Epidemiology of work-related back pain

Roger C. Jensen, JD
Senior Engineer
Division of Safety Research
National Institute for Occupational Safety and Health
US Public Health Service
Morgantown, West Virginia

MANY WORKERS experience problems with their backs. Back problems constitute 25% of workers' compensation claims in the United States.[1] Musculoskeletal injuries are listed second among leading occupational injury and illness problems, according to priorities of the National Institute for Occupational Safety and Health (NIOSH).[2] Data from the US Bureau of Labor Statistics indicate that there were 630,000 cases of back problems in the year 1979 that were severe enough to cause the worker to miss at least one day of work.[3]

There is extensive literature on the subject of personal and job factors that apparently affect risk of back pain. Personal factors that may affect risk of back pain (eg, age, physical condition, postural habits, load-handling technique, skeletal structure, and off-the-job activities) have been summarized in recent review articles, including articles by Andersson,[4] Kelsey,[5] Andersson et al,[6] and Yu et al.[7] This article updates and expands on ear-

Top Acute Care Trauma Rehabil 1988;2(3):1-15

lier publications (eg, publications by Brown,[8] Snook,[9] and NIOSH[10]) about job factors that affect risk of back pain.

EPIDEMIOLOGIC MEASURES

Numerous studies have been published that contribute to our understanding of the distribution and determinants of back pain. Understanding these studies requires an appreciation of the different epidemiologic measures used to quantify the extent of back problems in groups of people. These measures can be divided into two categories: prevalence measures and incidence measures.

Prevalence measures are used to characterize the proportion, or percentage, of individuals in a population who during some specified time have experienced back pain or shown some other condition, such as a certain degree of vertebral disk degeneration.[11] These measures often are categorized according to the applicable time frame:

- lifetime prevalence, if the time includes each surveyed individual's entire life;
- period prevalence, if the time period is for a specified time (eg, during the past year, in which case the measure would be called "one-year prevalence"); or
- point prevalence, if the time is limited to the moment at which the individual is responding to the question.

Incidence measures are used to characterize the frequency of back-pain episodes or injuries in a population. Sources of data and exact definitions vary considerably among studies, but only two basic quantities exist for expressing risk of a back-pain episode: incidence ratio and incidence rate. The incidence ratio is the number of episodes during the time period divided by the average number of workers in the population during the period. Typical units for such a quantity are cases per 100 employees. The incidence rate is the number of episodes during the time period divided by the total time worked by the workers in the population during the time period. Typical units for such a quantity are cases per 200,000 worker hours or cases per 100 worker years of work. Another label for this kind of measure is "incidence density,"[11] a term often used in cancer studies.

OCCUPATIONAL FACTORS

Exposure to various stressors on the job has been investigated and hypothesized as contributing to the risk of workers experiencing low-back pain or other back problems. These stressors can be categorized for convenience into the following groups: (1) general heavy work, (2) frequent manual load handling, (3) occasional very stressful load handling, (4) load handling near one's strength capacity, (5) accidents, (6) prolonged standing or sitting, and (7) other manual tasks. The epidemiologic data concerning each of these factors are summarized in this section.

Heavy work

Heavy work is associated with more back trouble than is light work, according to several studies. Rowe[12] reviewed the

medical and work histories of employees about to retire from the Eastman Kodak Company. Each was classified as having worked primarily in jobs involving heavy, moderate, or light manual work. Of those in the heavy-work category, 65% had been treated for back problems. The figures for the moderate exposure and light exposure groups were 50% and 51%, respectively. Hult[13] found that the prevalence of workers with a history of low-back trouble was 64.4% in those with heavy jobs and 52.7% in those with light jobs. This same study found that both groups of workers experienced degeneration of the cervical spine with age, but those in heavy jobs experienced degeneration at an earlier age than those in light jobs.[13] Wickström[14] summarized the epidemiologic studies linking heavy work to degenerative back disease, including an insightful reevaluation of data from Hult's study.[13] According to Wickström's reevaluation, Hult's data included two groups of workers with heavy jobs who had little opportunity to change jobs even if they developed back problems because few other job opportunities were available in the small town in which they lived. When compared with workers with light jobs, those with the heavy jobs had a four times greater lifetime prevalence of pronounced symptoms of lumbar insufficiency, a three times greater prevalence for recurrent attacks of lumbago, and a two times greater prevalence of pronounced sciatica.

Frequent manual load handling

Occupations that require frequent manual load handling have been associated with a larger incidence and prevalence of back problems than have occupations that involve little load handling. Magora and Taustein[15] compared eight occupational groups in Israel and found that point prevalence of back pain was greatest among heavy laborers. Nurses had the second greatest point prevalence. Nursing is an occupation that often involves lifting and transferring patients. The remaining occupational groups studied, in order of point prevalence, were farmers, light industry workers, bus drivers, post office clerks, bank clerks, and police officers. Some of Magora's data[16] allow for comparison of four of the occupational groups in terms of a measure that roughly equates to extent of exposure to manual load handling: the percentage of those within each occupational group who lifted a load of 5 kg or more at least 10 times a day. Fig 1 shows what appears to be a positive association between point prevalence (expressed as a percentage) and job lifting requirements (expressed as the percentage of workers in the occupation who lift as often as specified above).

When compared with workers with light jobs, those with the heavy jobs had a four times greater lifetime prevalence of pronounced symptoms of lumbar insufficiency.

Jensen[17] compared 24 occupational groups in four US states in terms of annual incidence ratio (number of workers' compensation claims for back injuries classified as sprains or strains per 1,000

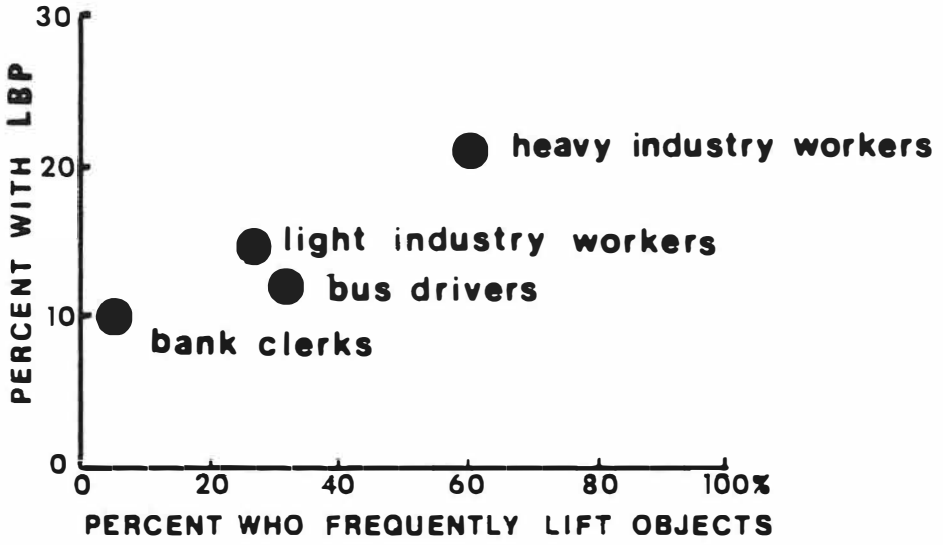

Fig 1. Point prevalence of low-back pain (LBP) in four occupational groups, shown in relation to the percentage of workers in the group who frequently lift objects on the job (data from Magora[16]).

employees). These occupations are listed in Table 1 in order of average rank. Frequency of load handling was not measured for the various occupations, but general familiarity with typical jobs performed by members of these occupational groups permits identification of a strong tendency. The four occupational groups with the greatest incidence ratios (nursing aides, construction laborers, garbage collectors, and licensed practical nurses) typically perform jobs that require frequent heavy load handling. Proceeding down the list one begins to find occupational groups that typically perform occasional heavy load handling (eg, truck drivers and registered nurses), and further down the list one finds occupational groups that rarely perform heavy load handling (eg, telephone operators and dental hygienists).

A survey of nursing personnel in Australia found a positive relationship between frequency of lifting per shift and one-month prevalence of a low-back pain.[18] Those who averaged zero lifts per shift had a 29% one-month prevalence of low-back pain. As the frequency of lifting increased, so did the one-month prevalence. Those who lifted 20 or more times per shift had a 54% one-month prevalence of low-back pain.

Also indicating that one's occupation affects risk of back pain was a study by Biering-Sørensen[19] based on a comparison of occupational groups in one town in

Table 1. Selected occupations ranked by one-year incidence ratio for workers' compensation claims classified as back sprain or strain per 1,000 workers[17]

Occupational category	Average rank
Nursing aides, orderlies, and attendants	1.4
Construction laborers	2.2
Garbage collectors	3.3
Licensed practical nurses	3.6
Truck drivers	4.7
Registered nurses	6.6
Health aides (except nursing aides)	7.0
Machinists	8.0
Radiologic technicians	8.3
Therapists	11.5
Cooks (excluding household cooks)	11.7
Cashiers	13.4
Health-record technicians	13.9
Clinical laboratory technicians	14.7
Dietitians	16.4
Stenographers	16.9
File clerks	17.1
Industrial engineers	17.5
Typists	17.6
Librarians	19.0
Dental assistants	19.1
Pharmacists	19.5
Telephone operators	19.9
Dental hygienists	22.2

Denmark. Several different prevalence and incidence measures were used, including one-year prevalence for the year before the initial survey and one-year prevalence for the year after the initial survey. The average of these two periods was computed and was used to produce a rank-ordered list of the occupations (see box, "Back Pain Prevalence in Seven Occupational Groups").

Damkot et al[20] reported the results of a survey of American men in the age range of 18 through 55 years. Subjects were classified as having a history of severe, moderate, or no low-back pain. The percentage of men in each category whose jobs involved repetitive weight lifting was found to be 53.8% in the severe low-back pain group, 47.7% in the moderate low-back pain group, and 44.4% in the no low-back pain group. Such findings support the association between exposure to frequent load handling and low-back pain. The difference in the percentages, however, are not very great. One obvious reason is that, generally, individuals who develop severe low-back pain will try to find a job without much load handling. Consequently, those who develop low-

Back Pain Prevalence in Seven Occupational Groups

Occupational group	Average one-year prevalence (%)
Assistant nurses	59.5
Forklift operators	58.0
Hospital porters (orderlies)	56.3
Nurses	50.0
Homemakers	49.5
Unskilled workers	46.9
Public service workers	44.0

back problems tend to gravitate toward jobs that require minimal heavy lifting.

Occasional very stressful manual load handling

Jobs that even occasionally require an individual to lift loads that create large compressive forces in the lower vertebral column put the individual into a higher risk category than do jobs with lesser load-lifting requirements. This has been shown by Chaffin and Park,[21] based on prospective data involving 103 jobs in five manufacturing plants. The strength requirements of the jobs were quantified using a biomechanical model and were subsequently quantified in comparison with the load a large, strong man can lift in the same body position. This measure of the intensity of load-handling requirements for a job was called the Lifting Strength Rating (LSR). It was computed as the ratio of the weight lifted to the weight that a large, strong man can be expected to lift in the same position. Thus, a value of LSR near 0 indicated that the task would be very easy for a large, strong man to perform, and an LSR value near 1.0 indicated that even a large, strong man would find that the task requires most of his strength. For each of the 103 jobs, the sagittal plane lifting tasks (those performed directly in front of

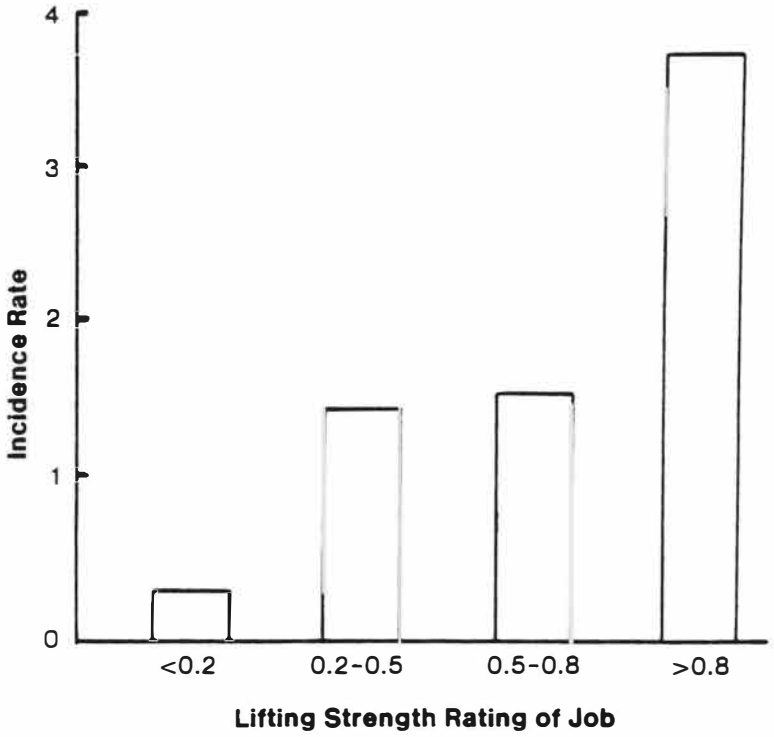

Fig 2. Incidence rates of back complaints (per 1,000 person-weeks) related to the Lifting Strength Rating for the most stressful task in the job (based on data from Chaffin and Park[21]).

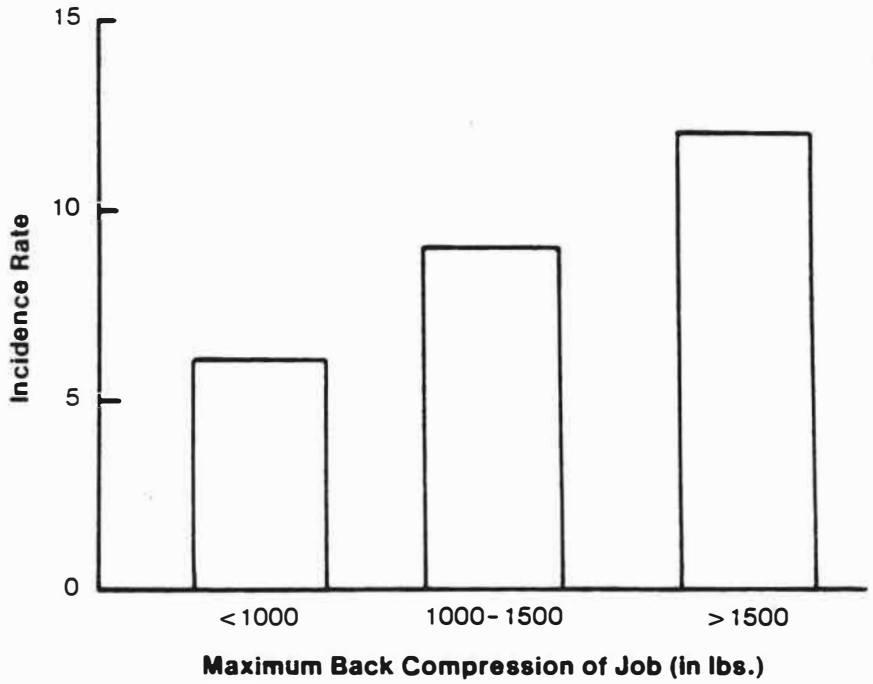

Fig 3. Incidence rates of back complaints (per 200,000 hours) for jobs classified by maximum compressive forces on the lower back (based on data from Herrin, Jaraiedi, and Anderson[22]).

the body) were assessed to determine the task in each job with the largest LSR. Thus, each job was characterized by the single lifting task with the largest LSR.

Fig 2 shows the incidence rate of low-back pain complaints received by the medical departments of the five participating plants for the jobs in four LSR categories. These results show that jobs with LSR values in the range 0.0 to 0.2 had the lowest incidence rate, jobs with LSR values greater than 0.2 but less than 0.8 had a larger incidence rate, and jobs with LSR values greater than 0.8 had a much larger incidence rate than the other jobs. Thus, a job with even one highly back-stressing lifting task can appreciably increase the risk of back pain complaints.

A subsequent study by Herrin, Jaraiedi, and Anderson[22] that used the same basic biomechanical model as a tool for job evaluation was performed pursuant to a contract with the NIOSH Division of Safety Research (DSR). The study involved 55 industrial jobs in five industries. The tasks in each job were identified, and each lifting task was evaluated using a biomechanical model. The most stressful task of each job was identified and used to classify the job into one of three categories defined by the maximum compressive load on the lower back when performing the most stressful task of the job. These job categories then were compared with medical records concerning complaints involving the back. Fig 3 shows the three job categories and the

It appears that a job only needs to include one task that imposes excessive loads on the back (or excessive strength demands) in order to increase the risk of worker complaints of back problems.

corresponding incidence rate for back complaints. Results indicated a consistent increase in incidence rate for back complaints as the jobs increased in compressive load. Similar findings were also reported when the jobs were evaluated using strength requirements instead of compressive load. The particularly important finding is that the jobs were classified only on the basis of their most stressful task. Thus, it appears that a job only needs to include one task that imposes excessive loads on the back (or excessive strength demands) in order to increase the risk of worker complaints of back problems.

The job evaluations for the preceding studies[21,22] were based on biomechanical theory. Another approach uses psychophysical theory as the basis for job evaluation. These approaches are explained by Ayoub, Selan, and Jiang.[23] Some epidemiologic studies have been based on psychophysically derived job evaluations. A study by Snook, Campanelli, and Hart[24] reported that workers were apparently three times more susceptible to low-back pain if their jobs required heavy manual load handling (defined as requiring performance of tasks that over 75% of the working population would consider too stressful). The Herrin et al[22] study also looked at psychophysically based methods for quantitatively evaluating the intensity of manual load handling required on the job. Their results indicated that job ratings derived from psychophysical methodologies are positively correlated with the incidence rate of back complaints.

Thus, even though these studies[21,22,24] differed in methods, measures, and populations, the results were consistent in finding that jobs that require very stressful manual load handling are associated with larger incidence rates of back pain complaints than are jobs with lesser manual load handling requirements.

Load handling near one's strength capacity

Four important prospective studies have shown that workers who must use most of their strength to perform their jobs are more likely to develop back problems than those who need to use a smaller fraction of their strength capacity to perform their job. In order to assess the relationship between employee strength and the strength demand of the job, Chaffin and associates reported the results of two studies. The first included 103 jobs populated by 411 employees,[25] the second included 900 jobs in 6 different plants.[26] For both studies the strength of each employee was measured by a static voluntary exertion in a posture similar to that used for the most stressful task of the worker's job. Strength demands of the most back-stressing task in each job were determined from a biomechanical model. The Job Strength Rating was computed by dividing the average strength of workers on that job into

the strength required for the most back-stressing task of the job. Jobs were classified into three groups according to their Job Strength Rating, and the incidence rate of work-related low-back pain complaints was determined for each job. Results of the first study[25] showed that, when the Job Strength Rating was greater than 1.0, the incidence rate for back complaints was about three times greater than for those jobs with average Job Strength Ratings less than 1. Similar results found in the second study[26] are shown in Fig 4.

The third study, by Keyserling, Herrin, and Chaffin,[27] involved 20 jobs in a tire and rubber manufacturing plant. One group of newly hired employees were assigned to jobs that they were strong enough to perform according to their performance on a static strength test in relation to the strength demands of the job. New hires in the control group were assigned to jobs using traditional assignment methods. Both cohorts of new hires were followed until the plant shut down for economic reasons. During the follow-up period, the 20 employees who had been assigned jobs according to their strength had no musculoskeletal incidents. Among the 51 employees in the control group, there were 19 musculoskeletal incidents. These results are consistent with the proposition that those workers who must use most of their strength to perform their jobs are more likely to develop back problems than are those who need to use a smaller fraction

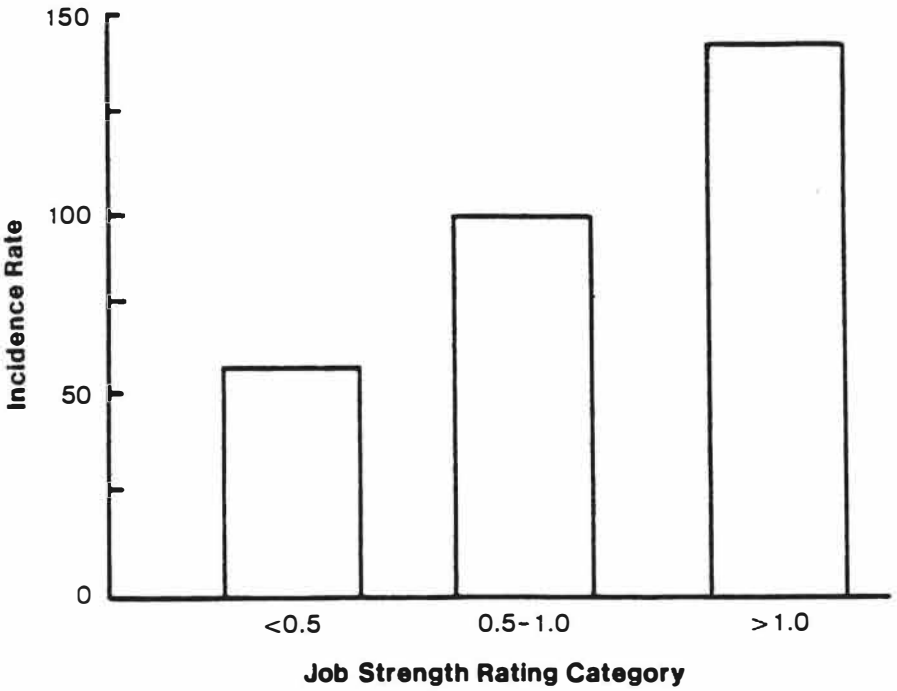

Fig 4. Incidence rates of back complaints (per 1 million person-hours) according to the Job Strength Rating for the most stressful task in the job (based on data from Chaffin[26]).

of their strength capacity to perform their jobs.

The fourth study, reported by Liles et al,[28] was based on 101 jobs. Each job was evaluated in terms of the percentage of workers who considered the tasks acceptable, according to data obtained in psychophysical experiments, and each of the 453 employees was tested for strength using a psychophysical procedure that determines the weight the individual considers acceptable to lift under specified conditions. These data allow for a comparison between the lifting demands of the job and the strength of the employees who perform the job. Among the results were some data particularly germane to the present discussion, although limited to male employees. The strength of each of the 385 men was compared against the lifting demands of the job they performed during the study. The jobs then were grouped according to the percentage of workers who performed the job who were apparently overstressed (ie, the job demands exceeded the weight they considered acceptable). The least stressful jobs were those in which 5% or fewer of the employees were overstressed. The moderately stressful jobs had 5% to 75% of employees overstressed. The most stressful jobs overstressed more than 75% of the workers who performed the job. Measures of injury frequency, severity, and cost then were determined for each group of jobs. The most relevant measure in this study was the incidence rate for disabling back injuries (disabling means the worker missed at least one day of work because of the injury). Fig 5 shows the disabling back-injury rate for each of the three job groupings. There was a clear increase in the disabling back-injury rate as the jobs increased in percentage of overstressed workers.

The study by Liles et al[28] involved different methods than those used in the other studies,[25-27] in terms of methods for assessing job strength requirements and methods for quantifying the strength capabilities of workers. But even with different methods, all four studies showed that, when a job requires much of the worker's strength capability, the chance of a back-problem complaint is appreciably increased.

Accidents

Some back pain can be traced directly to a specific event such as a stumble, a trip, a fall, or an impact, (ie, striking against an object or being struck by a moving object). Because there are considerable differences in accident rates between jobs, those workers in jobs with high accident rates may be more likely to develop back problems. Hult[13] found that workers employed in jobs involving heavy work had greater accident rates and greater prevalence of lumbago and sciatica than workers employed in jobs involving light work. It is unclear, however, to what extent the greater prevalence rates could be explained by differences in accident rates or differences in workload. Workers' compensation data in the United States indicate that falls were implicated in 4.3% and involuntary motions in 4.7% of all cases coded as back sprain or strain.[1] A review of injury reports involving hourly employees at the Boeing Company facilities in Seattle,

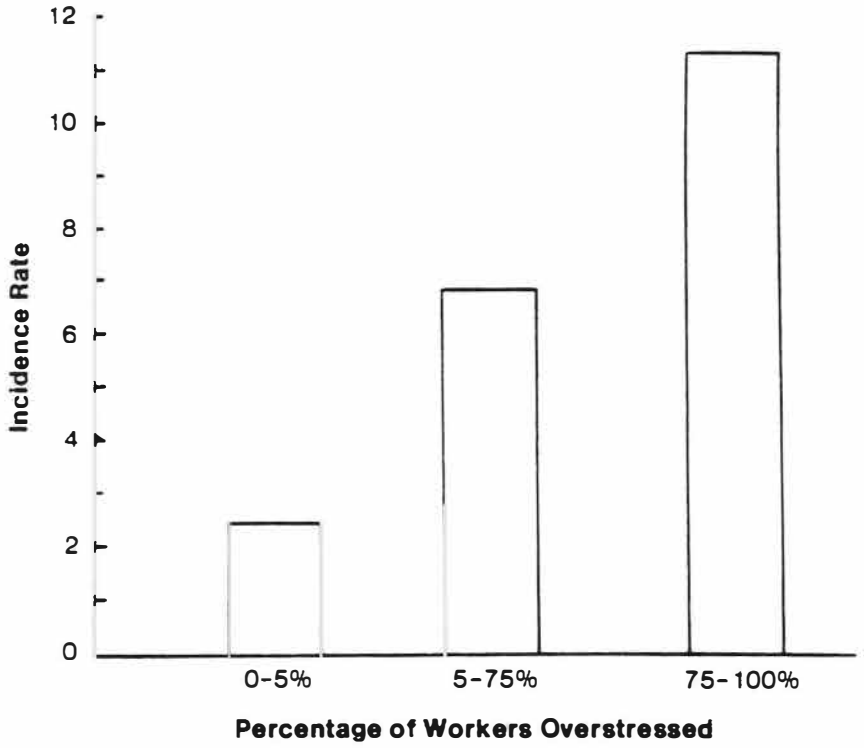

Fig 5. Incidence rates of back complaints (per 100 full-time employees) according to the percentage of employees who apparently were overstressed in their jobs (data from Liles et al[28]).

Washington, indicated that, of the back injuries, 10% were attributed to falls and 19% were associated with bodily motions.[29] Injury reports and workers' compensation data may not provide an accurate picture, however, of the contribution of accidents to the frequency of back injuries, because injury reports typically include only the event that directly inflicted the injury.

A study[30] of back injuries in a large automobile manufacturing facility looked beyond the traditionally simplistic identification of a single event as "the cause." The investigators interviewed injured workers in order to identify the first unforeseen event that started the chain of actions leading to the injury. There were 401 cases of employees having back pain that kept them from work for a day or more, including cases that arose either on or off the job. Of these, the first unforeseen event in 122 cases was an identified accident. These 122 cases were divided into four groups: work-surface related, such as slipping, tripping, stumbling, catching the foot on something, or having the surface (eg, a ladder) collapse or tilt suddenly (66%); a sudden unexpected load on the back (12%); blows to the back (6%); and traffic accidents (4%). These data suggest that traumatic events

besides manual load handling may contribute substantially to the incidence of work-related back pain.

Prolonged standing or sitting

Jobs that require workers to sustain a particular posture for prolonged periods may be associated with musculoskeletal problems related to those postures. According to the survey by Magora,[16] those jobs that involved nearly all standing or nearly all sitting postures were associated with larger point prevalence of back pain than were jobs involving changes in posture. Jobs that involve extended periods of sitting at a computer keyboard or typewriter often are associated with pain in the cervical or lumbar regions of the back. Also, sitting and operating heavy equipment or driving vehicles regularly for many years has been found to be associated with a slightly greater prevalence of back pain.[31] This increase, however, could be attributed to factors other than prolonged sitting, such as vibration, impacts experienced when jumping down from the vehicle, and manual-load-handling tasks.[20,31] The connection between exposure to extended periods of sitting and diagnosed back trouble is not well established, according to Troup.[31] He suggests, however, that extended sitting may increase the pain and discomfort felt by individuals who already had some back problems before the exposure.

Other manual tasks

In addition to manual lifting of loads in front of the body, several other load-handling tasks have been implicated in back injuries. An assessment of workers' compensation data[1] for cases coded as back sprain or strain associated the following percentages with the following activities: pulling or pushing objects, 9.0%; carrying, holding, wielding, or throwing objects, 5.7%; and voluntary bodily motions, 6.6%. These percentages are similar to those cited by Snook.[9] It has also been documented that nursing personnel experience large prevalence rates of back pain[32] and large incidence rates of compensable back injuries compared with other occupational groups[17] (see Table 1), and many of the tasks they perform involve pushing, pulling, carrying, and asymmetric lifting and lowering.

Carrying objects frequently or for extended periods may increase the risk of back trouble. Typically, carrying objects requires certain muscle groups to maintain tension in a relatively fixed position. This results in muscle fatigue. If the lower back muscles are affected, the individual may feel pain that could be considered one manifestation of the low-back-pain syndrome. Additionally, according to concepts of biomechanics, if the weight of the object is supported by the shoulders, there will be an extra load on the vertebral column that may, over extended periods of exposure, accelerate spinal degeneration. At present, the possibility that extended carrying of loads increases the risk of back pain is a proposition that finds support in biomechanical theory. Two epidemiologic studies[33,34] have provided evidence suggestive of an association between extended carrying of loads and low-back pain, but much stronger

evidence is needed to establish whether extended load carrying actually causes an increased risk of low-back pain.

Pushing and pulling objects can create relatively large biomechanical stresses on the vertebral column and back muscles. Consequently, these activities are suspected risk factors. Minimal epidemiologic data have been found to objectively evaluate the effects of pushing and pulling. Damkot et al[20] found that, of those workers studied who did some pushing or pulling on the job, those with severe low-back pain did the most pushing and pulling, followed by those with moderate and no low-back pain, respectively. Frymoyer et al[33] found that low-back pain patients were more likely to do pushing and pulling tasks than were patients who sought medical attention for reasons other than low-back pain.

Many experts consider asymmetric lifting tasks more hazardous than symmetric lifting tasks.

Many jobs require workers to pick up an object and transfer it from one side of their body to the other (asymmetric lifting). During such load handling, the spinal column is aligned in a less structurally stable position than when lifting directly in front of the body (symmetric lifting). Asymmetric lifting can involve concentrated stresses that might cause failure of the annulus and protrusion,[34] strain a muscle, or sprain or strain a ligament. Consequently, many experts consider asymmetric lifting tasks more hazardous than symmetric lifting tasks.[34-37] Asymmetric lifting is a suspected risk factor because of the biomechanics of the spine. Unfortunately, there have not been any epidemiologic studies that either support or contradict the proposition that asymmetric lifting is more hazardous than symmetric lifting.

There is, however, some epidemiologic data indicating that twisting and bending frequently on the job may increase the risk of back problems.[20,32] The study by Damkot et al[20] categorized workers into three groups according to their back pain experiences. Of those with severe low-back pain, 59% had jobs requiring stretching and reaching. In the moderate low-back pain group, 36% had to stretch and reach on the job. Among those with no history of back pain, 40% had jobs that involved stretching and reaching.

• • •

The likelihood of an individual worker experiencing an episode of back pain depends on a combination of factors, including personal factors and occupational factors. This article has reviewed only occupational factors.

Occupational factors that are associated with increased prevalence or incidence of back pain, according to epidemiologic studies, are jobs that involve one or more of the following:

- general heavy work,
- frequent manual load handling,
- occasional very stressful load handling,
- load handling near one's strength capacity,
- accidents, and

• prolonged standing or sitting.

Additionally, other manual tasks likely to increase the risk of experiencing low-back pain include pushing, pulling, carrying, asymmetric lifting, and twisting and bending. More epidemiologic research is needed to better understand the above factors and to determine the extent to which these various factors affect the risk of experiencing low-back pain.

REFERENCES

1. Klein BP, Jensen RC, Sanderson LM: Assessment of workers' compensation claims for back strains/sprains. *J Occup Med* 1984;26:443-448.
2. National Institute for Occupational Safety and Health: *Proposed National Strategy for the Prevention of Leading Work-Related Diseases and Injuries, Part 1.* Washington, DC, Association of Schools of Public Health, 1986.
3. Bureau of Labor Statistics: Occupational safety and health statistics, in *Handbook of Methods,* US Dept of Labor Bulletin 2134-1, Government Printing Office, 1982, pp 123-134.
4. Andersson GBJ: Epidemiologic aspects of low back pain in industry. *Spine* 1981;6:53-60.
5. Kelsey JL: *Epidemiology of Musculoskeletal Disorders.* New York, Oxford Univ. Press, 1982.
6. Andersson GBJ, Pope MH, Frymoyer JW: Epidemiology, in Pope MH, Frymoyer JW, Andersson GBJ (eds): *Occupational Low Back Pain.* New York, Praeger, 1984, pp 101-114.
7. Yu TS, Roht LH, Wise RA, et al: Low-back pain in industry: An old problem revisited. *J Occup Med* 1984;26:517-524.
8. Brown JR: *Manual Lifting and Related Fields: An Annotated Bibliography.* Toronto, Labour Safety Council of Ontario, 1972.
9. Snook SH: Low back pain in industry, in White AA (ed): *Symposium of Idiopathic Low Back Pain.* St. Louis, Mosby, 1982, pp 23-38.
10. National Institute for Occupational Safety and Health: *Work Practices Guide for Manual Handling.* Akron, Ohio, American Industrial Hygiene Association, 1981.
11. Kleinbaum DG, Kupper LL, Morgenstern H: *Epidemiologic Research: Principles and Quantitative Methods.* London, Lifetime Learning, 1982.
12. Rowe ML: Low back disability in industry: Updated position. *J Occup Med* 1971;13:476-478.
13. Hult L: Cervical, dorsal and lumbar spinal syndromes. *Acta Orthop Scand* 1954;Suppl 17:7-102.
14. Wickström G: Effect of work on degenerative back disease: A review. *Scand J Work Environ Health* 1978;4(suppl 1):1-12.
15. Magora A, Taustein I: An investigation of the problem of sick-leave in the patient suffering from low back pain. *Industrial Med* 1969;38:398-408.
16. Magora A: Investigation of the relation between low back pain and occupation: 3 physical requirements: Sitting, standing and weight lifting. *Industrial Med* 1972;41(12):5-9.
17. Jensen RC: Disabling back injuries among nursing personnel: Research needs and justification. *Res Nurs Health* 1987;10:29-38.
18. Arad D, Ryan MD: The incidence and prevalence in nurses of low back pain: A definitive survey exposes the hazards. *Australian Nurses Journal* 1986;16(1):44-48.
19. Biering-Sørensen F: Risk of back trouble in individual occupations in Denmark. *Ergonomics* 1985;28:51-60.
20. Damkot DK, Pope MH, Lord J, et al: The relationship between work history, work environment and low-back pain in men. *Spine* 1984;9:395-399.
21. Chaffin DB, Park KS: A longitudinal study of low-back pain as associated with occupational weight lifting factors. *Am Ind Hyg Assoc J* 1973;34:513-525.
22. Herrin GD, Jaraiedi M, Anderson CK: Prediction of overexertion injuries using biomechani-

cal and psychophysical models. *Am Ind Hyg Assoc J* 1986;47:322-330.
23. Ayoub MM, Selan JL, Jiang BC: Manual materials handling, in Salvendy G (ed): *Handbook of Human Factors.* New York, Wiley, 1987, pp 790-818.
24. Snook SH, Campanelli RA, Hart JW: A study of three preventive approaches to low back injury. *J Occup Med* 1978:20:478-481.
25. Chaffin DB: Human strength capability and low-back pain. *J Occup Med* 1974;16:248-254.
26. Chaffin DB, Herrin GD, Keyserling WM: Preemployment strength testing: An updated position. *J Occup Med* 1978:20:403-408.
27. Keyserling WM, Herrin GD, Chaffin DB: Isometric strength testing as a means of controlling medical incidents on strenous jobs. *J Occup Med* 1980;22:332-336.
28. Liles DH, Deivanayagam S, Ayoub MM, et al: A job severity index for the evaluation and control of lifting injury. *Human Factors* 1984;26:683-693.
29. Bigos SJ, Spengler DM, Martin NA, et al: Back injuries in industry: A retrospective study, II. Injury factors. *Spine* 1986;11:246-251.
30. Manning DP, Mitchell RG, Blanchfield LP: Body movements and events contributing to accidental and nonaccidental back injuries. *Spine* 1984;9:734-739.
31. Troup JDG: Driver's back pain and its prevention: A review of the postural, vibratory and muscular factors, together with the problem of transmitted road-shock. *Applied Ergonomics* 1978;9:207-214.
32. Jensen RC: Low back pain and back injury among health care workers, in *Occupational Hazards to Health Care Workers.* Cincinnati, Ohio, American Conference of Governmental Industrial Hygienists, 1987, pp 41-50.
33. Frymoyer JW, Pope MH, Costanza MC, et al: Epidemiologic studies of low-back pain. *Spine* 1980;5:419-423.
34. Garg A, Badger D: Maximum acceptable weights and maximum voluntary isometric strengths of asymmetric lifting. *Ergonomics* 1986;29:879-892.
35. Hickey DS, Hukins DWL: Relation between the structure and the annulus fibrosus and the function of the intervertebral disc. *Spine* 1980;5:106-116.
36. Mital A, Fard HF: Psychophysical and physiological responses to lifting symmetrical and asymmetrical loads symmetrically and asymmetrically. *Ergonomics* 1986;29:1263-1272.
37. Kumar S: The physiological cost of three different methods of lifting in the sagittal and lateral planes. *Ergonomics* 1984;27:425-433.