	0.8242	0.6005
Sagittal maximum	0.1902	0.0797	0.1731	0.4876
Sagittal ROM	0.7930	0.5596	0.3679	0.9098
Sagittal velocity	0.0079*	0.0035*	0.0011*	0.0057*
Sagittal acceleration	0.0098*	0.0019*	0.0075*	0.0038*
Lateral minimum	0.8097	0.0303*	0.2282	0.7008
Lateral maximum	0.0783	0.2861	0.9732	0.5120
Lateral ROM	0.3636	0.0119*	0.2305	0.8724
Lateral velocity	0.0007*	0.0002*	0.0038*	0.0089*
Lateral acceleration	0.0003*	0.0013*	0.0389*	0.0004*
Twisting minimum	0.0005*	0.0001*	0.0041*	0.0089*
Twisting maximum	0.0103*	0.0808	0.4904	0.4500
Twisting ROM	0.0183*	0.0009*	0.0039*	0.0109*
Twisting velocity	0.0015*	0.0004*	0.0173*	0.0119*
Twisting acceleration	0.0016*	0.0009*	0.0337*	0.025*
Sagittal range at 0	0.6817	0.1078	0.0268*	0.2251
Sagittal flexion velocity at 0	0.2159	0.0412*	0.0207*	0.0316*
Sagittal extension velocity at 0	0.1260	0.0111*	0.0144*	0.0188*
Sagittal flexion acceleration at 0	0.2703	0.1684	0.1223	0.0409*
Sagittal extension acceleration at 0	0.1442	0.0671	0.0591	0.0199*
Normalized sagittal range at 0	0.8248	0.0982	0.1837	0.4365
Normalized sagittal flexion velocity at 0	0.8233	0.0499*	0.1686	0.0732
Normalized sagittal extension velocity at 0	0.6821	0.0291*	0.1840	0.0612
Normalized sagittal flexion acceleration at 0	0.8467	0.1965	0.2975	0.0119*
Normalized sagittal extension acceleration at 0	0.6497	0.1246	0.2769	0.0364*
Ability at 15 right	0.4254	0.2603	0.4966	0.3513
Sagittal range at 15 right	0.8787	0.3026	0.028*	0.1106
Sagittal flexion velocity at 15 right	0.7637	0.2422	0.0006*	0.0015*
Sagittal extension velocity at 15 right	0.3991	0.1229	0.001*	0.0324*
Sagittal flexion acceleration at 15 right	0.2640	0.2282	0.0006*	0.0004*
Sagittal extension acceleration at 15 right	0.0707	0.0722	0.0013*	0.0038*
Ability at 15 left	0.0553	0.0278*	0.1368	0.1569
Sagittal range at 15 left	0.0558	0.0036*	0.0014*	0.0037*
Sagittal flexion velocity at 15 left	0.0243*	0.0006*	0.0005*	0.0001*
Sagittal extension velocity at 15 left	0.0414*	0.0038*	0.0013*	0.0021*
Sagittal flexion acceleration at 15 left	0.0632	0.0059*	0.0001*	0.0001*
Sagittal extension acceleration at 15 left	0.0832	0.0142*	0.0007*	0.0009*

A statistically significant difference indicates the variable is associated with a difference between recurrence and nonrecurrence.
*Significance at $P = 0.05$.

and psychosocial measures. The medical visit model also uses at least 1 variable from each category of measures to predict recurrence with a sensitivity of 78% and specificity of 74%. The model of lost time relies heavily on a combination of worker's perception of impairment response and 2 quantitative descriptions of the kinematic capacity of the worker and has a sensitivity of 79% and specificity of 78%. The confirmed lost time model had the best balance between sensitivity and specificity both were 80%.

The predictive ability of the individual variables that entered into the multiple logistic regression prediction models (Table 9) is reported in Table 10. It is important to acknowledge that some of the variables (*e.g.*, supervisor support), while contributing to the multivariate prediction, were not statistically significant by themselves in the multivariate analyses (Table 9), however, when evaluated independently of the other predictors they were significant (Table 10).

■ Discussion

Originally, it was hypothesized that the factors influencing the risk of LBP recurrence may change as a function of the definition of recurrence and that, as the definition of recurrence becomes more restrictive, the predictors of recurrence may become more quantitative or objective. Several of our findings support the hypothesis. First, the univariate *P*-values for the objective functional assessment measures show that more than twice as many objective measures were significant for the more restrictive measure of recurrence (confirmed lost time) as compared with the most liberal (pain) recurrence measure. The univariate analyses of symptom reporting (pain perception) and personality measures (Table 5) indicated several significant factors for all measures of recurrence; however, the most liberal recurrence measures (reported pain) yielded the greatest number of significant measures. Thus, pain perception and attitudes about low back im-

Table 7. Significance (*P*-values) for Each Psychosocial Workplace Measure Shown as a Function of the Definition of Recurrence

Psychosocial Workplace Measures	Pain	Medical Visit	Lost Time	Confirmed Lost Time
Skill discretion	0.8091	0.2245	0.2599	0.6987
Decision authority	0.7029	0.6779	0.3484	0.9689
Decision latitude	0.7128	0.3879	0.2428	0.8254
Physical demand	0.5179	0.4081	0.6376	0.3000
Role conflict	0.8745	0.8893	0.4734	0.2328
Task control	0.2515	0.3418	0.5766	0.4334
Decision control	0.8658	0.6257	0.6196	0.4164
Physical environment control	0.5931	0.6202	0.9302	0.6008
Resource control	0.7945	0.8502	0.2920	0.0967
Job control	0.4212	0.5326	0.4477	0.4299
Supervisor support	0.3240	0.4270	0.2170	0.4263
Coworker support	0.7410	0.6798	0.5027	0.7237
Family/friend support	0.6740	0.5911	0.6415	0.3632
Workload variability	0.4319	0.1565	0.2735	0.5307
Cohen Stress Questionnaire	0.2684	0.4254	0.5942	0.6929
Job satisfaction	0.0652	0.2263	0.0680	0.0753
Subjective physical demands	0.8391	0.6126	0.8117	0.8251

A statistically significant difference indicates the variable is associated with a difference between recurrence and nonrecurrence.
*Significance at $P = 0.05$.

pairment as well as objective functional assessment measures play an important role in predicting recurrence in the univariate analyses. However, the objective functional assessment measures (Table 6) play a larger role in predicting the more restrictive definitions of recurrence (*i.e.*, confirmed lost time).

Second, when variables were considered collectively in the multivariate prediction models, a complex mix of perceptual impairment, psychophysical, kinematic ability, and physical demand variables were able to predict LBP recurrence. Here again, the combination of variables that best predict recurrence is highly dependent on how one defines LBP recurrence. In the model predicting pain, the most liberal definition of recurrence, a broad mix of all combinations of variable categories (*i.e.*, perceptual, workplace, functional status) was used in the prediction; whereas in the model predicting the more restrictive definition of recurrence, lost time, only the subjective impairment and functional assessment measure categories were useful. Hence, this shift from a broad mix of categories that predict the more liberal definition of recurrence to a model using more objective physical measures also supports our hypothesis.

Third, the hypothesis is supported by the univariate odds ratios shown in Table 10. The subjective MVAS, which reveals how the worker feels that their LBP is interfering with activities of daily living, appears in all multivariate LBP recurrence models. However, the strength of the prediction (odds ratio) varied depending on the definition of recurrence. The MVAS measure was not particularly discriminating in identifying recurrent LBP, by itself, producing a sensitivity/specificity of 33%/94% for recurrence defined by pain, 75%/58% for medical visits, 38%/91% for lost time defined recurrence, and 50%/91% for confirmed lost time defined recurrence. Hence, although it was often useful in rejecting recurrent cases, for many of the recurrence definitions, it was not very useful in identifying those at risk of recurrence. On the other hand, Table 10 indicates that a higher-order kinematic variable (sagittal extension acceleration at 15° left asymmetry) was better able to distinguish between recurrence and nonrecurrence as the recurrence definition becomes more restrictive. This is a very quantitative variable that does not distinguish between recurrence and nonrecurrence when the less restrictive definitions are used but yields the highest odds ratios in identifying recurrence when the more restrictive definitions of recurrence are considered (Table 10). This variable yielded a sensitivity/specificity of 86%/61% and 90%/63%, for the lost time and confirmed lost time definitions of recurrence, respectively, thus outperforming the less quantitative variables for the more restrictive definitions of recurrence.

Finally, the hypothesis is supported by the variable importance assigned by CART for each variable and shown in Figure 2. The medical visit and pain reporting models relied heavily on the subjective measures of MVAS and SF-36pf, and had the highest variable importance scores for those definitions. However, when lost time models were considered, the quantitative measures of velocity and acceleration had the highest importance scores. Thus, as the definition of recurrence becomes more restrictive, the more the objective quantitative measures contribute to the model predictions.

It is important to note differences between these findings and some of the previous literature. Surprisingly, the univariate psychosocial factors were not predictive of recurrence, regardless of how it was defined, whereas much of the literature has reported a significant association between these factors and LBP.[29,53,54] This may emphasize that LBP recurrence should be considered as very different in nature from the initial LBP and influenced by very different factors.

The LBP recurrence rates found in this study are similar to some of those found in the literature as a function of the various definitions of recurrence. The most liberal definition, pain symptom recurrence, has been used frequently in the literature. In a cohort of 288 scaffolders, LBP recurrence rates were examined for 3 years, resulting in recurrence rates of 65%, 77%, and 64% in the 1-, 2-, and 3-year follow-up periods.[2] These rates of recurrence are slightly higher than the 58% recurrence rates found in the current study but might be due to the more homogeneous population. Kaaria *et al*[55] examined 902 workers in a metal corporation with follow-up evaluations at 5, 10, and 28 years, resulting in LBP recurrence rates of 75%, 73%, and 88%, respectively. Compared with the current study, Kaaria *et al*[55] found a 30% higher rate of recurrence at the 28-year follow-up, which may be due to the longer follow-up time. Salminen *et al*[56]

Table 8. Significance (*P*-values) for Each Physical Workplace Measure Shown as a Function of the Definition of Recurrence

Physical Workplace Measures	Pain	Medical Visit	Lost Time	Confirmed Lost Time
Lift rate	0.3871	0.3636	0.5584	0.4080
Mean moment	0.4126	0.6152	0.5706	0.1402
Mean load	0.3143	0.4115	0.5924	0.2499
Mean moment arm	0.3485	0.3163	0.1168	0.0728
Mean destination moment arm	0.5730	0.5220	0.2781	0.1447
Mean start height	0.7783	0.0749	0.9815	0.8119
Mean end height	0.3087	0.2062	0.2026	0.4398
Mean minimum lateral position	0.9528	0.9038	0.8588	0.7676
Mean maximum lateral position	0.0876	0.5923	0.4078	0.5601
Mean job lateral range of motion	0.0303*	0.5664	0.5695	0.8005
Mean minimum sagittal position	0.0116*	0.7018	0.8392	0.7859
Mean maximum sagittal position	0.2286	0.6619	0.3264	0.5752
Mean job sagittal range of motion	0.2247	0.8381	0.3247	0.6214
Mean twist left	0.4410	0.009*	0.3044	0.7405
Mean twist right	0.0946	0.5402	0.5855	0.2814
Mean twist range of motion	0.0054*	0.0538	0.1813	0.2770
Mean average lateral velocity	0.0028*	0.0354*	0.4264	0.6704
Mean maximum lateral velocity	0.0806	0.1563	0.3693	0.6804
Mean average sagittal velocity	0.0128*	0.1082	0.7802	0.7903
Mean maximum sagittal velocity	0.0904	0.1190	0.1630	0.4161
Mean average twisting velocity	0.0081*	0.0266*	0.3136	0.3748
Mean maximum twisting velocity	0.0012*	0.0065*	0.0575	0.2423
Mean maximum lateral acceleration	0.005*	0.0680	0.2385	0.6588
Mean maximum sagittal acceleration	0.0059*	0.1133	0.1455	0.4928
Mean maximum twisting acceleration	0.0032*	0.0074*	0.1078	0.3993
Peak load	0.4305	0.6938	0.5441	0.2141
Peak moment arm	0.4298	0.1740	0.1144	0.1270
Peak destination moment arm	0.6196	0.4553	0.3492	0.4211
Peak start height	0.8046	0.1862	0.4947	0.5788
Peak destination height	0.8188	0.1573	0.1525	0.6519
Peak minimum lateral position	0.8503	0.9965	0.4907	0.5199
Peak maximum lateral position	0.3463	0.4207	0.5841	0.5477
Peak job lateral range of motion	0.0729	0.3933	0.9546	0.7535
Peak minimum sagittal position	0.0601	0.6157	0.6665	0.9632
Peak maximum sagittal position	0.0314*	0.3775	0.2062	0.3442
Peak job sagittal range of motion	0.1308	0.1940	0.1408	0.3487
Peak twist left	0.1941	0.1316	0.8186	0.7251
Peak twist right	0.1752	0.2994	0.4420	0.5685
Peak twist range of motion	0.0101*	0.0107*	0.1688	0.3456
Peak average lateral velocity	0.0027*	0.0115*	0.7038	0.7465
Peak maximum lateral velocity	0.0004*	0.0770	0.4259	0.6761
Peak average sagittal velocity	0.0649	0.0750	0.7865	0.6345
Peak maximum sagittal velocity	0.0137*	0.0106*	0.0069*	0.0611
Peak average twisting velocity	0.1053	0.0985	0.3351	0.4046
Peak maximum twisting velocity	0.0248*	0.0304*	0.0423*	0.2119
Peak maximum lateral acceleration	0.0027*	0.1172	0.7716	0.7104
Peak maximum sagittal acceleration	0.1448	0.1809	0.0915	0.3008
Peak maximum twisting acceleration	0.0465*	0.0471*	0.1074	0.4113
LMM job risk	0.1434	0.4836	0.5213	0.6165
Peak moment	0.2956	0.8363	0.4226	0.1377

A statistically significant difference indicates the variable is associated with a difference between recurrence and nonrecurrence.
*Significance at $P = 0.05$.

examined teenagers with LBP symptoms, a 35% recurrent or continuous symptom rate was found at an 8-year follow-up. The low rate of recurrence in the Salminen *et al* study may be due to the study population. Thus, the LBP recurrence rates found in the literature are highly variable and may be dependent on the sample population as well as length of follow-up. However, our 58% pain symptom recurrence rate was generally comparable to previous reports.

Medical visits, the second most liberal outcome measure of recurrence, have been cited much less frequently in the literature. Shekelle *et al*[57] examined medical records of 3105 adults during 3 to 5 years and found that 29% sought treatment for more than 1 episode of LBP (recurrent LBP). Thus, our 36% recurrence rate for medical visits was slightly greater than that reported in the literature.

The lost time recurrence rates reported here (15% and 10% for confirmed lost time) are also comparable with those found in the literature. Taimela *et al*[58] investigated a group of 125 occupational LBP patients and found that 11% reported having lost at least 1 day of work during a 2-year follow-up. MacDonald *et al*[7] investigated over 100,000 low back claims of workers compensation and

Table 9. Variables Used in the Multivariate Models That Collectively Best Distinguish Between Low Back Pain Recurrence and Nonrecurrence as a Function of the Various Definitions of Recurrence

Model Parameters	Pain	Medical Visits	Lost Time	Confirmed Lost Time
Million Visual Analog Score	72.0*	45.0*	86.0*	86*
SF-36 Physical Function	26.5*			
Sagittal flexion velocity at 15 left		11.2*		
Sagittal extension acceleration at 15 left			63.1*	59.8*
Sagittal range of motion at 0			33.4*	
Clinical lateral velocity (°/s)	48.9*			
Lateral acceleration demand to capacity				1.44
Mean load (kg)		88		
Mean moment (Nm)	36			
Hours worked		48*		
Supervisor support	3.38			
Workload variance		2.84		
Role conflict				2.82
Sensitivity (%)	79	78	79	80
Specificity (%)	73	74	78	80
Decision rule >	0.54	0.38	0.16	0.16

*Significance for univariate analysis ($P > 0.05$).

found that 14% of claimants had file more that 1 LBP claim. These results facilitate our understanding of how rates of recurrence vary within an industrial population as the definition of recurrence changes.

These analyses may also provide insight into causality associated with recurrent LBP. Several points are noteworthy in this respect. First, perhaps the most useful point associated with recurrence prediction is the ability to define categories of variables that contribute to the prediction of recurrence. In these analyses, we included all categories of variables that might predict recurrent LBP based on the literature. As discussed earlier, different combinations of variables predict different definitions of recurrence. This confirms some previous contentions,[15–17] suggesting difficulty in interpreting much of the recurrence literature unless the definition of recurrence is clearly defined.

Second, we identified the specific categorical variables that produced the best models of recurrence. Our goal in model building was to produce models with the least number of variables but that distinguished best between recurrence and nonrecurrence. The nature of multivariate procedures (*i.e.*, CART) is such that, even though 1 variable appears in the model, it represents other variables through their underlying intercorrelations. For example, although sagittal extension acceleration was chosen as a variable in the logistic regression model, other kinematic variables derived from this test may also be well correlated with the recurrence event; however, this variable is the one that best represents the combination of underlying variables associated with recurrence. Therefore, it is important to consider the categories of variables that best represent recurrence when exploring recurrence causality.

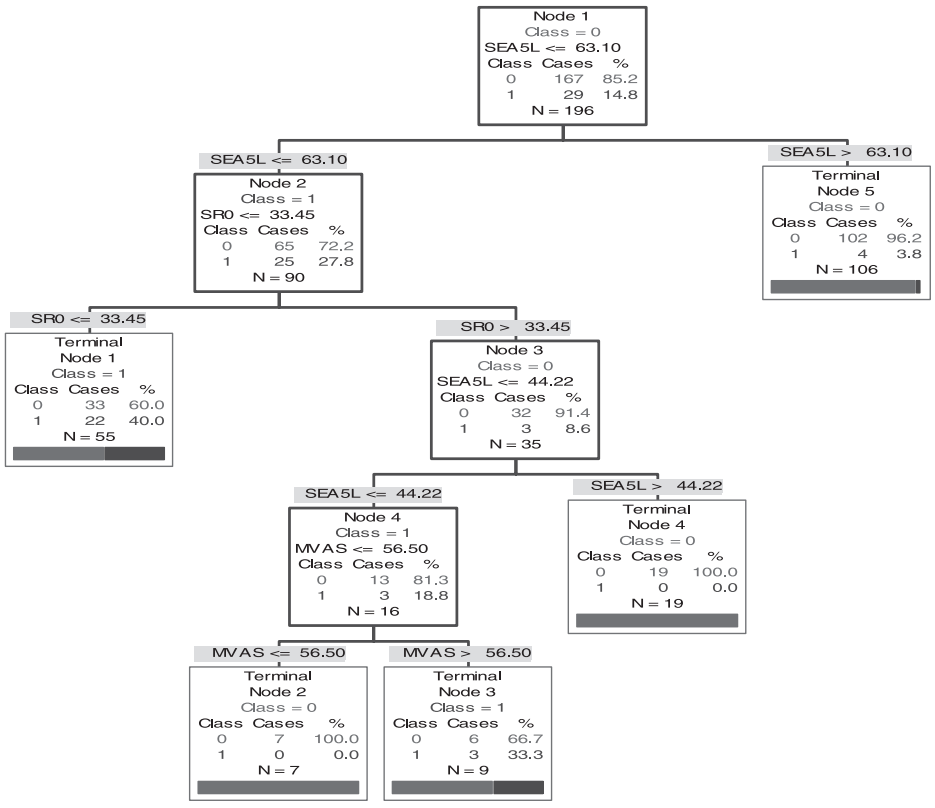

Figure 1. An example of CART assessment for LBP recurrence as defined by self-reported lost time.

Table 10. Univariate Odds Ratios and (95% Confidence Intervals) for Variables That Entered the Recurrence Prediction Models

Model Parameters	Pain	Medical Visits	Lost Time	Confirmed Lost Time
Million Visual Analog Score	7.70 (2.88–20.62)	4.13 (2.17–7.86)	6.19 (2.47–15.52)	10.00 (3.62–27.62)
SF-36 physical function	6.29 (3.14–12.59)			
Sagittal flexion velocity at 15 left		4.18 (2.22–7.86)		
Sagittal extension acceleration at 15 left			9.81 (3.26–29.47)	15.37 (3.46–68.37)
Sagittal range of motion at 0			2.84 (1.10–7.34)	
Clinical lateral velocity (°/s)	3.85 (2.08–7.16)			
Lateral acceleration demand to capacity				6.53 (1.47–29.00)
Mean load (kg)		1.53 (0.84–2.78)		
Mean moment (Nm)	1.01 (0.58–1.79)			
Hours worked		2.79 (1.50–5.17)		
Supervisor support	3.39 (1.23–9.31)			
Workload variance		2.32 (1.28–4.26)		
Role conflict				2.91 (0.65–13.04)

With this understanding in mind, we observe that in the less restrictive definitions of recurrence *all* classes of categorical variables play a role. It is interesting to note that some of these variables, by themselves (*e.g.*, psychosocial factors), do not play a role in identifying recurrence. However, when combined with other workplace, kinematic functional abilities, and perception of pain variables, they can identify pain reporting or visits to medical facilities well. Hence, pain reporting and experiencing symptoms severe enough to seek medical attention are influenced by a number of psychometric impairment and physical factors, supporting a biopsychophysical model of pain, whereas kinematic functional assessments played a major role along with perception in identifying lost time and confirmed lost time definitions of recurrence.

Third, the increasing importance of the kinematic functional assessments as a function of more restrictive definitions of recurrence (indicated by the generally increasing odds ratios) suggest a greater biomechanical role in the causality of more restrictive definitions of recurrence. While the workplace analyses indicated that most jobs to which workers returned would be classified as moderate risk,[43,44] laboratory assessments of deficits in kinematic abilities have reported much greater spine loading of patients who had kinematic impairments compared with patients who possessed greater kinematic capacities.[59] Hence, collectively, these findings suggest that patients returning to the workplace with less kinematic capacity were experiencing greater spine loadings as they performed their regular jobs. This suggests caution in early return to work unless the patient's kinematic functional abilities are near-normal when they return to even moderately demanding jobs.

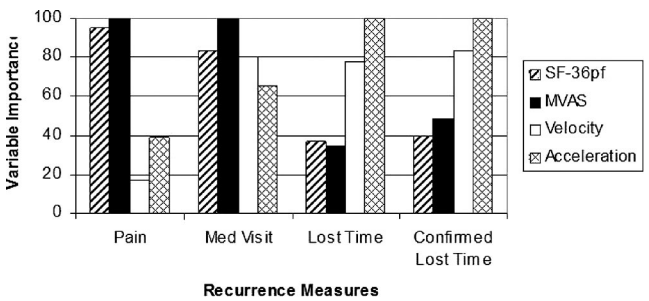

Figure 2. Variable importance as determined by CART.

Several potential limitations must be considered to place this study in perspective. First, it must be reemphasized that this study focuses exclusively on LBP recurrence. These findings may have little relevance to the initial LBP report. Thus, although a large literature exists that indicates the importance of psychosocial factors in LBP development, they might not be as important, by themselves, for recurrence. Second, the workplace evaluations indicated that 58% of the jobs to which patients returned could be classified as moderate risk. A more uniform distribution of risk exposures might have yielded more of an impact of workplace physical variables. Third, the reduction in the number of patients associated with the different recurrence definitions may have been influenced by different policies among the various companies participating in this study. Some companies may encourage reporting or have liberal policies as to what is constitutes a lost day, whereas other companies may discourage reporting and not consistently identify lost days. Fourth, the overall sample size was modest and the duration of follow-up time was relatively short. A longer follow-up time as well as larger sample size may influence the recurrence rates as well as recurrence predictions. Finally, the issue of LBP reports being a new or recurrent episode is always a problem in these types of studies. However, the wording of our questionnaires was careful to distinguish between LBP recurrences *versus* a new LBP problem.

■ Conclusion

LBP recurrence rates vary dramatically depending on the definition of recurrence, with the most liberal definitions of recurrence yielding the highest rate of recurrence (58%). Excellent model predictions of recurrence (as defined by each definition) can be constructed provided that the models are multivariate in nature and contain various categories of assessments. Symptoms, the most liberal definition of LBP recurrence, can be predicted

using combinations of variable from many categories of measures (*e.g.*, personal, kinematic, psychosocial, job demands, *etc.*), whereas when the more restrictive measures of recurrence are evaluated, the models rely heavily on a combination of worker's perception of impairment response and quantitative descriptions of the kinematic capacity of the worker.

■ Key Points

- Four definitions of LBP recurrence in order from most liberal to most conservative were examined, including symptoms, medical visits, lost time, and confirmed lost time in the same industrial population.
- Low back pain recurrence rates at work vary dramatically, depending on the definition of recurrence, with symptoms the most liberal definition of recurrence yielding the highest rates of recurrence.
- Recurrent LBP symptoms can be predicted using combinations of variables from many categories of measures (*e.g.*, personal, kinematic, psychosocial, job demands, *etc.*), whereas, when lost time the more restrictive measure of recurrence are evaluated, the models rely heavily on a combination of worker's perception of impairment response and 2 quantitative descriptions of the kinematic capacity of the worker.
- Low back pain recurrence models yielding the best sensitivity (80%) and specificity (80%) have been developed for the most restrictive definitions of recurrence (confirmed lost time).

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