

# NATURE AND COST OF LOW BACK PAIN

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## ABSTRACT

Low back pain (LBP) represents a huge expense to the mining industry and to society as a whole. Any effort to control the problems associated with LBP requires an understanding of the nature of LBP. This review paper was written by the U.S. Bureau of Mines to describe the

current state of knowledge regarding LBP—the causes, risk factors for LBP, effectiveness of treatments, recovery from back pain, and methods that can be used to help control the problem.

## INTRODUCTION

Low back pain (LBP) is very common in Western countries and is a major cause of worker disability, limitation of activity, and economic loss. Many studies have indicated that up to 80% of the general population are affected by LBP at some time during their lives (26, 35).<sup>3</sup> Furthermore, it is estimated that approximately one in seven Americans are currently experiencing LBP (25). The cost of back injuries in the United States in 1989 was variously estimated to be anywhere from \$27 to \$56 billion (38). These costs have undoubtedly risen by a substantial amount since that time.

Few need to be reminded of the magnitude of the back pain problem in the mining industry. Back injuries

consistently rank as the leading cause of lost workdays, account for up to 40% of worker compensation payments, and cost the industry tens of millions of dollars every year (20). In underground coal mines alone, back injuries cost the industry in excess of \$30 million in 1991. The average cost of a back injury that year was over \$8,000.<sup>4</sup> As part of its mission to enhance the safety and efficiency of mining, this review paper was written by the U.S. Bureau of Mines to describe the current state of knowledge regarding LBP—the causes, risk factors for LBP, effectiveness of treatments, recovery from back pain, and methods that can be used to help control the problem.

## CAUSE OF LBP

While a great deal of knowledge has been accumulated regarding LBP in the past couple of decades, doctors and scientists still cannot explain the exact mechanisms causing pain in the majority of patients with LBP. Many experts believe that LBP is caused by changes in the spine as an

individual ages. It is thought that the changes that occur as one gets older may lower the resistance of the spine to heavy workloads. Consequently, heavy loads on the spine trigger the onset of low back symptoms (26-27, 34, 41).

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<sup>3</sup>Italic numbers in parentheses refer to items in the list of references at the end of this paper.

<sup>4</sup>Unpublished data prepared by C. A. Hamrick in 1994; available upon request from S. Gallagher, BuMines, Pittsburgh, PA.

## TYPICAL LBP HISTORY

LBP typically begins fairly early in life (usually in one's twenties). Back pain during this period is typified by a mild and diffuse pain of relatively short duration, which is followed by a return to full activity. In one's thirties, there are often more frequent attacks of LBP, which are relieved by rest and followed by relatively pain-free periods. Back pain typically peaks in the forties; episodes of sciatica

(radiating back pain) are more frequent, and there is often residual pain between attacks. Improvement is frequently seen in the fifties. This period is characterized by less severe pain, which appears to be arthritic in nature (morning stiffness) and is largely relieved by activity during the day. The sixties often bring substantial relief from pain for the LBP patient (41).

## BACK INJURY RISK FACTORS

Effective control of LBP requires an understanding of activities that increase the risk of an injury. Some of the major factors associated with increased risk of back pain follow:

- Manual materials handling (especially lifting).
- Twisting of the trunk.
- Bending the trunk forward.
- Bending the trunk to the side.
- Excessive reaching.
- Falls.
- Prolonged sitting.
- Sedentary jobs.
- Highly physical jobs.
- Exposure to whole-body vibration.
- Cigarette smoking.
- Obesity.
- Extreme tallness.

As can be seen, a wide variety of activities are associated with back injuries (from prolonged sitting to heavy lifting). The following sections give some additional detail with regard to these risk factors.

### SPECIFIC RISK FACTORS FOR LBP

*Manual Materials Handling.*—According to a study performed by Bigos (7), manual handling tasks are associated with almost two-thirds of all low back compensation claims. Lifting is a particular concern, being associated with 49% of low back compensation cases (43). Studies have shown that lifting is especially hazardous if the object workers have to lift is excessive, i.e., greater than 15.9 kg (35 lb) in weight (13, 30, 42). Perhaps more important than the actual weight of an object is the moment that is imposed on the low back. Figure 1 illustrates this point by posing the question: Which is more stressful on the low back, 15 kg (33 lb) of feathers or 15 kg (33 lb) of lead? In this example, 15 kg (33 lb) of feathers actually makes the load experienced by the spine greater. This is because the 15 kg (33 lb) of feathers must be packaged in a bulky

container, which causes the worker to hold the object further away from his or her body (creating a larger moment). This increases low back stress. Fifteen kilograms (thirty three pounds) of lead, on the other hand, makes for a compact load that can be carried quite close to the body, which will decrease the stress on the low back. Many other aspects of manually lifting a load have been shown to be potential hazards to the musculoskeletal system. These include horizontal and vertical location of the load, shape and size of the load, lifting frequency, load stability, couplings, duration of lifting, workplace geometry, asymmetric lifting, environmental issues, etc. (21).

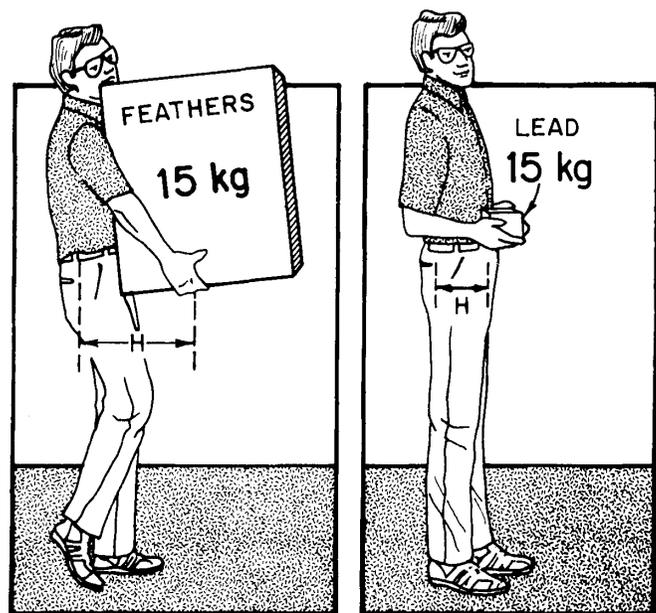


Figure 1.—Fifteen kilograms (thirty-three pounds) of feathers result in increased loading on the spine compared with 15 kg (33 lb) of lead. The lead (being compact) can be held much closer to the body, which decreases the horizontal distance (H) from the low back to the center of gravity of the object. The result is a decreased load on the low back. (Adapted from "UAW-Ford Job Improvement Guide," copyright 1988, Regents of the University of Michigan. Used by permission.)

*Body Motions.*—Twisting of the trunk is associated with a significant proportion of low back compensation cases (approximately 18%). Bending the trunk forward is also associated with such cases, but to a somewhat lesser degree (12% of cases).<sup>5</sup> More recent studies have also shown that the more quickly one twists the trunk or bends the trunk to the side, the higher the back injury risk (32). Other studies have demonstrated that excessive reaching (for example, reaching over obstacles or handling bulky objects) is associated with higher back injury rates (3, 48). Falls are responsible for only about 10% of compensation cases (7), but these cases tend to be somewhat more severe and costly (7, 47).

*Environmental Factors.*—Workers who are required to sit for prolonged periods of time have a higher risk of back pain (31). This may be due in part to the fact that the spine is almost fully bent forward in a relaxed sitting posture (4). It appears that jobs with low physical demands (sedentary jobs) and jobs possessing high physical demands both have somewhat higher incidences of LBP (36). A moderate amount of physical work is related to lowest back injury rates. Exposure to whole-body vibration (such as that experienced by shuttle car drivers) has also been implicated as a risk factor (9, 19). Another environmental factor that has received a great deal of attention recently is that of job satisfaction. Several studies

have recently reported that an employee's satisfaction with his or her job, working environment, and/or first line supervisor is related to LBP (6, 45). One reason for this relationship may be that workers who enjoy their jobs are willing to work through minor bouts of back pain, while persons who do not like their job will use the same type of pain as a chance to get away from an undesirable situation.

*Personal Factors.*—A recent study has demonstrated that smokers have an increased risk of LBP (17). In fact, this study showed a dose-response relationship between cigarette smoking and LBP. What this means is that the more a person smokes, the greater is his or her risk of LBP. The reasons for a smoker's increased LBP risk are probably due to two factors: (1) Smokers develop a deep cough, which places increased stress on the low back, and (2) smoking decreases blood circulation to the spine, which prevents essential nutrients from being delivered, causing tissues to be increasingly vulnerable to injury. Other personal risk factors involve body size. Back pain appears to be about twice as common in the 20% most obese (17). Furthermore, exceptionally tall individuals seem to have a higher incidence of LBP (3). Certain types of LBP (especially those cases involving intervertebral disk problems) seem to have a genetic component, as well (39).

## MULTIPLE RISK FACTORS

Although the exact relationship is not known, it is believed that the various personal and task risk factors listed above interact with one another (21). That is, several risk factors may be present at the same time, which may increase the chances of a worker experiencing a back injury (14). Thus, in a general sense, the greater the number of risk factors an individual has, the greater the likelihood will be that an individual will experience an episode of LBP.

As an example, let's look at a truck driver, whom we'll call Charlie. In his everyday job, Charlie may be exposed to a large number of back injury risk factors. As a truck driver, Charlie typically has to remain seated for prolonged periods of time and is exposed to whole-body vibration when driving. Charlie is a two-pack a day smoker and is also very obese, both of which may increase the likelihood of experiencing LBP. Furthermore, Charlie has to do heavy lifting to unload his truck. In the unloading process, Charlie is forced to bend and twist to get some of the loads off of the truck. One can easily see that Charlie has a large number of risk factors that increase the likelihood that he will experience an injury to his lower back.

Contrast Charlie's situation with that of Frank. Frank works in an office. While he sits at his desk a fair amount of the time, he's often called upon to do other jobs that require him to be up and around the office. Frank is rarely required to do any heavy lifting, but is called upon to do light lifting every so often. Frank is a nonsmoker and takes pride in keeping himself in shape. Compared to Charlie, it should be fairly obvious that Frank has fewer risk factors for LBP and would be less likely to experience an injury. The authors want to make it clear that it is *possible* that Frank might experience a back injury, while Charlie may remain injury-free. However, the *probability* is that we would expect Charlie to be the one to most likely experience bouts of LBP and disability.

Looking at these two cases brings up another point. Let's suppose that both Charlie and Frank are experiencing a moderate amount of back pain. Frank may well be able to go to work and tolerate his LBP and still be able to do his job effectively. However, the same amount of back pain might be disabling for Charlie, because the pain may well prevent him from being able to perform the tasks that are required in his job. So not only does Charlie's job increase the chances that he will experience a back injury, it also increases the chances that his back pain will result in lost time.

<sup>5</sup>Private communication from Stover H. Snook, Liberty Mutual Insurance Co., Aug. 1989.

## TREATMENT OF LBP

### CHOICE AND EFFECTIVENESS OF TREATMENT

The majority of individuals who experience LBP cope with their pain without seeking any sort of medical treatment. While a large number of therapies have been attempted to combat LBP, most studies have demonstrated relatively little difference in the effectiveness of various therapies (49). One therapy that clearly fares worse than others is extended bed rest (49). It is clear that a few days of bed rest may be necessary during episodes of acute LBP; however, it is important that the patient be mobilized as soon as possible.

### MANIPULATION

One difference that was noted in a large, carefully controlled study was that patients who received "chiropractic-type" rotational manipulation of the spine reported more immediate relief than that of the control group. However, over the long run there was no difference in pain relief between those receiving spine manipulation and those who did not (24).

### EXERCISE

There is some support for the use of exercises to decrease the degree of incapacity and increase the mobility of the spine that typically accompanies LBP. Furthermore, endurance training of the back muscles appears to have some benefits in patients with postural LBP. Finally, exercise appears to have a significant effect in decreasing stress, improving the patient's attitude, and allowing better

sleep; exercise may provide a positive alternative to prolonged use of medication in the chronic LBP patient.

### BACK SCHOOLS

Back schools appear to reduce sick leave, improve work status, decrease pain intensity or duration, and increase the activity level of patients. The "self-care" approach taught at back schools generally consists of enhanced knowledge of the anatomy and physiology of the back, better body mechanics and work techniques, and improved muscle strength and flexibility. Back schools have been used for patients with chronic pain, short-term (acute) pain, and as a preventive technique for industrial workers. Of the three groups, back schools appear to provide most help to patients with acute pain.<sup>6</sup>

### SURGERY

Surgery is only helpful in a very small segment (1% to 2%) of back pain cases. Successful surgery is reliant upon careful selection of the patient. The successful surgical patient must have unrelenting sciatica (back pain that radiates down the leg), and even then, only 5% to 10% of such patients should be candidates for surgery. The unfortunate fact is that surgery often only provides short-term benefits to the patient. Comparisons of surgical and nonsurgical patients indicate that surgical patients do somewhat better after 1 year, but after 4 years have passed, surgical and nonsurgical groups fare about the same (18).

## RECOVERY FROM LBP

### RETURN TO WORK

A study of compensation cases in 22 States for 1982 indicated that the average duration of a lost time back injury was 14 scheduled workdays (48). However, data from the U.S. Mine Safety and Health Administration records of mining accidents in 1990 indicated that the average days lost for a back injury was more than three times as long as that mentioned in the previous study (an average of 43 days lost)! Table 1 illustrates the percentage of compensation cases returning to work, by time (44). This table illustrates that almost two-thirds of patients returned to work within 2 weeks and four out of five returned within 6 weeks. However, after 6 weeks, the return to work was much slower. Seven percent of compensation cases lasted longer than 1 year.

Table 1.—Low back compensation cases returning to work, by time (44)

Week	Workers returning, %
1 .....	42
2 .....	62
6 .....	79
12 .....	87
24 .....	89
52 .....	93

### PROBABILITY OF RETURNING TO WORK

Data show quite clearly that there is a limited time to get workers back on the job once they have experienced a

<sup>6</sup>See footnote 5.

back injury. Table 2 illustrates the probability of a worker returning to active employment after various durations of being off work, based on data collected in two different studies (33, 40). This table shows that if a worker is off 6 months with a back injury, the chances are even that he or she will return to productive employment. If the worker is off for 1 year, there is only a one in four chance that the worker will return to work. But if the worker is off for 2 years, the chances are very slim that the worker will ever return to the active work force.

**Table 2.—Probability of worker returning to work for low back compensation cases, percent**

	McGill (33)	Rosen (40)
Off work over 6 months . . .	50	35-55
Off work over 1 year . . . . .	25	10-25
Off work over 2 years . . . . .	Nil	2- 3

## CONTROL OF LBP

There are three traditional approaches to the control of back pain that will be considered here. These are (in order of effectiveness) job design (ergonomics), worker selection and job placement, and education and training. These will be discussed briefly below; however, a more extended treatment of job design is given in a companion paper in this proceedings (23).

### JOB DESIGN (ERGONOMICS)

Ergonomics is a science that strives to improve job design so that job or task demands do not exceed the physical capabilities of the worker. This approach has become quite popular in general industry over the past couple of decades, and a scattering of ergonomic committees have been created in the mining industry over the past several years (37). Studies have indicated that the proper design of jobs can reduce up to one-third of all low back compensation by reducing the onset of painful episodes, allowing the worker to stay on the job longer and permitting the worker to return to the job more quickly (43).

The job design approach begins with the evaluation of existing jobs to identify risk factors that may lead to back injury. As identified previously, back injury risk factors may include manual handling tasks; body movements such as bending, twisting, and reaching; excessive loads; prolonged sitting; prolonged work in static postures; and exposure to whole-body vibration. Job redesign consists of reducing the risk factors associated with the job. For example, exposure to excessive loads may be reduced by providing the worker with mechanical aids. Improving the layout of the workplace may also help to reduce

## DETERRENTS TO RETURNING TO WORK

There are several factors that may act as barriers to the worker returning to work. Malingering by the worker is sometimes observed, but studies generally find that malingering is less prevalent than is generally believed. More likely deterrent factors associated with workers are psychological disability (anxiety and depression associated with chronic pain) (5) or illness behavior (a magnified or abnormal response to illness) (50-51). Management may also prevent an early return to work through policies that it may put in place. Often management does not provide followup or encouragement for the injured worker. Providing modified, alternative, or part-time work to an injured employee may help facilitate his or her early return (16). Other deterrents to a quick return to work may include specific contract rules, extended treatment by the medical practitioner (15), or situations where legal proceedings result.

unnecessary bending and twisting. Appropriate packaging of objects (to ensure that object weights match worker capabilities) will also reduce exposure to excessive loads. In addition, proper seat design (providing an adjustable seat with good lumbar support and vibration damping) can reduce the stress on the low back (28, 46).

Management is sometimes reluctant to redesign jobs because of the costs involved. However, many companies have learned that devoting capital to job redesign is indeed a sound business investment.<sup>7</sup> Reduced compensation costs and increases in worker productivity will return the cost of the initial investment over time. Determining the payback period will help persuade management of the cost effectiveness of redesigning jobs.

## WORKER SELECTION AND JOB PLACEMENT

### Medical Examination

It has been estimated that a maximum of 1 in 12 young (first hire age) workers susceptible to low back problems may be identified by performing a careful examination and obtaining a thorough medical history (41). The effectiveness of this approach for older workers may be somewhat higher (41). However, it should be pointed out that there is no guarantee that the workers screened out through this process will ever experience a bout of LBP. Use of X-rays in the examination process has been controversial, with the majority of physicians recommending that routine pre-placement X-rays not be used (2).

<sup>7</sup>See footnote 5.

### Strength and Fitness Testing

Studies have indicated that the chance of a musculo-skeletal injury is up to three times higher when the lifting requirements of a job approach or exceed a worker's isometric lifting capacity (12, 29). However, it is important to note that if strength testing is used to place workers in jobs, there is a risk of possible legal problems involving discriminatory hiring practices. To prevent such accusations, it is crucial that the strength tests used to select workers match the job demands as closely as possible.

In recent years, a large number of sophisticated strength testing devices have appeared on the market. However, thus far, there are no data regarding the effectiveness of these devices in reducing LBP.

## EDUCATION AND TRAINING

### Training in Safe Lifting

Teaching workers the proper method of lifting would appear to be a useful way to prevent back problems. However, the studies examining the effectiveness of this approach have failed to demonstrate that training has any effect on LBP (8, 15, 43, 52). There may be several reasons why these studies have shown no effect. For one thing, the quality of training in industry is typically lacking. Presentations are generally poor, the content of programs uneven, and there is usually no followup associated with training programs. Furthermore, workers tend not to comply with safe lifting recommendations, unless a program of performance feedback is provided (1). Safe lifting is not a natural way to lift, requires more energy to perform, and is generally harder to do (22). Uninjured workers are particularly hard to motivate. A better approach

may be to concentrate training efforts on workers with a history of LBP, rather than attempting to train the entire work force.

### Strength and Fitness Training

Some research appears to support the notion that improving worker fitness decreases the chances of worker compensation claims (10). Table 3 shows the results of a study examining the fitness of 1,652 Los Angeles firefighters. The firefighters were divided into three fitness categories based on strength, flexibility, heart rate and blood pressure, and physical work capacity. This study demonstrated that the most fit workers had fewer back-related compensation claims, the least fit had the highest number of claims, and those in between had a moderate number of claims. In a separate study (11), compensation costs were compared between workers with the greatest and least flexibility, strength, and physical work capacity. This study showed that workers with the greatest flexibility, strength, and work capacity had much lower compensation costs compared to those with the least flexibility, strength, and work capacity. The authors concluded that physical fitness and conditioning may have some preventive effect with regard to back disorders.

Table 3.—Low back compensation claims for Los Angeles firefighters, by level of fitness (10)

	Most fit	Middle fit	Least fit
Number of firefighters . . . . .	266	1,127	259
Low back compensation claims . . % . .	0.77	3.19	7.14

## SUMMARY

The economic costs of LBP are overshadowed only by the pain and disability experienced by the sufferer. Despite significant advances in knowledge of the low back, the exact causes of LBP remain largely unknown. We do know that there are several risk factors that increase the chances of experiencing LBP. These include lifting, bending and twisting of the trunk, prolonged sitting, exposure to whole-body vibration, and smoking. The best methods for controlling LBP in the workplace is to reduce the worker's exposure to these risk factors. If a back

injury does occur, there is a limited amount of time to get the worker back on the job. The longer the worker is off the job, the greater the chances are that the worker will not return. Three main approaches have been used to control LBP: job design (ergonomics), worker selection and job placement, and education and training. Of these, job design appears to offer the greatest ability to reduce the occurrence of LBP; however, most effective back injury control efforts use a combination of the approaches listed above.

## REFERENCES

1. Alavosious, M. P., and B. Sulzer-Azaroff. The Effects of Performance Feedback on the Safety of Client Lifting and Transfer. *J. Appl. Behav. Anal.*, v. 19, 1986, pp. 261-267.

2. American Occupational Medical Association. Guidelines for Use of Routine X-ray Examinations in Occupational Medicine. *J. Occup. Med.*, v. 21, 1979, pp. 500-502.

3. Andersson, G. B. J. Epidemiologic Aspects of LBP in Industry. *Spine*, v. 6, 1981, pp. 53-60.
4. \_\_\_\_\_. Measurement of Loads on the Lumbar Spine. Paper in Symposium on Idiopathic Low Back Pain. C. V. Mosby Co., St. Louis, MO, 1982, pp. 220-251.
5. Beals, R. K., and N. W. Hickman. Industrial Injuries of the Back and Extremities. *J. Bone and Jt. Surg.*, v. 51A, 1972, pp. 1593-1611.
6. Bigos, S. J., D. M. Spengler, N. A. Martin, J. Zeh, L. Fisher, and A. Nachemson. Back Injuries in Industry: A Retrospective Study. III. Employee-Related Factors. *Spine*, v. 11, 1986, pp. 252-256.
7. Bigos, S. J., D. M. Spengler, N. A. Martin, J. Zeh, L. Fisher, A. Nachemson, and M. H. Wang. Back Injuries in Industry: A Retrospective Study. II. Injury Factors. *Spine*, v. 11, 1986, pp. 246-251.
8. Brown, J. Lifting as an Industrial Hazard. *Am. Ind. Hyg. Assoc. J.*, v. 34, 1973, pp. 292-297.
9. Burton, A. K., and J. Sandover. Back Pain in Grand Prix Drivers: A Found Experiment. *Appl. Ergon.*, v. 18, 1987, pp. 3-8.
10. Cady, L. D., D. P. Bischoff, E. R. O'Connell, P. C. Thomas, and J. H. Allen. Strength and Fitness and Subsequent Back Injuries in Firefighters. *J. Occup. Med.*, v. 21, 1979, pp. 269-272.
11. Cady, L. D., P. C. Thomas, and R. J. Karwasky. Program for Increasing Health and Physical Fitness of Firefighters. *J. Occup. Med.*, v. 27, 1985, pp. 110-114.
12. Chaffin, D. B. Human Strength Capability and LBP. *J. Occup. Med.*, v. 16, 1974, pp. 248-254.
13. Chaffin, D. B., and K. S. Park. A Longitudinal Study of Low-Back Pain as Associated With Occupational Weight Lifting Factors. *Am. Ind. Hyg. Assoc. J.*, v. 34, 1973, pp. 513-525.
14. Dehlin, O., and S. Berg. Back Symptoms and Psychological Perception of Work: A Study Among Nursing Aides in a Geriatric Hospital. *Scand. J. Rehabil. Med.*, v. 9, 1977, pp. 61-67.
15. Dehlin, O., B. Hedenrud, J. Horal. Back Symptoms in Nursing Aides in a Geriatric Hospital. *Scand. J. Rehabil. Med.*, v. 8, 1976, pp. 47-53.
16. Derebery, V. J., and W. H. Tullis. Delayed Recovery in the Patient With a Work Compensable Injury. *J. Occup. Med.*, v. 25, 1983, pp. 829-835.
17. Deyo, R. A., and J. E. Bass. Lifestyle and LBP: The Influence of Smoking and Obesity. *Spine*, v. 14, 1989, pp. 501-506.
18. Frymoyer, J. W. Back Pain and Sciatica. *N. Engl. J. Med.*, v. 318, 1988, pp. 291-300.
19. Frymoyer, J. W., M. H. Pope, J. H. Clements, D. G. Wilder, B. McPherson, and T. Ashikaga. Risk Factors in LBP. *J. Bone and Jt. Surg.*, v. 65A, 1988, pp. 213-218.
20. Gallagher, S., T. G. Bobick, and R. L. Unger. Reducing Back Injuries in Low-Coal Mines: Redesign of Materials-Handling Tasks. *BuMines IC 9235*, 1990, 33 pp.
21. Garg, A. Epidemiological Basis for Manual Lifting Guidelines. Paper in Scientific Support Documentation for the Revised 1991 NIOSH Lifting Equation: Technical Contract Reports. NIOSH, Washington, DC, 1991, 58 pp.
22. Garg, A., and G. D. Herrin. Stoop or Squat: A Biomechanical and Metabolic Evaluation. *Am. Inst. Ind. Eng. Trans.*, v. 11, 1979, pp. 293-302.
23. Hamrick, C. A., and S. Gallagher. Job Design: An Effective Strategy for Reducing Back Injuries. Paper in this proceedings.
24. Hoehler, F. K., J. S. Tobis, and A. A. Buerger. Spinal Manipulation for LBP. *J. Am. Med. Assoc.*, v. 245, 1981, pp. 1835-1838.
25. Holbrook, T. L., K. Grazier, J. L. Kelsey, and R. N. Stauffer. The Frequency of Occurrence, Impact and Cost of Selected Musculoskeletal Conditions in the United States. *Am. Acad. Orthop. Surg.*, 1984.
26. Hult, L. Cervical, Dorsal, and Lumbar Spine Syndrome. *Acta Orthop. Scand. Suppl.*, No. 17, 1954, pp. 1-102.
27. Jayson, M. I. V. Back Pain: Some New Approaches. *Med. J. Aust.*, v. 1, 1979, pp. 513-516.
28. Kelsey, J. L., P. B. Githens, T. O'Connor, U. Weil, J. A. Calogero, T. R. Holford, A. A. White, S. D. Walter, A. M. Ostfeld, and W. O. Southwick. Acute Prolapsed Lumbar Intervertebral Disc: An Epidemiologic Study With Special Reference to Driving Automobiles and Cigarette Smoking. *Spine*, v. 9, 1984, pp. 608-613.
29. Keyserling, W. M., G. D. Herrin, and D. B. Chaffin. Isometric Strength Testing as a Means of Controlling Medical Incidents on Strenuous Jobs. *J. Occup. Med.*, v. 22, 1980, pp. 332-336.
30. Liles, D. H., S. Deivanyagam, M. M. Ayoub, and P. Mahajan. A Job Severity Index for the Evaluation and Control of Lifting Injury. *Hum. Factors*, v. 26, 1984, pp. 683-693.
31. Magora, A. Investigation of the Relation Between LBP and Occupation. 3. Physical Requirements: Sitting, Standing, and Weight Lifting. *Ind. Med. and Surg.*, v. 41, 1972, pp. 5-9.
32. Marras, W. S., S. A. Lavender, S. E. Leurgans, S. L. Rajulu, W. G. Allread, F. A. Fatallah, and S. A. Ferguson. The Role of Dynamic Three-Dimensional Trunk Motion in Occupationally-Related Low Back Disorders: The Effects of Workplace Factors, Trunk Position, and Trunk Motion Characteristics on Risk of Injury. *Spine*, v. 18, 1993, pp. 617-628.
33. McGill, C. M. Industrial Back Problems: A Control Program. *J. Occup. Med.*, v. 10, 1968, pp. 174-178.
34. Nachemson, A. L. Editorial Comment: Lumbar Discography—Where Are We Today? *Spine*, v. 14, 1989, pp. 555-557.
35. \_\_\_\_\_. The Lumbar Spine: An Orthopaedic Challenge. *Spine*, v. 1, 1976, pp. 59-71.
36. Nordin, M. Workplace Evaluation and Design. Pres. at the Tenth Annual Occupational LBP Conference, Long Beach, CA, Oct. 18-21, 1989; available upon request from S. Gallagher, BuMines, Pittsburgh, PA.
37. O'Green, J., R. H. Peters, and A. B. Cecala. AEP Fuel Supply's Ergonomic Approach to Reducing Back Injuries. Paper in Proceedings of the Twenty-Third Annual Institute on Mining Health, Safety and Research (Blacksburg, VA, Aug. 24-26, 1992). VA Polytech. Inst. and State Univ., Blacksburg, VA, 1992, pp. 187-195.
38. Pope, M. H., G. B. J. Andersson, J. W. Frymoyer, and D. B. Chaffin. Occupational LBP: Assessment, Treatment and Prevention. *Mosby Year Book*, St. Louis, MO, 1991, pp. 95-113.
39. Postacchini, F., R. Lami, and O. Pugliese. Familial Predisposition to Discogenic Low-Back Pain. *Spine*, v. 13, 1988, pp. 1403-1406.
40. Rosen, N. B. Treating the Many Facets of Pain. *Bus. and Health*, May 1986, pp. 7-10.
41. Rowe, M. L. Backache at Work. Perinton Press, Fairport, NY, 1983, pp. 94-101.
42. Snook, S. H. The Design of Manual Handling Tasks. *Ergonomics*, v. 21, 1978, pp. 963-985.
43. Snook, S. H., R. A. Campanelli, and J. W. Hart. A Study of Three Preventive Approaches to Low Back Injury. *J. Occup. Med.*, v. 20, 1978, pp. 478-481.
44. Snook, S. H., and B. Webster (Liberty Mutual Insur. Co., Hopkinton, MA). Unpublished data, 1987; available upon request from S. Gallagher, BuMines, Pittsburgh, PA.
45. Svensson, H., and G. B. J. Andersson. The Relationship of Low-Back Pain, Work History, Work Environment, and Stress. *Spine*, v. 14, 1989, pp. 517-522.
46. Troup, J. D. G. Driver's Back Pain and Its Prevention. *Appl. Ergon.*, v. 9, 1978, pp. 207-213.
47. Troup, J. D. G., J. W. Martin, and D. C. E. F. Lloyd. Physical Exercise in the Treatment of LBP. *Orthop. Rev.*, v. 17, 1988, pp. 724-729.
48. U.S. Bureau of Labor Statistics (Dep. Labor). Back Injuries Associated With Lifting. *Bull.* 2144, Aug. 1982.
49. Waddell, G. A New Clinical Model for the Treatment of Low-Back Pain. *Spine*, v. 12, 1987, pp. 632-644.
50. Waddell, G., C. J. Main, E. W. Morris, M. DiPaola, and I. C. M. Gray. Chronic Low-Back Pain, Psychologic Distress, and Illness Behavior. *Spine*, v. 9, 1984, pp. 209-213.
51. Waddell, G., J. A. McCulloch, E. Kummel, and R. M. Venner. Nonorganic Physical Signs in Low-Back Pain. *Spine*, v. 5, 1980, pp. 117-125.
52. Wood, D. J. Design and Evaluation of a Back Injury Prevention Program Within a Geriatric Hospital. *Spine*, v. 12, 1987, pp. 77-82.

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Compiled by Robert H. Peters



United States Department of the Interior  
Bureau of Mines  
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*U.S. Department of the Interior  
Mission Statement*

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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**UNITED STATES DEPARTMENT OF THE INTERIOR  
Bruce Babbitt, Secretary**

**BUREAU OF MINES**