

Epidemiological Basis for Manual Lifting Guidelines

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CHAPTER 2

BASIS FOR GUIDE: EPIDEMIOLOGICAL APPROACH

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Epidemiology can be defined as the science or discipline of the occurrence of illness in human populations including factors that influence and predict these patterns. The role of epidemiology in controlling low-back pain is to clarify the natural history and clinical course of the pain and to identify workplace and individual factors of importance (Andersson, 1981). This assumes that a set of factors is associated with low-back pain. Thus, epidemiology can play an important role in instituting preventive measures and eliminating risk factors.

One of the most serious and persistent problems in occupational medicine has been that of low-back pain (Brown, 1973). The importance of low-back pain syndrome is due to its high prevalence in the workers, and its effect on them in terms of pain and disability. Low-back pain is one of the most frequent and disabling conditions affecting workers in their productive years. In the United States, impairments of the back and spine are the most frequent cause of activity limitation in individuals less than 45 years old, and these conditions rank third, after heart disease and arthritis and rheumatism, in persons who are 45 to 64 years old (Kelsey et al., 1979). Further, recurrences are frequent, and three or more episodes have been reported in 30%-70% of the afflicted patients (Hult, 1954; Horal, 1969; Bergquist-Ullman and Larson, 1977). It is generally recognized that probably up to 80% of all people will experience back pain to some extent in their active life (Hult, 1954; Horal, 1969; Nachemson, 1976; Andersson, 1981; Snook, 1985). Further, low-back pain affects quality of life (Andersson, 1979); one out of 25 men changes his work because of low-back pain (Taylor, 1976); and it results in early retirement and disability pensions (Andersson, 1981).

According to Rowe (1983), "low-back pain is common symptom of many diseases affecting organs of lower abdomen and pelvis as well as soft tissues and bones and joints of the spine." Multiple causes, both in and around the spine, can contribute to the production of low-back pain (LBP). Back pain is a clinical manifestation that can be caused by a variety of known diseases and morphological changes (Bergquist-Ullman and Larson, 1977). However, the underlying pathophysiology for back pain is unfortunately unclear. Rowe (1983) believes that it is not possible to make a definite diagnosis in the majority of cases in their early phases. The likelihood of identifying a specific cause for low-back pain is very small, in the order of 5-10% (Frymoyer et al., 1980) and a definite structural diagnosis can be reached in no more than 50% of all cases (Pope et al., 1979).

The problem is further complicated by the frequent presence of multiple causes in the same patient (Rowe, 1983). Further, there is a wide variation in individual patient response to seemingly similar degrees of pathological changes in the low back. This makes it difficult to judge even the severity of the condition. Lack of satisfactory etiological understanding and the inability to give a precise diagnosis are severe obstacles in the prevention, treatment and prognosis of low-back pain and disability.

LOW-BACK PAIN, IMPAIRMENT, DISABILITY AND COMPENSATION

A distinction should be made between low-back pain, low-back impairment, low-back disability and low-back compensation (Snook, 1985). Low-back pain is generally defined as lumbosacral pain as well as buttock pain and leg pain. It can be acute as well as chronic pain. Low-back impairment represents a decrease or loss of ability to perform various musculoskeletal activities. The decrease in ability is dependent upon the severity of low-back pain. Low-back disability is defined as the time lost from the job, or assignment to restricted duty. Low-back disability is very dependent upon the nature of the job (Rowe, 1983; Snook, 1985; Stubbs et al., 1986). Low-back compensation is reimbursement for lost wages and is dependent upon the nature of the compensation laws. These compensation laws vary from country to country and, in the United States, from state to state. Therefore, the same low-back disability may be compensatory in one state, but not in another. Some studies have shown that the physical demands of the job have little effect on the incidence of low-back pain, but have a much greater effect on the incidence of low-back disability and low-back compensation (Hult, 1954; Magora and Taustein, 1969; Cust et al., 1972; Bergquist-Ullman and Larson, 1977; Rowe, 1983). For example, Hult (1954) reported that 53% of the workers in the light occupations and 64% of the workers in the heavy occupations experienced low-back pain but low-back disability in the heavy occupations was twice as much as in the light occupations. Cust et al. (1972) found little difference between nurses and teachers in overall prevalence of low-back pain. However, LBP came earlier in nurses and was largely precipitated by occupational factors; whereas in the teachers, the incidence of LBP gradually increased with time and it was generally non-occupational in origin. Bergquist-Ullman and Larson (1977) found little difference in LBP between office workers and manual workers, but the latter group had a significantly longer period of disability during the initial and recurring episodes of LBP. Rowe (1983) believes that normally a sedentary worker might be able to perform with a level of low-back impairment which would be disabling for a person with a heavy job.

Rowe (1983) believes that the real objective should be to minimize low-back disability. Snook (1985) also believes that the primary emphasis should be to (i) reduce the number of painful episodes triggered by the job, (ii) allow the worker with the LBP to stay on the job longer, and (iii) permit the worker with LBP disability to return to the job sooner.

CAUSES OF LOW-BACK PAIN

Several different causes of LBP have been identified (Table 2.1). The most common diagnoses include lumbosacral strain and sprain, postural LBP, muscular insufficiency, "sprung back," sacroileitis, annular tears, building disc, degenerative spinal disease, or simply "low-back syndrome" (Benn and Wood, 1975). The most common cause of nonspecific LBP is the degeneration of intervertebral disc (Rowe, 1983). The general attributes of idiopathic LBP are the absence of true sciatica, an increase in pain with increased physical activity and relief with rest (Bergquist-Ullman and Larson, 1977; Damkot et al., 1984).

There is a considerable disagreement as to the cause of LBP (such as muscular deficiency, degeneration of intervertebral disc, facet joint theory, etc.). Kraus (1965), Chaffin et al. (1978), Horal (1969), Cady et al. (1979), Wiesel et al. (1984), and Mayer et al. (1985), etc., have indicated (directly or indirectly) muscle weakness as the cause for LBP. Horal (1969) found that lumbar spine insufficiency was most common in the young-age group, later lumbago set in and became predominant while sciatica developed still later and progressed with increasing age up to 59 years. Klein et al. (1984) reported that muscle strains and sprains constituted the largest single category of back injuries and accounted for 87% of all back compensation claims. Wiesel et al. (1984) reported that the majority of patients were diagnosed as having back strain. Hult (1954), Kellgren and Lawrence (1952) and Horal (1969) reported that more severely affected subjects had degenerative diseases of the spine, including disc disease with or without nerve root involvement and degeneration of the facets. Spangfort (1972) reported that the degree of disc herniation was the single most important factor for the incidence of persistent LBP. Rowe (1963, 1969) and Kelsey and Ostfeld (1975) reported that the prolonged intermittent LBP was often attributable to disc disease.

However, the relationship between the occurrence of disc degeneration and LBP is controversial. Disc degeneration per se is not symptomatic and is a more or less physiological aging phenomenon (Lawrence, 1969; Bergquist-Ullman and Larson, 1977; Andersson, 1981; Rowe, 1983; Pope et al., 1984). Degenerative discs are found in 10% of persons between the ages of 20 to 29, and there is an increase with age to 96% in those over the age of 60 (Lawrence, 1969). Though, there is a lack of conclusive

Table 2.1: Possible causes of low-back pain (Rowe, 1983)

A. Referred Pain from Abdominal or Pelvic Organs

1. Urinary Tract (kidney, ureter, bladder, prostate)
2. Gastro-Intestinal Tract (ileum, colon, rectum)
3. Female Genital System (uterus, ovaries, cervix)
4. Vascular System (aneurism, arterial insufficiency)

B. Pain Originating in the Spine

1. Abnormalities of Bony Structure
 - a. Segmentation errors (4 or 6 lumbar, transitional vertebrae)
 - b. Ossification defects (spondylolysis, spondylolisthesis)
 - c. Dimension and angulation defects
 2. Functional Abnormality
 - a. Anterior-posterior trunk imbalance (pregnancy, potbelly obesity, pelvic tilt, poor workplace design)
 - b. Lateral trunk imbalance (spine curvature, hearing or vision impairment, poor workplace design)
 3. Inflammation
 - a. Systemic infection or toxicity
 - b. Infection of bones or joints (osteomyelitis, tuberculosis)
 - c. Arthritis (ankylosing spondylitis, rheumatoid)
 4. Metabolic or Hormonal
 - a. Osteoporosis (post-menopausal, hyperthyroid or hyperparathyroid)
 - b. Diabetes, gout, Paget's disease
 5. Degenerative (discs, facet joints)
 6. Tumor
 - a. Primary of bone (multiple myeloma, hemangioma, etc.)
 - b. Primary of spinal cord or nerve roots
 - c. Metastases from other organs (breast, lung, prostate, etc.)
 7. Injury
 - a. Fracture of vertebral bodies or processes
 - b. Sprains (ligaments) and strains (muscles)
 - c. Acute rupture of disc
-

evidence, but there are a number of indirect indications that the disc plays a central role in the etiology of LBP (Nachemson, 1971). Also, back pain appears to be more frequent in those having severe degenerative changes involving several discs (Hult, 1954; Caplan et al., 1966; Rowe, 1963, 1965, 1969; Lawrence, 1969; Magora and Schwartz, 1976; Torgerson and Dotter, 1976; Wiikeri et al., 1978). The situation is less clear in moderate or light degeneration (Splithoff, 1953; Hult, 1954; Hirsch, 1969; Horal, 1969; Mogora and Schwartz, 1976) and some studies have reported no strong association between disc degeneration and LBP (Splithoff, 1953; Horal, 1969; Mogora and Schwartz, 1976; Pope et al., 1984). Disc degeneration has also been reported to be more frequent in workers who do heavy manual work (Hult, 1954; Kellgren and Lawrence, 1952; Lawrence, 1969), although the nature of the stress inducing the degenerative changes is not clear (Andersson, 1981). Also, it is not clear why some people with degenerative disc changes suffer LBP or become disabled and others do not. Although it is widely believed that disorders of the lumbar intervertebral disc may be the most common single factor to which back and sciatic pain may (directly or indirectly) be ascribed, there are a growing number who consider that disorders of the apophyseal joints are of equal importance (Farfan et al., 1970; Lamy et al., 1975; Fiorini and McCammond, 1976; Farfan et al., 1976, Pope et al., 1984; Gracovetsky, 1986). At present, it is misleading to select a single factor for the etiology of LBP. Distinctions which exist between these "causes" in theory are not always distinguishable in practice. As stated earlier, multiple causes can contribute to the production of LBP.

A musculoskeletal injury can be triggered by a direct trauma, a single overexertion, or repetitive loading. The strengths of various tissues are affected by such factors as age, fatigue, and concomitant diseases and, therefore, an injury can occur at different loading levels (Pope et al., 1984). In single overexertion injuries and repetitive loading, failure usually occurs at one level while in the case of direct trauma, several different structures can be damaged at the same time. Fatigue failure may not become obvious until complete failure occurs and the final event may be trivial (Pope et al., 1984). Bergquist-Ullman and Larson (1977) reported that the onset-of back pain was sudden in 44% of the group while 56% of the patients reported a more insidious onset. The insidious group also had a longer duration of the initial episode.

Generally, an injury will heal if given sufficient time. Based on a selected population of patients (acute and subacute LBP, duration of pain before entry \leq 3 months and a pain-free year before the onset of current episode), Bergquist-Ullman and Larson (1977) reported that the pain disappeared within 1 month in 35% of the patients, within 2 months in 70% and within 3 months in 86% of the patients. An initial episode of pain

lasting more than 6 months was found in 6% of the patients, while 4% still experienced pain after 1 year. More importantly, 62% of the patients had one or more recurrences of pain during the year of observation; 52% of the patients with acute pain changed their jobs; and the intensity of the pain at the first visit was no indication of the duration of pain (Bergquist-Ullman and Larson, 1977).

COMPARATIVE ANALYSIS OF RISK FACTORS: SOME CONCERNS

A voluminous literature exists in which almost every possible contributing factor has been studied. However, there are conflicting studies practically on most, if not all, risk factors identified in the literature. Direct comparisons between epidemiologic studies are often methodologically difficult. A comparative review is almost impossible because the variables studied (such as parameters chosen, population examined, methods of sampling and data collection, occupations studied, task and time scales, etc.) rarely coincide (Troup and Edwards, 1985). Studies are confounded by the high prevalence of LBP in the general population, the wide range of back disorders, its non-specific nature and its frequent association with non-occupational factors. The relationships between the LBP and the risk factors may become more apparent if a precise and accurate measure of outcome were available (Frymoyer et al., 1983). There is also an inherent problem in the epidemiological studies that the observed associations between the LBP and the variables studied may not be causal. It is impossible to determine whether some of the observed relationships were causal, or whether the workers had modified their behaviors, their activities and occupational demands because of low-back pain. There is also the possibility that some of the relationships may be coincidental as significant differences may occur by chance alone when several variables are tested against each other. These indications of possible correlations need to be validated by prospective studies. Therefore, caution is warranted in interpreting the data. In addition to the above concerns, the following problems are identified with the epidemiological data in the hope that future studies may address them in more detail:

- (1) There is lack of consistency among investigators of back injuries or LBP with regard to definition of terms. Different definitions of low-back pain have been used. A clear distinction between low-back pain, low-back impairment, low-back disability and low-back compensation has not been maintained. It is widely believed that there is a significant difference in the four measures. Similarly, some studies have included chronic cases while others have studied acute or subacute cases or both.

- (2) Different epidemiological measures and time scales were used to quantify the extent of low-back problems in groups of people (lifetime prevalence, period prevalence, point prevalence, incidence ratio, incident rate, etc.). Some researchers believe that different measures are assessing different back pain conditions (Stubbs et al., 1986).
- (3) Some studies are based on a single population, occupation or restricted data base (individual insurance companies, specific industrial settings or samples from nationalized health systems) and, therefore, the sample may not be representative of the general population. Lack of controlled studies and differences in the methods of statistical analysis used compound the problem.
- (4) In general, studies have relied on self-assessments of physical workloads by the subjects. Uhl et al. (1987) found that the workers perceived themselves to do much more physical work than the observational data could support. For example, the most frequently reported number of patient lifts by the nursing personnel on self-report was ten and the most frequent number of patient lifts by observation was zero. Similarly, Stubbs et al. (1986) found large and significant differences between subjective and observed estimates of time spent in working postures.
- (5) Generally, the work has been arbitrarily classified as light, moderate or heavy. Rarely, task variables have been quantified and mechanical load on the spine has been defined and measured.
- (6) There is an interactive effect between various personal and task variables. Both somatic and psychological variables may act at the same time and may influence one another (Dehlin and Berg, 1977). Since different workplace factors are often present at the same time, the association with a single factor is difficult to establish because of the interaction between them.
- (7) There is a concern that the data derived from compensation claims may have an inherent bias (Venning et al., 1987). It rewards work-related causation but does not show temporary non-compensable disability. A patient is more likely to attribute LBP to a specific occupational event if there is a potential form of compensation (Damkot et al., 1984). Further, time off work may be more a reflection of the demands of the job than the severity of the back pain (Stubbs et al., 1986).

Many sufferers will attribute a cause to an episode of pain. Such associated events, in fact, could be triggers and the true cause may lie in cumulative events.

NEED

Knowledge on workplace and individual factors is far from complete. Certainly, there is a need for long-term, prospective and controlled studies of large samples of many variables to identify workplace factors from which individuals must be protected. Prospective studies are needed so that factors contributing to the development of low-back pain can be differentiated from factors resulting from low-back pain. Nevertheless, this current knowledge about risk factors is our only basis for controlling back injuries and for planning safety strategies (Bigos et al., 1986). There is also a need for developing an improved standardized reporting system in order to monitor the low-back problem.

RISK FACTORS

Many personal and job factors have been studied to determine their association with the incidence and prevalence of low-back complaints. These are summarized in Table 8.2. The capacity to perform the physical work varies considerably not only from individual to individual but within any given individual over time. Furthermore, the limitations of this capacity are complex and interrelated. Similarly, many aspects of the physical act of manually lifting a load have been identified as potentially hazardous to a person's musculoskeletal system. Understanding the relationship between these individual and job factors and the resulting risk of injury to the worker is a prerequisite to the development of schemes for safe workplace designs and placing people in jobs which do not compromise their health and safety. The following is a brief description of personal and job risk factors.

PERSONAL RISK FACTORS

Age

Age brings a reduction in the range of lumbar spinal motion, decline in muscle strength and aerobic capacity, slowing of muscle contraction speed, a decrease in mineral bone content, loss of gel from the nucleus, and an increase in the amount of disc degeneration and an increase in body weight. However, there is a wide variation in both the physiological and anatomical changes associated with aging.

Table 2.2: Risk factors identified in the literature

| Personal Risk Factor | Job Risk Factor |
|--|---|
| Age | Heavy Physical Work |
| Gender | Lifting (weight, location, dimension, frequency duration, etc.) |
| Anthropometry (body weight, height) | |
| Physical Fitness and Training | Bending, Stretching and Reaching |
| Lumbar Mobility | Twisting |
| Strength | Pushing and Pulling |
| Medical History (repeated episodes of low-back pain) | Prolonged Sitting and Standing |
| Years of Employment | Accidents |
| Smoking | |
| Psychosocial Factors | |
| Structural Abnormalities | |

With the usual exception of childhood and adolescence, LBP is common to all age groups. Some studies have shown that age has no significant association with back pain, back abnormalities or time off from work (Magora, 1970; Chaffin and Park, 1973; Kelsey and Ostfeld, 1975; Frymoyer et al., 1983; Astrand, 1987; Uhl et al., 1987). A few studies have reported that younger workers are at a higher risk for back injuries (Ward et al., 1968; Horal, 1969; Blow and Jackson, 1971; Stubbs and Nicholson, 1979; Afacan, 1982; Bigos et al., 1986). Lack of experience or training in handling loads and a tendency to take substantially greater physically demanding tasks are offered as some of the reasons for a higher incidence of LBP among younger workers. On the other hand, the majority of studies has shown that the prevalence of back pain (point and lifetime prevalence, incident rate, etc.) increases with an increase in age up to a certain age (Figure 2.1) (Hirsch et al., 1969; Magora, 1970; Karvonen et al., 1980; Porter et al., 1980; Biering-Sorensen, 1982; Valkenburg, and

Haanen, 1982; Rowe, 1983; Owen and Darmon, 1984; Videmann et al., 1984). Whether this is because older workers are not as likely to be exposed to injury producing stresses of manual materials handling, or whether only those older workers who have survived a rigorous history of earlier stresses remain in the workforce, is not clear.

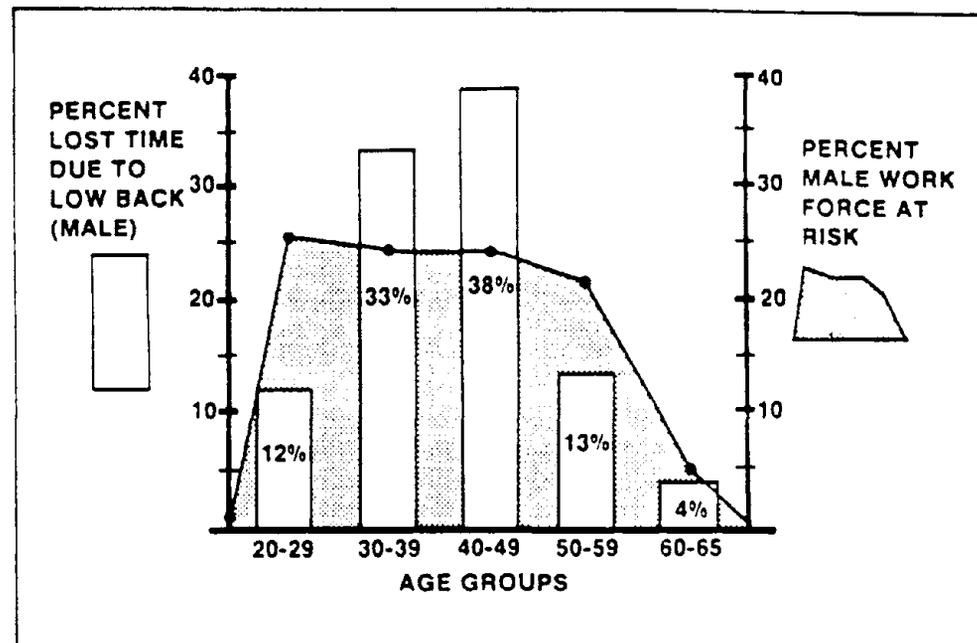


Figure 2.1: Lost time by age. (Men in their thirties and forties, who constitute 46% of the total male work force, account for 71% of lost time from work attributable to low-back conditions (Rowe, 1983)).

The highest incidence of LBP occurs in the thirties and/or forties (Caplan et al., 1966; Hirsch et al., 1969; Rowe, 1969; Brown, 1973; Kelsey and Ostfeld, 1975; Biering-Sorenson, 1982). Most patients who have operations for disc herniations are in their thirties and forties (Rowe, 1965; Spangfort, 1972; Pope et al., 1984). The 31 to 40 year old age group is most susceptible to high cost back injuries (Bigos et al., 1986). However, long-term disabilities and recurrences are more pronounced in the older age group, about 45 to 70 years of age (Hirsch et al., 1969; Horal, 1969; Haber, 1971, Wood and McLeish, 1974; Dehlin et al., 1976). Rowe (1969) believes that LBP attacks usually begin in the late twenties or early thirties, reach a maximum frequency and intensity in the late thirties and forties, and then taper off in the fifties and become more infrequent in the sixties.

During the twenties and early thirties LBP is likely to appear as a series of sudden acute attacks of short duration and recovery is usually prompt (3 to 10 days). Around the mid and late thirties the pain is more localized. In the forties, radiation of pain down the back of a leg is a frequent occurrence showing positive neurological findings (Row, 1983).

In summary, it appears that (i) LBP usually begins early in life, (ii) the maximal frequency is between the ages of about 35 to 55 years, (iii) recurrences, duration of symptoms and disability increase with increasing age, and (iv) maximum disc surgeries occur between 35 and 45 years of age. Age must, therefore, be viewed as a potential risk factor but the exact form of this risk is not yet fully understood.

Gender

In general, women have lower strength and aerobic capacity than men. Female to male strength ratios range from 35% to 74% (Troup and Chapman, 1969; Laubach, 1976; Chaffin et al., 1977; Yates et al., 1980; Pheasant and Grieve, 1981; Griffin et al., 1984; Garg et al., 1988). It appears that on the average, women's lifting strengths (primarily arm and torso strengths) are about 60% of men's (Asmussen and Heeboll-Neilson, 1962; Troup and Chapman, 1969; Petrofsky and Lind, 1974; Laubach, 1976; Chaffin et al., 1977; Snook, 1978). Hence, if asked to handle moderate to heavy loads, the average woman is more highly stressed than the average man relative to their strengths. Similarly, on the average, a female's aerobic capacity is about 70% of that of a male (Astrand and Rodahl, 1977). The average female is more likely to be fatigued than the average male on those jobs where energy expenditure requirements are moderate to high. However, there are large variations in the strengths and aerobic capacities of both males and females. In other words, there are females who have significantly higher strength and/or aerobic capacity than those of an average male. Gender, thus, becomes secondary to strength and endurance factors per se.

LBP appears as frequently in females as in males (Horal, 1969; Svensson and Andersson, 1982; Valkenburg and Haanen, 1982). There are no differences between men and women regarding duration of back pain and subsequent absence from work (Bergquist-Ullman and Larson, 1977). Hirsch et al. (1969) found a lower frequency of LBP among females than in males. However, when the work situation is taken into account, the pattern may change due to the above mentioned reasons. For example, Magora (1970) reported that 35% of the women in physically heavy jobs had LBP as compared to 19% of the males. Brown (1973) reported similar results. In Sweden, there are higher absence rates in women with physically heavy work than in men doing the same job (Pope et al., 1984). Bigos et al. (1986) reported that women tended to have a higher-than-expected number of high cost claims but

lower-than-expected number of low cost claims. Leavitt et al. (1971) and Snook et al. (1978) also reported that women comprised a large percentage of expensive back claims. However, the above statistics are not supported by others. Chaffin and Park (1973) studied both men and women performing equally demanding light-to-moderate load handling jobs and reported an equal incidence of LBP cases. Operations for disc herniations seem to be performed about twice as often in males as in females (Spangfort, 1972; Brown, 1973; Kelsey and Ostfeld, 1975; Lawrence, 1969; Weber, 1983). Workers' compensation claims show that about 75% to 80% of back injury claims are filed by males (Leavitt et al., 1971; Snook et al., 1978; Woodyard, 1980; Johnston, 1982; Klein et al., 1984). It is not clear why men have a greater number of surgical cases for herniated lumbar intervertebral discs and worker's compensation claims. Partially, it may be because more men traditionally have jobs with heavier physical demands than women (Bergenudd and Nilsson, 1988). Chaffin and Park (1973) reported that women were found to be working on jobs with lifting strength rating (LSR) values of about 63% of the men's.

Future studies are needed to study the effect of gender on LBP, while controlling the job physical demands. Based on the current knowledge, it does not appear that gender is a significant risk factor.

Anthropometry

Body weight, stature and body build have been studied to determine their effects on an individual's risk of an injury during manual materials handling. In general, a heavier person is usually stronger than his lighter counterpart and usually has the mass necessary to counter-balance the handling of large objects (Troup and Chapman, 1969; Konz et al., 1973; Chaffin et al., 1976). When lifting, a heavy person may transmit some part of the vertical force directly through the abdomen and thighs to the lower limbs when these parts are in physical contact with the object (Troup and Edwards, 1985). Body weight is also a major factor for most pushing and pulling activities. However, body weight has a direct effect on energy expenditure while lifting and carrying loads (Garg et al., 1978). A heavier person would have a greater metabolic rate and concomitant circulatory load, which would lead to earlier fatigue (Petrofosky and Lind, 1974). Further, obesity prevents carriage of the loads close to the body and may result in greater compressive force on the low-back while lifting and carrying. Also, there is a very wide range of strength in each subgroup, regardless of age, sex, body weight, stature or body build, etc.

Anthropometric data are conflicting, but in general indicate that there is no strong correlation between stature, body weight, body build and LBP. Some studies have reported that people with back-pain are, on the average, taller than those without it

(Rowe, 1965; Tauber, 1970; Gyntelberg, 1974; Kelsey, 1975; Merriam et al., 1983; Biering-Sorensen, 1983). Taller persons often complained of back-hip sciatic pain and had more severe radiological changes. However, height did not appear to play an important role in determining the onset and progress of disc degeneration (Lawrence, 1955).

Brown (1972) suggested that excessive weight made an individual more susceptible to back symptoms. Cust et al. (1972) reported that nurses who were relatively underweight and those who were overweight had a higher prevalence of LBP than those in the normal range. Ikata (1965) and Karvonen et al. (1980) reported that obesity was associated with backache. However, the bulk of epidemiological studies have not been able to support the notion that neither fat nor thin nor tall nor short people are at a significantly higher risk of LBP (Hult, 1954; Hirsch et al., 1969; Westrin et al., 1972; Chaffin and Park, 1973; Svensson and Andersson, 1982).

It is concluded that the selection of individuals for manual materials handling jobs based on their anthropometry is not justified in terms of low-back pain incidence rates. There is, however, the need to design workplaces based on anthropometric dimensions of U.S. population in terms of reach, mobility and strength. Further, those jobs that do not allow for a large range of anthropometric variation in the population should be identified and specific function limiting dimensions should be stated in the job descriptions.

Physical Fitness and Training

It is widely believed that there would be a reduction in injuries and an increase in capacity for work with an improvement in physical fitness. However, it is not clear exactly what this training should be and how it can be given to the naive worker without harm. Individuals with high aerobic capacity may be fit for those jobs which require high oxygen uptake, but will not necessarily be fit for those jobs which require high static and dynamic strengths and vice versa. In general, fitness for most physical activities requires combinations of strength, endurance, flexibility, musculoskeletal timing and coordination (Cady et al., 1979).

Kraus (1967) believes that more than 80% of low-back pain is due to lack of adequate physical activity. Astrand (1987) reported a strong association between back pain and perceived health and general working capacity. Cady et al. (1979) evaluated male fire fighters and concluded that physical fitness and conditioning had significant preventive effects on back injuries (least fit 7.1% injured, moderately fit 3.2% injured and most fit 0.8% injured). But the most fit group suffered the most severe back injuries. It is possible that more physically fit individuals may have a

higher tolerance for minor injuries and, therefore, a higher threshold for injury reporting. In this regard, Brooke (1967) and Scott and Gijsbers (1981) did find an association between athletic performance and pain tolerance.

Based on extensive functional restoration program (specific exercises, training in functional tasks, work hardening, education, psychological counseling, etc.), Mayer et al. (1985) reported that approximately 80% of the chronic LBP patients showed improvement in the functional capacity measures and psychologic measures, and about twice the number returned to work as compared to the comparison group.

Other studies have found that physical fitness and training had either little or no effect in preventing back injuries. Dehlin et al. (1978, 1981), based on the effect of training to increase trunk and quadriceps strengths, reported that increased strengths resulted in a perceived reduction of workload and back symptoms were shorter in duration but not less frequent or intense. They concluded that the effect of training on low-back symptoms was negligible. Cox et al. (1981) concluded that given 20% participation in an exercise class, there is a potential for a 1% reduction in payroll costs resulting from reduced turnover and absenteeism. Kelsey (1975) reported that insufficient physical exercise, as well as participation in some sports (baseball, golf and bowling), were marginally associated with the risk for the development of a prolapsed lumbar disc. Videmann et al. (1984) found no difference in prevalence of back pain between those who were and were not physically fit. The study found that those who exercised two to three times weekly had a higher prevalence of sciatic symptoms than those who did so less often. Bergquist-Ullman and Larson (1977) found no difference in the course of back pain or rate of recovery from acute LBP episodes with improved physical fitness. Similarly, Frymoyer et al. (1983) found no difference between occurrences of LBP and a variety of sporting activities (tennis, football, baseball, basketball, downhill skiing and snowmobiling). On the other hand, cross-country skiing and jogging were associated with complaints of moderate non-disabling pain. Further, subjects with severe LBP had participated in sport activities during adolescence to the same degree as asymptomatic patients and those with mild pain, but had become relatively less active in later years.

In summary, the importance of physical fitness and training in reducing musculoskeletal injuries is generally accepted in the literature. However, epidemiological literature at present does not support the use of physical fitness and training as a primary criterion for preventing musculoskeletal and back injuries. Injuries from training and physical fitness programs are frequent and benefits and risks from these programs are not quite clear.

Lumbar Mobility

Presence of back pain may cause restriction in back movements, especially flexion, but lumbar stiffness itself may not interfere with normal activities, provided that the mobility of the hips and thoracic spine is unimpaired (Troup and Edwards, 1985). Most LBP patients also complain of increased pain when bending forward or extending their trunk. Increase of pain is not frequent in other planes of motion (lateral flexion and rotation) (Bergquist-Ullman and Larson, 1977). There is no evidence that the reduced spine mobility is a risk factor in the causation of low-back pain.

Horal (1969) found "normal mobility" (based on finger to floor distance on bending with straight knees) in 96% of individuals with no recent back pain and in 82% with recent back pain. Biering-Sorensen (1983) reported that the reduced flexibility of the back was more pronounced in subjects who experienced recurrences of LBP. Bergquist-Ullman and Larson (1977) did not find decreased lumbar flexion to have any influence on the risk of occurrence and duration of a LBP episode. Karvonen et al. (1980) found no strong relationship between lumbar mobility and subsequent back pain. Wickström et al. (1978) reported that restricted lumbar mobility was more closely related to age than to back pain.

Strength

Muscle strength has long been considered of importance in relation to LBP. Measurements of trunk strength have been used to determine if there are differences between subjects with and without LBP. Workers' strengths in relation to job physical requirements have also been studied to determine future risks of musculoskeletal and back injuries. This is discussed later in this chapter under prevention of low-back pain.

Many investigations have established that patients with LBP have lower mean trunk strength than healthy subjects (Alston et al., 1966; Nachemson and Lindh, 1969; Pedersen et al., 1975; Nummi et al., 1978; Berkson et al., 1977; Addison and Schultz, 1980; Hasue et al., 1980; McNeil et al., 1980; Nordgren et al., 1980; Langrana et al., 1984; Mayer et al., 1985). McNeil et al. (1980) reported that both male and female patients with LBP and/or sciatica had approximately 60% of the trunk strengths of the healthy subjects. Jorgensen and Nicolaisen (1987) found that the trunk extensor strength was independent of a person's earlier low-back episodes but the isometric endurance time was shorter in those with LBP to a degree that made work impossible than in others. Failure or poor performance in dynamic strength tests of trunk muscles (such as sit-up) is more common in those with previous back trouble (Rowe, 1971; Nummi et al., 1978; Troup and Edwards, 1985). However, this predictive value is not established.

Rowe (1963) reported that when patients were retested a few days later after clearing of the severe pain, some patients showed normal abdominal strength. Similarly, Nachemson and Lindh (1969) reported that those male patients who were incapacitated less than one month did not have significantly lower strength than the control groups. However, those who had been inactive for more than one month had lower extension and flexion strengths. The study concluded that the strengths of spinal and abdominal muscles are of doubtful importance for the prevention of low-back syndrome.

Muscle strength may be influenced by many factors, such as age, height, body weight, training, motivation and fear of pain, etc. Prolonged inactivity imposed by pain resulting in deconditioning, disuse and immobilization (bracing of back) appears to be a major cause for weak trunk flexors and extensors observed in chronic low-back patients (Alston et al., 1966; Nachemson and Lindh, 1969; Mayer et al., 1985). This appears to be true even though the initial syndrome might have been caused by acute muscle strain, disc disease or other organic disorder (Alston et al., 1966). Another major factor for reduced strength appears to be fear of pain and/or injury, intensified by psychological factors such as anxiety and somatization especially in chronic low-back patients (Alston et al., 1966; Nachemson and Lindh, 1969; Mayer et al., 1985). Pain can produce neuromuscular inhibition, joint splinting and lowered performance. Mayer et al. (1985) believe that there is some conscious effort on the part of some LBP patients to mislead the analyst.

The strengths of trunk flexors and extensors without relating these to job physical requirements are apparently of little significance in determining risk of future injury. It is not clear whether the trunk muscle weakness is the cause, effect or mere accompaniment of the low-back pain (Rowe, 1963). Though the mean values for normal healthy subjects tend to be more than for patients with back pain, there is a considerable overlap in isometric trunk muscle strength between those with and without LBP (Alston et al., 1966; Nachemson and Lindh, 1969; Berkson et al., 1977). Some subjects in both groups show similar strengths.

Medical History

Those with a history of back pain have a greater prevalence of back pain and prolonged disability (Lawrence, 1955). Recurrence of back symptoms are reported as high as 85% (Rowe, 1969; Nachemson, 1982) and as high as 50 to 60% in the first year after treatment (Bergquist-Ullman and Larson, 1977; Troup et al., 1981). Rowe (1983) found that 72% of the patients had a history of one or more episodes of low-back disability prior to the compensable incident. It is widely agreed that a previous history of back or sciatic pain is one of the most reliable

predictive factors for subsequent work related back problems (Dillane et al., 1966; Rowe, 1971; Karvonen et al., 1980; Nordgren et al., 1980; Troup et al., 1981, 1987; Lloyd and Troup, 1983; Biering-Sorensen, 1983). Hult (1954) and Rowe (1969) recommended that good medical histories are necessary to determine personal risks of incurring repeated episodes. Chaffin and Park (1973) found previous history of LBP to be associated with an increased risk of low-back injury. The study recommended that if a person has a history of repeated LBP episodes, he/she should not be engaged in jobs requiring heavy lifting. It is concluded that the repeated episodes of LBP are a significant risk factor for heavy physical work.

Years of Employment

Some people believe that the lack of experience is associated with the risk of a musculoskeletal injury. However, epidemiological data does not support the above notion. Caplan et al. (1966) and Uhl et al. (1987) did not find length of employment to be a significant factor. Bergquist-Ullman and Larson (1977) reported that only 4% of the patients had been employed for less than one year and 28% had been employed for more than ten years. Harley (1972) reported that a majority of cases appeared after fifteen to twenty-five years at work. Magora (1970) found a positive relation between years of employment and frequency of back pain. Wiikeri et al. (1978) reported that the length of work exposure was strongly related to the degree of degeneration.

Smoking

An association has been identified between smoking and LBP (Svensson et al., 1983; Frymoyer et al., 1983; Owen and Darmon, 1984). Other studies found no association between smoking and LBP (Biering-Sorensen, 1983; Astrand, 1987). Svensson (1983) speculated that coughing leading to increased intradiscal pressure was the mediary in this relationship. Biering-Sorensen, 1983) also found an association between LBP and coughing (but not smoking). However, Frymoyer et al. (1983) found that coughing alone was insufficient to account for the observed differences in LBP patients. The study suggested that smoking might cause a reduction in vertebral-body blood flow. At present, the relationship between smoking and LBP and the role of smoking in the production of LBP are not clear. Future studies are needed on this issue.

Psychosocial Factors

Individual psychosocial factors are commonly found in patients with LBP. Some of these factors include a history of depression, hysteria, hypochondriasis, previous back surgery, alcoholism, extreme religious attitudes, job dissatisfaction, low education

level, disabled relatives, family problems, and low level of recreational activities, etc. Although psychosocial factors are unproven as predictors of LBP and other musculoskeletal injuries, some people believe that psychological testing may predict an individual's response to treatment and surgery (Sternback et al., 1973). Others disagree (Kellgren and Lawrence, 1952; Westrin, 1970, 1973; Bergquist-Ullman and Larson, 1977, Currey et al., 1979).

Patients with chronic and disabling LBP often show abnormal findings such as hysteria, hypochondriasis, anxiety, emotional stability, somatization and depression (Sternback et al., 1973; Bergquist-Ullman and Larson, 1977; Frymoyer et al., 1980; Pope et al., 1984). The most widely used test is the Minnesota Multiphasic Personality Inventory (MMPI). However, it is not clear which comes first: the back disorders or psychological problems (Sternback et al., 1973; Magora, 1973; Dehlin and Berg, 1977; Bergquist-Ullman and Larson, 1977; Pope et al., 1984). Also, most of the above mentioned traits have a tendency to become normal after successful rehabilitation (Bergquist-Ullman and Larson, 1977).

Magora (1973) reported a higher incidence of LBP in subjects who were not satisfied with their occupation, place of employment and social status. Also, a higher incidence of LBP was found in those who felt that a higher degree of mental concentration and responsibility was required of them and those who complained of a relatively high degree of nervousness and fatigue after work. Similarly, Dehlin and Berg (1977) reported that nursing aides with back pain symptoms in general exhibited a lower level of overall satisfaction with the job, perceived more negative relations with their supervisors and workmates and perceived a greater demand for physical and psychic strength. Other studies have also shown that patients reporting monotony and dissatisfaction with their jobs have a higher incidence of LBP and a longer absence from work than the satisfied patients (Taylor, 1968; Bergquist-Ullman and Larson, 1977; Svensson and Andersson, 1983; Bigos et al., 1986, Bergenudd and Nilsson, 1988). Astrand (1987) reported that back pain was associated with occupational status, shorter education, duration of employment, low performance on cognitive tests and neuroticism. An association has also been reported between higher socio-economic status and increased occurrence of back and leg complaints (Kelsey and Ostfeld, 1975; Karvonen et al., 1980).

Low-back pain is dependent on a variety of objective and subjective factors and appears impossible to assess objectively. An assessment of psychosocial factors is difficult and often inexact (Magora, 1973). No firm conclusions about the importance of psychosocial factors or the mechanism of the causal association can be drawn from the results of these studies (Bergquist-Ullman and Larson, 1977). It is unclear whether these

psychologic abnormalities are the cause or the result of the continued LBP symptoms. At present, the influence of psychosocial factors on LBP has not been fully elucidated.

Structural Abnormalities

A number of studies have been carried out for establishing if a relationship exists between skeletal defects, congenital or acquired, and low-back pain. Medical literature has numerous papers describing the relationship between certain structural defects of the lumbosacral region and the clinical behavior of the back. However, architectural peculiarities of bone are fairly common and can be seen in about 40% of all lower back x-rays (Rowe, 1983). It has been clearly established that different defects do not necessarily give rise to back pain (Splithoff, 1953; Hult, 1954; Rowe 1963, 1969; Horal, 1969, LaRocca and Macnab, 1969, Redfield, 1971; Hodgson et al., 1974; Magora, 1975; Andersson, 1981; Troup and Edwards, 1985).

Structural defects such as scoliosis, hyphosis, hypo- or hyperlordosis, leg length discrepancy, increased lumbosacral angle, partial and complete sacralization, spina bifida occulta, osteoarthritis, spondylolysis and spondylolisthesis do not seem to predispose LBP (Hult, 1954, Kellgren and Lawrence, 1958; Rowe, 1963, 1969; Horal, 1969; Hodgson, 1974; Magora, 1975; Magora and Schwartz, 1976, 1978). It appears that these abnormalities, with the exception of spondylolisthesis, have little predictive value in determining the long-term behavior of the back, at least as a single factor (Rowe, 1983). However, they may have a significance as contributing causes of low-back pain and are associated with increased risk of LBP. Sacralized transverse process is found with approximately equal frequency in patients and in the control population (Rowe, 1969). Spondylolysis does not appear to bear any relation to LBP (Torgerson and Dotter, 1976). Spina bifida occulta appears equally frequently both in healthy subjects and those suffering from LBP (Splithoff, 1953; Hult, 1954; Horan, 1969; LaRocca and Macnab, 1969; Magora and Schwartz, 1976). Low-back pain appears to be more common in subjects with spondylolisthesis (Hult, 1954; Fisher et al., 1958; Horal, 1969; Kettelkamp and Wright, 1971; Wiltse, 1971; Magora and Schwartz, 1976), but there are several reports indicating the opposite (Splithoff, 1953; Rowe, 1963; LaRocca and Macnab, 1969). Spondylolisthesis, which occurs in about 6% of the U.S. population, does not always produce pain even over a lifetime of heavy work and is not a definite diagnosis (Rowe, 1983). Scoliosis has received special attention, but there is lack of hard evidence associating sciolosis to LBP (Collis and Ponseti, 1969). The authors reported that most patients with idiopathic scoliosis let active and productive lives despite spinal curvatures of more than 50 degrees in 71%. However, LBP may be more prevalent if the scoliosis is greater than 80 degrees, especially with the vertex in the lumbar region (Andersson, 1981).

Abnormal or asymmetrical placement of the facet joints and the degree of forward slope of the sacrum may have some significance as contributing factors to LBP, but there is insufficient evidence at this point (Rowe, 1983). Normally, facet joints face roughly in a lateral plane and check any tendency toward forward slip of the spine. When they face in the sagittal plane, they provide less stabilizing function, may result in increased shearing stress and may contribute to mechanical instability (Rowe, 1983).

Osteoarthritis (growth of bony blebs, lips and spurs from the margins of vertebral bodies) occurs as frequently and as severely in patients with no back pain as in those with back complaints (Rowe, 1983). However, if the spinal canal is too small or has an abnormal configuration, disc protrusion or degenerative bony productive changes may produce pressure upon or may cause entrapment of nerve root elements within the canal (Rowe, 1983). Osteoporosis (decalcification of vertebral bone) with macro or micro fractures can cause LBP. However, osteoporosis is no more common in subjects with LBP than in those without it (Horal, 1969; LaRocca and Macnab, 1969). Similarly, no relationship was found between degenerative osteoarthritis and LBP (Magora and Schwartz, 1976).

JOB RISK FACTORS

Heavy Physical Work

One of the problems in the evaluation of the relationship between heavy physical work and LBP is the difficulty in defining and quantifying heavy physical work. Most studies have somewhat arbitrarily classified occupations as light, medium and heavy work. Some have used weight of the load and others high energy demand or subjective perceptions to define heavy physical work. In general, job physical requirements have neither been measured nor quantified. It is also clear that the above classifications of jobs as heavy physical work may not have any significant relationship with the load on the spine during work.

Several investigations have indicated a significantly higher incidence of LBP among heavy industry workers than among workers with less strenuous jobs (Kellgren and Lawrence, 1952; Magora and Taustein, 1969; Lawrence, 1969; Magora, 1970; Chaffin, 1974; Wickstrom, 1978; White and Gordon, 1982; Tabor, 1982; Stubbs et al., 1983; Videmann et al., 1984; Klein et al., 1984; Harber et al., 1985; Bigos et al., 1986; Jensen, 1987, 1988; Valles-Pankratz, 1989). Others have reported either a moderate difference or no significant difference in frequency of LBP between workers on light and heavy jobs (Hult, 1954; Rowe, 1963, 1969; Partridge and Duthie, 1968; Kelsey, 1975; Damkot et al., 1984). Information based on worker's compensation claims and insurance data shows that LBP is much more prevalent in heavy

physical jobs (Dehlin et al., 1976; Bergquist-Ullman and Larson, 1977; Jensen, 1987, 1988). Workers with heavy manual jobs are more likely to develop compensable back injuries than other workers (Rowe, 1969, 1971; White and Gordon, 1982; Jensen, 1987, 1988). The severity of back pain is also significantly greater in manual workers than in workers in light jobs. Several studies have reported significantly longer durations of initial and recurrent episodes in heavy jobs than in light jobs (Caplan et al., 1966; Partridge and Duthie, 1968; Bergquist-Ullman and Larson, 1977; Wickstrom, 1978). Wickstrom (1978) reported that those with the heavy jobs had a four time greater lifetime prevalence of lumbar insufficiency, a three times greater prevalence for recurrent attacks of lumbago, and a two times greater prevalence of pronounced sciatica than those with light jobs. A higher prevalence of disc degeneration has also been reported among those who perform heavy physical work (Kellgren and Lawrence, 1952; Hult, 1954; Lawrence, 1969).

It is widely recognized that an increased load on the already afflicted back produces more pain (Hult, 1954; Rowe, 1969; Nachemson, 1971; Magora, 1974; Bergquist-Ullman and Larson, 1977). Also, it is reasonable to assume that back symptoms are much more likely to interfere with work when it is heavy, i.e., a worker with a backache would have more difficulty performing a heavy job than a light one (Rowe, 1969, 1983). For example, Hult (1954) reported that 43.5% in heavy work versus 25.5% in light work had been off work due to LBP. Individuals with severe LBP try to find a job without much manual materials handling (Jensen, 1988).

At present, the specific cause of LBP as related to heavy physical work is not fully clear. However, based on pathobiomechanics of disc degeneration and facet joints, the potential for producing low-back disability is higher in those whose jobs demand heavy physical activity (Rowe, 1983). The potential for overexertion injuries is also greater in heavy physical jobs. Workers in heavy physical work have a much greater need to report LBP symptoms. It is concluded that heavy physical work is a significant risk factor for low-back pain.

Lifting

It has been clearly established that back pain can be triggered by lifting. The combination of lifting, bending and twisting is believed to be the most frequent cause of back injuries. (Andersson, 1981; Rowe, 1983; Kelsey et al., 1984). Unexpected maximal efforts and repetitive heavy lifting are particularly harmful (Magora, 1972; Rowe, 1983; Frymoyer et al., 1983). Several investigations have found a strong relationship between lifting and incidence and duration of LBP (Hult, 1954; Lawrence, 1955; Horal, 1969; Ferguson, 1970; Chaffin et al., 1976; Snook et al., 1978; Ayoub et al., 1983; Frymoyer et al., 1983;

Biering-Sorensen, 1983; Svensson and Anderson, 1983; Greenwood, 1986; Bigos et al., 1986; Jensen, 1988; Klein et al., 1988). Snook et al. (1978) reported that manual handling tasks (i.e., lifting, lowering, pushing, pulling and carrying) were implicated as the specific act or movement associated with back pain in 70% of the injuries (Tables 2.3 and Figure 2.2). Other studies have implicated lifting tasks in 25% to 60% of the back injuries (Cust et al., 1972; Horal, 1969; Ferguson, 1970. Snook et al., 1978; Raistrick et al., 1981; Owen, 1987; Klein et al., 1984, Greenwood, 1986; Harber et al., 1985; Stubbs et al., 1983; Venning et al., 1987).

Many aspects of manually lifting a load have been identified as potentially hazardous to a person's musculoskeletal system (Herrin et al., 1974). These include weight or force required, horizontal and vertical location of the load, shape and size of the load, frequency of lifting, stability of the load, couplings, duration of lifting, workplace geometry, asymmetric lifting and environment, etc. Some of these are briefly discussed here.

Weight of the load handled is perhaps the most obvious factor which modifies risk of injury. As stated earlier under heavy physical work, several investigations have shown that both frequency and severity of back injuries are greater in heavy than in light industries. Herrin et al., (1986) showed that a single task in a job that produces excessive compressive force on the low-back or requires excessive strength would increase the risk of back injuries. Chaffin et al. (1976) reported that heavier jobs (in terms of maximum load lifted) resulted in increased severity of injuries (severe sprains, joint dislocations and bone fractures) in terms of total lost workdays or medical work restriction days. Chaffin and Park (1973) concluded that the "lifting of loads greater than about 35 pounds (16 kg) when held in close to the body, or equivalent conditions, such as 20 lbs. (9 kg) between 25 and 35 inches (64 and 89 cm) in front of the body, would be potentially hazardous for some people." Based on an epidemiological case-control study, Kelsey et al. (1984) concluded that jobs requiring lifting objects weighing more than 11.3 kg (25 lbs) more than 25 times per day had over three times the risk for acute prolapsed lumbar intervertebral disc as compared to those involving lifting less than 11.3 kg. Damkot et al. (1984) also reported that the maximal weight lifting requirements were greater in the severe LBP group as compared to no pain and moderate pain groups.

The physical dimensions of the load handled are important from a biomechanical, physiological, and psychophysical point of view. Several studies have demonstrated that the moment (the product of the weight of the load and the distance from the spinal axis) rather than the weight of the load or lifting method is most important in affecting stresses on the spine (Nachemson and Elfstrom, 1970; Martin and Chaffin, 1972; Tichauer, 1975;

Chaffin et al., 1976; Chaffin and Andersson, 1984). Chaffin and Park (1973) reported that the incidence rate of LBP was strongly correlated with the lifting strength rating of a job (based on a combination of weight, horizontal and vertical locations of the object, and the strength of a large strong man) (Figure 2.3). In a subsequent study, Chaffin et al. (1976) concluded that "the more remote the load center of gravity from the body (due to either the bulk of the object being handled or the workplace layout), the greater the frequency and severity of musculoskeletal problems and contact injuries." It appears that position of the load relative to the body is as important as the weight of the load within a given range.

Table 2.3: Acts or movements associated with low-back injuries (Snook et al., 1978)

| Act or Movement | Percentage of Injuries |
|--------------------------|------------------------|
| Lifting | 49 |
| Twisting/turning | 18 |
| Bending | 12 |
| Pushing | 9 |
| Pulling | 9 |
| Lowering | 7 |
| Sudden change in posture | 5 |
| Carrying | 5 |
| Slipping/tripping | 4 |
| Standing | 4 |
| Falling | 3 |
| Squatting | 2 |
| Catching | 2 |
| Sitting | 1 |
| Throwing | 0.5 |
| Walking | 0.5 |
| Shoveling | 0 |
| Other | 9 |

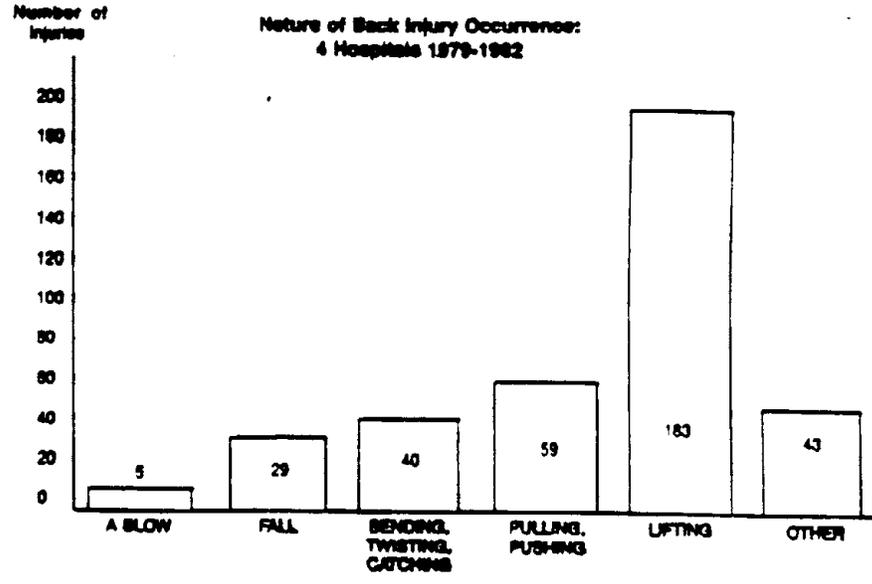


Figure 2.2: Nature of back injury occurrences from four hospitals (Greenwood, 1986).

Frequent lifting is important from both a physiological and psychophysical point of view. Recently, Brinckmann et al. (1988) have raised the possibility of a fatigue fracture with repetitive loading of the spine. In addition to fatigue fracture, moderate to high frequency lifting can cause muscle fatigue, an uncoordinated muscle action during a lift and could accelerate wear and tear in connective tissues. The combination of moderate to heavy loads and frequent lifting can result in physical fatigue as demonstrated by excessive energy expenditure, heart rate and subjective fatigue (Garg et al., 1986). Several investigations have shown that repetitive lifting of moderate to heavy loads is an important risk factor associated with the frequency, severity and resultant disability of LBP (Hult, 1954; Horal, 1969; Magora, 1970; Chaffin et al., 1976; Bergquist-Ullman and Larson, 1977; Frymoyer et al., 1980, 1983; Kelsey et al., 1984; Arad and Ryan, 1986; Venning et al., 1987). Chaffin et al. (1976) concluded that, "the more frequent the lifting of maximal loads on a job, the greater the frequency and severity rates of musculoskeletal problems (other than backs) and the greater the severity of contact injuries." Frymoyer et al. (1983) identified repetitive lifting of 20 kg or more as the most important prognosis variable for LBP. Similarly, Frymoyer et al. (1980) found that the patients who reported LBP to the physician had occupations that required more repetitive lifting. Arad and Ryan (1986), based on a survey of nursing personnel in Australia, found a positive relationship between frequency of lifting per shift and one-month prevalence of LBP. Those who lifted 20 or more times per shift had about twice the one-month prevalence

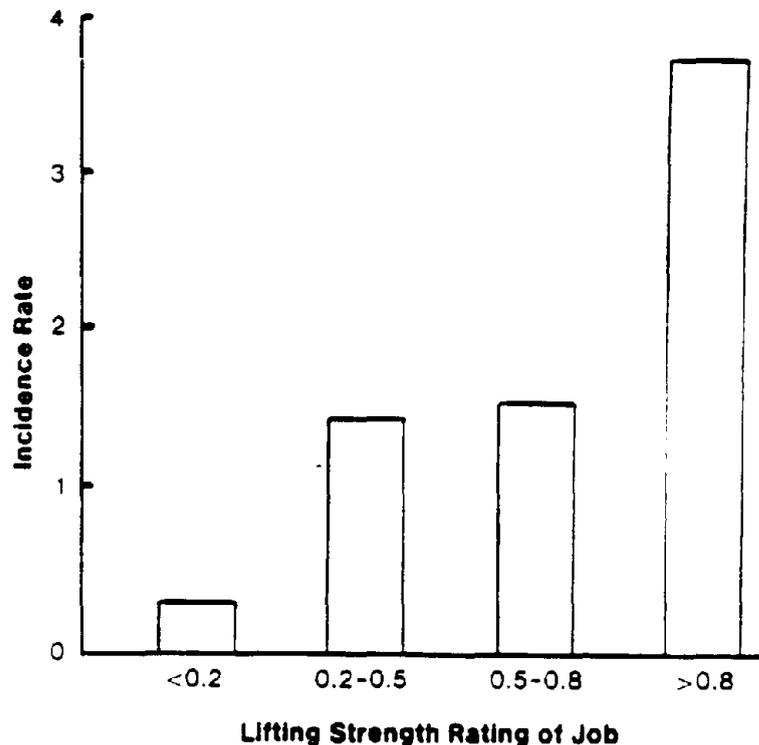


Figure 2.3: Incidence rates of back complaints (per 1,000 person-weeks) related to the lifting strength rating for the most stressful task in the job (from Jensen, 1988 based on data from Chaffin and Park, 1973).

of LBP (54%) than those who averaged zero lifts per shift. Damkot et al. (1984) reported a slight increase in the percentage of men with LBP and the severity of LBP with repetitive lifting. Bergquist-Ullman and Larson (1977) found a significantly longer duration of the initial episode of LBP in those who experienced daily fatigue in their backs and who were exhausted after work.

Sudden maximal physical efforts and unguarded moves have also been found to be related to LBP. Magora (1973) reported that sudden maximal physical efforts, characterized by their unexpectedness, were related to a high incidence of LBP. Bigos et al. (1986) reported haste, speed and inattention as the cause for 18% of all high-cost (> \$10,000) low-back injuries. This may be due to sudden strain of soft tissues. Rowe (1965) recommends that the load should at all times be under the control of the person performing the lifting maneuver. Sudden unexpected moves, as in turning suddenly to catch a falling object or having a load shift or slip, may initiate an acute episode of LBP (Rowe, 1983).

Bending, Stretching and Reaching

As mentioned earlier, a decrease in ability to bend forward as well as an increase in pain when bending forward is common among those suffering from LBP. It appears that bending in combination with lifting is the most common cause for LBP (Lawrence, 1955; Troup et al., 1970; Cust et al., 1972, Bergquist-Ullman and Larson, 1977; Snook et al., 1978; Johnston, 1982; Rowe, 1983; Klein et al., 1984; Punnett et al., 1987, Takala and Kukkonen, 1987). Based on a case-referent study, Punnett et al. (1987) concluded that forward trunk flexion (mild or severe), twisting of the spine, and trunk lateral bending were significant risk factors and the risk increased if a person spent more than 10% of the work cycle in a flexed posture. Rowe (1983) suggests that work requiring the maintenance of a slightly trunk flexed posture, such as over a drafting board or a slightly low workbench, or making beds, frequently causes LBP. Cust et al. (1972) reported that bending was the most frequent precipitating event of occupational LBP in teachers. Lawrence (1955) concluded that prolonged stooping (number of years) is associated with loss of work, prolonged disability, multiple discs changes and severe disc degeneration. Snook et al. (1987) reported that 66% of the lifting tasks involved bending but they were associated with 78% of the lifting injuries. Takala and Kukkonen (1987) also reported that persons who lifted in bent positions had more LBP trouble during the preceding year. Garg (1989) reported significantly greater perceived stresses for the back for lifting from floor to bench height than for lifting from bench height to about shoulder height even though the weights at the higher height were about 8% to 30% greater than those at the lower height (Figure 2.4). In this regard, it should be noted that lifting above chest height may result in excessive stresses on shoulder and wrist joints (Figure 2.4). Rowe (1983) believes that lifting loads above chest level with arching of the back may precipitate LBP.

Damkot et al. (1984) found an association between stretching and reaching and LBP. The study reported that in the severe LBP group 59% had jobs requiring stretching and reaching as compared to 36% in the moderate pain group and 40% in the no pain group. The authors concluded that the severe LBP group respondents were more likely to reach with arms fully extended.

Twisting

The association between low-back pain and twisting and bending is difficult to evaluate separately, as lifting is usually also involved (Andersson, 1981). Lifting in combination with twisting and/or lateral bending has been implicated with low-back pain in several studies. Troup et al. (1970) found the combination of lifting, bending and twisting to be the most frequent cause of back injuries in England. Bending, lifting and twisting are

believed to be especially representative of body movements contributing to nonaccidental low-back injuries (Figures 2.2 and 2.5). For example, nursing aids who have a much greater amount of lifting, bending and twisting as compared to nurses, also have a very high prevalence of LBP (Greenwood, 1986; Videmann et al., 1987; Jensen, 1987). Frymoyer et al. (1980) found that patients who reported LBP to the physician had occupations that required more twisting. Bergquist-Ullman and Larson (1977) concluded that frequent bending and twisting, fixed postures, lifting and forceful movements, general fatigue and daily back fatigue, etc., were all related to either a longer initial episode of pain or a longer absence from work or both.

Rowe (1983) suggests that lifting and twisting as in swinging luggage may precipitate an attack of LBP. Glover (1960) found that a twisting lift was the commonest cause of LBP in many patients (Figure 2.5). Snook et al. (1978) reported that twisting/turning accounted for 18% of all back injuries. Kelsey et al. (1984) concluded that there was an especially high risk for prolapsed lumbar disc if the job required lifting of objects weighing more than 11.3 kg (25 lbs) while twisting the body even if the lifting was done less frequently (less than 25 times/per day). Also, the authors concluded that lifting while twisting the body without bending the knees was more detrimental. Lifting of objects weighing less than 11.3 kg and twisting without lifting were not associated with an increased risk of prolapsed lumbar disc. In this regard, Punnett et al. (1987) found twisting of the spine and lateral bending to be significant risk factors even if no or relatively light loads were lifted. The study concluded that jobs requiring both mild flexion and twisting were particularly hazardous.

Pushing and Pulling

There are relatively few studies on pushing and pulling activities and their role in work related LBP. Klein et al. (1984), based on workers' compensation data, reported that pushing and pulling of objects accounted for 9% of all back strains and sprains. Snook et al. (1978) reported that pushing and pulling were associated with 18% of all back injuries. Frymoyer et al. (1980) found that low-back patients were more likely to do pushing and pulling tasks than were patients who sought medical attention for reasons other than low-back pain. Similarly, Damkot et al. (1984) reported that severe LBP respondents had much more pushing and pulling (as determined by weight multiplied by number of pushing efforts) than controls. The study also found that the severity of LBP increased with an increase in pushing and pulling requirements. White and Punjabi (1978) showed that high disc loads accompany these activities. It is believed that the coefficient of friction between the shoes and the floor is of primary importance as it would affect the static and dynamic pushing and pulling strengths. Studies by Fox

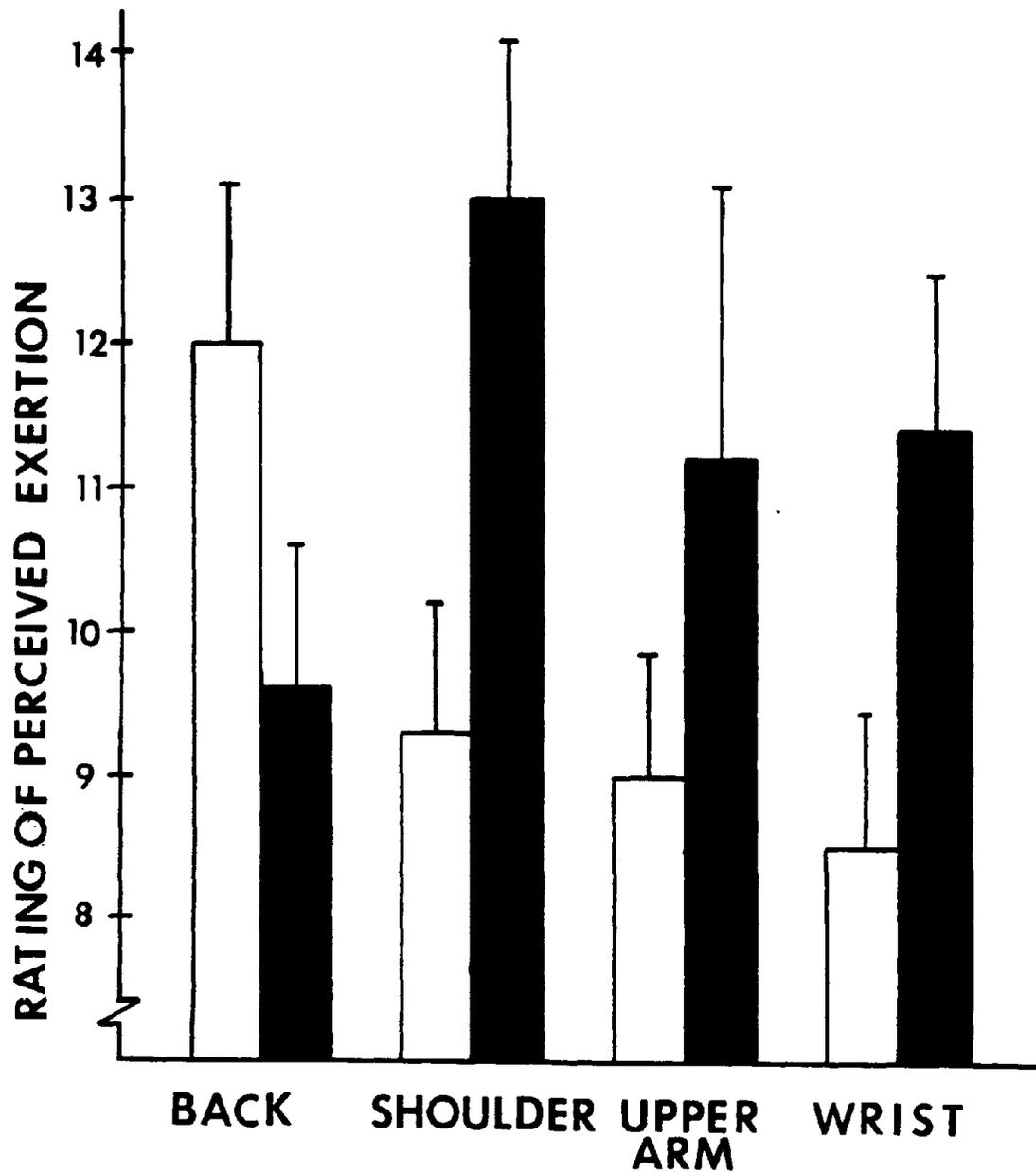


Figure 2.4: Mean ratings of perceived exertion for different body parts for lifting weights from floor level to 0.8 m height (0) and from 0.8 m to 1.5 m height (Garg, 1989).

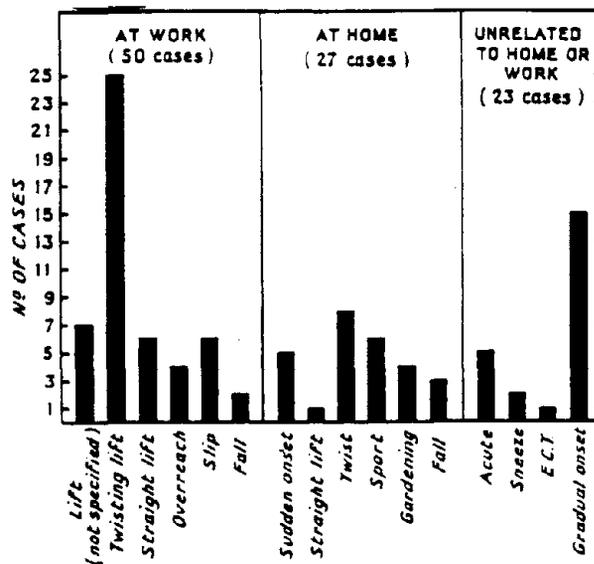


Figure 2.5: Causes of back pain in 100 cases (Glover, 1960).

(1967) and Kroemer and Robinson (1971) showed that the static pushing or pulling strength increased by about 50% (from 200 N to 300 N for healthy young males) with an increase in the coefficient of friction from 0.3 to 0.6. Also, the vertical height of the handle against which one pushes and pulls has a profound effect on pushing and pulling strengths (Martin and Chaffin, 1972; Ayoub and McDaniel, 1974; Lee, 1982; Chaffin et al., 1983, Garg et al., 1988). Based on a limited amount of data, the optimum height for a handle to be pushed or pulled appears to be approximately 90 cm (35.5 inches) to 115 cm (44.5 inches) (i.e., about hip height) to maximize strength and minimize compressive force (Pope et al., 1984).

Prolonged Sitting and Standing

Jobs that require workers to sustain a particular posture for prolonged periods may be associated with musculoskeletal problems related to those postures. Jobs demanding long periods of immobility, either standing or sitting, have been shown to cause muscle fatigue and to have ill effects upon discs (Magora, 1972; Rowe, 1983). Several investigations have shown that jobs that involved nearly all standing or nearly all sitting postures were associated with larger point prevalence or increased risk of LBP than were jobs involving changes in posture (Hult, 1954; Lawrence, 1955; Kroemer and Robinette, 1969. Nachemson and Elfstrom, 1970; Magora, 1972; Kelsey and Hardy, 1975; Bergquist-Ullman and Larson, 1977; Rowe, 1983; Jensen, 1988). Bent-over work postures also have an increased risk for low-back pain as discussed earlier.

Mogora (1972) reported that both too much or too little sitting or standing were related to a high incidence of LBP. Several investigations found an increase in risk of LBP in subjects who performed work in a predominantly sitting posture (Hult, 1954; Lawrence, 1955; Kroemer and Robinette, 1969; Magora, 1972). Kelsey and Hardy (1975) reported that men who spent more than half of their workday in a car had a threefold increased risk of disc herniation. However, it is not clear whether the increased risk is due to vibration or sitting. Nachemson and Elfstrom (1970) reported similar disc pressures for bending forward 20 degrees and sitting unsupported. Other studies did not find sitting to be a risk factor (Westrin, 1973; Bergquist-Ullman and Larson, 1977; Svensson and Andersson, 1983). Troup (1978) suggests that extended sitting may increase the pain and discomfort felt by individuals who already have some back problems. Bergquist-Ullman and Larson (1977) reported that patients who sat less than 2 hours per day bent and twisted their backs more than 10 times per hour and those who were forced into fixed postures for the greater part of the working day had longer durations of initial episodes.

The above studies show that occupations allowing a proper amount of variation of postures are preferable to those which require prolonged standing or sitting. It is important that a worker should be allowed to change work posture. In fact, some studies have reported that postural fatigue and sickness absences decreased when such changes were required (Griffing, 1960; Kroemer and Robinette, 1969; Magora, 1972).

Vibrations

There is no doubt that vibration is a significant risk factor in low-back disorders (Kelsey, 1975; Kelsey and Hardy, 1975; Troup, 1978; Frymoyer et al., 1980, 1983; Wilder et al., 1982; Pope et al., 1984). Vibrations are transmitted through the use of powered hand tools, floors on which the workers are standing (such as pallet jacks) or through the seats of vehicles. Frymoyer et al. (1983) reported that the overall cumulative exposure to vibrational equipment (such as jackhammers, chainsaws and rotary cultivators) was higher in both groups with LBP than in the asymptomatic group. Several studies have shown a relationship between vehicular exposure (vibrations) and frequency and severity of LBP (Kelsey and Hardy, 1975; Pope et al., 1980, 1984; Frymoyer et al., 1983; Damkot et al., 1984). Many vehicles and industrial devices vibrate at a fundamental frequency similar to the body's natural frequency (4 to 6 HZ) (Frymoyer et al., 1983) and amplification of imparted motion occurs in this range. Exposure to these vibrations can cause fatigue of the paraspinal muscles and ligaments and disc herniations (Pope et al., 1984). Kelsey (1975) reported that truck drivers were four times more likely and commuters traveling more than twenty miles/day two times more likely to have had a disc herniation as compared to those who did not hold such jobs.

Accidents

Traumatic events besides manual handling may contribute substantially to the incidence of work related LBP. Some back injuries can be caused by a specific event such as a stumble, a trip, a fall, or an impact (i.e., striking against an object or being struck by a moving object)(Jensen, 1988). In the United States, falls were implicated in 4.3% and involuntary motions in 4.7% of all cases classified as back sprain or strain (Klein et al., 1984). Other investigations have reported much higher statistics. Horal (1969) reported that about 25% of all LBP was due to accidents. Manning et al. (1984) reported that 47% of the true accidents and 24% of all attributable injuries were caused by slipping of feet. Further, the study found that about 26% of the back pain cases involved an unforeseeable event as the cause of the accident (slipping, tripping, stumbling, catching the foot on something, having the surface collapse or tilt suddenly, a sudden unexpected load on the back, blows to the back, and traffic accidents). Bigos et al. (1986) found that about 10% of back injuries were associated with falls and 19% with bodily motions. Also, back injuries due to accidents such as slips or falls had a much greater tendency to result in an expensive claim. Troup et al. (1981) also found that the duration of symptoms and subsequent expense tended to be greater for back injuries associated with an obvious accident such as a slip or fall. Conversely, prospective studies by Weber (1983) and Roland and Morris (1983), indicated that an insidious onset of symptoms rather than sudden onset (such as an accident) indicated a poor prognosis for those having LBP or disc herniation.

PREVENTIVE APPROACHES

Several different criteria have been used to prevent or reduce low-back pain in industry. Some of these include (i) selecting workers based on their anthropometry (age, sex, body weight, height, etc.), (ii) physical fitness, (iii) radiological screening, (iv) training in lifting technique, (v) preemployment strength testing, and (vi) ergonomic job design. The first two criteria were discussed under personal risk factors. The following is a brief discussion of the remaining four criteria:

Radiological Screening

In the past several companies used preemployment radiological screening and claimed a reduction in subsequent back injury rate (Troup and Edwards, 1985). A survey by Poda et al. (1982) showed that only 39% of the American Occupational Medicine Association members used preemployment X-rays routinely and 20% felt that X-rays were useful in predicting future risks. Based on a large study, Rowe (1969, 1971, 1983) concluded that routine radiological screening was "neither cost nor risk benefit effective." In general, there appears to be a consensus that

radiological screening should be limited to those with significant back symptoms and/or a past medical history of back problems, except where there is a serious risk of back injury (Troup and Edwards, 1985).

Experience over the past several years has shown that X-rays are of little value (LaRocca and Macnab, 1969; Rowe, 1969; Leavitt et al., 1971; Redfield, 1971; Troup et al., 1974; Alexander et al., 1977; Snook et al., 1978), since individuals with various structural abnormalities of the spine do not appear to have a greater incidence of low-back pain than those with so-called "normal spines." Most structural defects are not significant risk factors for LBP, though some with severe scoliosis (greater than 80 degrees, and spondylolisthesis are more susceptible to low-back pain. There is also the risk that continued spinal radiographs may give rise to leukemia or anemia (Court-Brown and Doll, 1959; cited in Brown, 1973). Snook et al. (1978) reported that the number of injuries experienced by employers who used medical histories, examinations and X-rays were about the same as by employers who used no selection techniques. Leavitt et al. (1971) concluded that "one can not hope to obtain early identification of a major portion of high-cost cases by the use of screening methods." Rowe (1969) estimates that only about 10 percent of the workers who would become low-back disability problems can be identified by the present diagnostic methods at the time of hiring. Studies by LaRocca and Macnab (1969), Redfield (1971), Troup et al. (1974), and Alexander et al. (1977), supported the earlier findings of Splithoff (1953) and Rowe (1969) that the lumbosacral X-rays taken at the time of employment did not predict or screen out injury prone applicants. Redfield (1971) using the criteria of the Ad Hoc Committee on Low Back X-rays (1964) found a lower injury rate for the "high risk" than for the "low risk" group.

In summary, there is little evidence that routine occupational health screening can identify those who may be susceptible to a first attack of back pain. Routine medical examination of all workers is neither necessary nor desirable (Troup and Edward, 1985). However, full clinical assessment may be necessary if the initial screening shows a previous or current health problem relevant to heavy manual work.

Lifting Technique

A substantial amount of literature has been published on lifting techniques. Unfortunately, no controlled epidemiological study has validated any of the contemporary theories on the subject. Proponents of the straight-back, bent-knee lift posture predict their views on a simplistic mechanical logic. They assume that this posture would allow the load to be held close to the torso resulting in a small bending moment and a small and uniformly distributed compressive force on the back (Floyd, 1958; Davis,

1959; Munchinger, 1962; Himbury, 1967; Anderson, 1970; Nachemson, 1971). These analyses do not account for the practical fact that many heavy objects are too large to be lifted between the knees, as is required by the squat lift method. Further, the stresses on the knees and in some cases on the back could be excessive. When the knees are acutely flexed, the thighs and legs cannot exert the thrust needed to lift the load and the body. Also the feet usually are not flat on the floor and may not be far enough apart for good leverage (Davis et al., 1965; Owen, 1985). Troup (1965, 1977) believes that moderate flexion of the torso provides more effective abdominal pressure assistance during lifting and therefore decreases stress on the back musculature. Park and Chaffin (1974) and Garg and Herrin (1979) reported that a stooped over position resulted in about one-third less compressive force on the low-back than the squat posture when lifting bulky loads. Most researchers, however, agree that hyperflexion is potentially dangerous. Ekholm et al. (1982) reported that lifting with straight knees and lifting with bent knees resulted in about the same bending moment and compressive force for loads in front of the body. Several studies have disclosed that leg lifting from a squat position is metabolically more demanding, thus possibly leading to fatigue related injuries (such as slips and falls, dropping objects, etc.) (Brown, 1973; Jorgensen and Poulsen, 1974; Garg et al., 1978; Garg and Saxena, 1985).

Several different lifting techniques have been recommended over the past several years. Some of these include: straight-back, bent-knees (Floyd, 1958; Davis, 1959; Munchinger, 1962; Anderson, 1970; Nachemson, 1971); kinetic method of lifting (International Labor Office, 1967; Anderson, 1970; Davies, 1978); squat position with a flexed (curved) back (Williams, 1974; Adams and Hutton, 1985); squat posture, straddle foot stance and flat back (erect back) (Anderson and Chaffin, 1986); back flexed and knees slightly flexed (Caliet, 1981); free-style posture (Brown, 1971; Snook, 1978; Garg and Saxena, 1979; Garg et al., 1983); and flexed-back and flexed-knee position with feet about a shoulder length apart (Jones, 1973). Unfortunately, there is no concrete evidence that one method is safer than the others. The use of term "right" has led to a rigid discipline which does not allow for any variations within its framework (Brown, 1973). Andersson et al. (1976) believe that the method used to lift a load is relatively unimportant and the horizontal distance is much more important. In certain situations, the practicability of a recommended method is rendered almost impossible by the fact that time standards or production standards are invariably based on traditional work measurement techniques, which do not differentiate between stoop posture and the straight-back, bent-knee methods for determining allowed time for the task and fatigue allowances. Based on a study of three different warehouses, Garg and Saxena (1985) concluded that "it is practically impossible for most workers to meet companies' time standards when using the straight-back, bent-knee method. Time

standards based on traditional work measurement techniques do not provide additional time for using the recommended straight-back, bent-knee method even though it is slower and more fatiguing."

Anderson (1970) and Brown (1973) concluded that the systems advocated in the official manuals are incorrect and likely to do more harm than good. Very little research has been carried out to determine the validity of the recommended methods of lifting. So far, lifting instructions have shown little or no effect in controlling low-back injuries (Brown, 1972; Dehlin et al., 1978, 1981; Snook et al., 1978; Stubbs et al., 1983; Wood, 1987; Venning et al., 1987). There is a wide variation in the manner of lifting, and very seldom is the prescribed straight-back, bent-knee method used (Brown, 1971; Garg and Saxena, 1985). This would indicate that either the indoctrination has been unsuccessful or the workers prefer to use some method which is more suitable to their own physical strength and physical anthropology.

Damkot et al. (1984) reported that the severe pain group had much more bending of legs and less lifting with bent back than no pain and moderate pain groups. Stubbs et al. (1983) observed that the low-back pain rates for nurses remained very high even though all of them had participated in a mandatory training program. Dehlin et al. (1981), Snook et al. (1978) and Venning et al. (1987) concluded that lifting instructions and choice of lifting technique did not affect the occurrence of low-back pain symptoms. Based on a study of nurses in a hospital, Wood (1987) suggests that experienced workers will not benefit from training programs as most of them have learned the basic safety elements of the job.

In summary, although instructions on manual handling and lifting are fairly widely believed to have some prophylactic value, there is no scientific evidence that these are, in fact, effective in reducing the frequency or severity of musculoskeletal injuries and, in particular, back pain. As stated by Stubbs et al. (1983), "if the work is intrinsically unsafe, then no amount of training can correct the situation." Clearly, it is not the lifting technique that has a major impact on the relative risk of back injury. It is the job that puts the worker at risk (Venning et al., 1987).

Preemployment Strength Testing

Studies of low-back pain and other musculoskeletal injuries in relation to isometric strength show some predictive value (Chaffin and Park, 1973; Chaffin, 1974; Chaffin et al., 1978; Keyserling et al., 1980, a,b; Cady et al., 1979; Karvonen et al., 1980; Anderson and Catterall, 1987). These studies have demonstrated that both a worker's likelihood of sustaining contact, musculoskeletal and back injuries and severity of injuries increase when job lifting requirements approach or

exceed the strength capability demonstrated by the individual on an isometric simulation of the job (Figure 2.6). Similar, observations have been reported by Ayoub et al. (1983) using psychophysically determined maximum acceptable weights (Figure 2.7). The basic premise for preemployment strength testing is that most of the musculoskeletal and back injuries are caused by overexertion due to a mismatch between worker's strength and job strength requirements. In other words, the job physical requirements exceed the physical strength capability of the worker.

Magora (1974) reported that when a job exceeded the lifting capability of the worker, symptomatic low-back pain was more likely to develop. Poulsen and Jorgensen (1971) and Poulsen (1981) proposed that the weight limits should be based on isometric back muscle strength. Chaffin and Park (1973) and Chaffin (1974) reported a sharp increase in the mean low-back pain incidence rates (by a factor of 3:1) for those jobs where the job strength requirements exceeded the lifting strength of the workers. In a subsequent study, Chaffin et al. (1978) confirmed that as the job strength requirements approached or exceeded the demonstrated isometric strength of workers on the job, the mean incident and severity rates increased at a ratio of about 3:1 (Figure 2.6). Keyserling et al. (1980a) supported these findings and concluded that the medical incidence rate of employees who were selected using the strength tests was approximately one-third that of employees selected using the traditional medical criteria. In a subsequent study, Keyserling et al. (1980b) reaffirmed the earlier findings and found significant relationships among job strength requirements, worker strengths and medical incidents. The study concluded that the workers with strength abilities less than job strength requirements suffered a higher rate of medical incidents than workers whose strength abilities matched or exceeded job demands. Recently, Anderson and Catterall (1987) concluded that isometric strength testing by itself can be very effective in reducing contact, musculoskeletal and back injuries. Also, a test of endurance along with strength testing can enhance the effectiveness of a screening battery.

Ayoub et al. (1983) proposed the use of a job severity index (JSI) as a tool for job design and employee placement. The authors showed that the ratio of job physical demand to the capacity of the worker (psychophysically determined maximum acceptable weight) was related to the frequency and severity of back injuries suffered during manual materials handling jobs (Figure 2.7).

It is clear from the above studies that the inability to demonstrate a lifting strength equal to that required on the job is a significant risk factor. However, it can not be stated that physical ability and/or endurance testing will always be effective. Strength testing does not account for hazardous

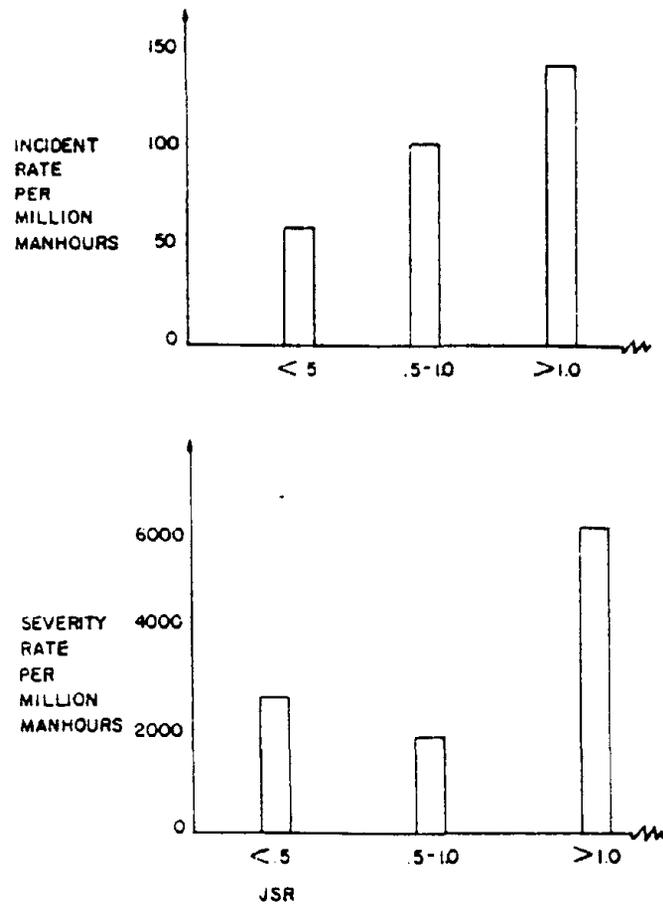


Figure 2.6: Back injuries vs. job strength ratings (Chaffin et al., 1978).

levels of stress to the spinal structure such as high compressive and shear forces. In spite of these concerns, strength testing can be used to identify workers who would be at an increased risk of suffering medical incidents if placed on jobs which exceed their strength capability. Thus, it can be effectively used to minimize overexertion types of musculoskeletal and back injuries such as muscle strains and sprains. In this regard, the preemployment strength testing test should be safe, reliable, related to specific job requirements, practical and should predict risk of future injury or illness.

Ergonomic Job Design

Job design is an ergonomic approach which attempts to fit the job to the worker. As far as manual materials handling is concerned, the objective is to design the job so that (i) physical requirements will not exceed strength and endurance capabilities of a large percentage of workers, (ii) it would not produce undue

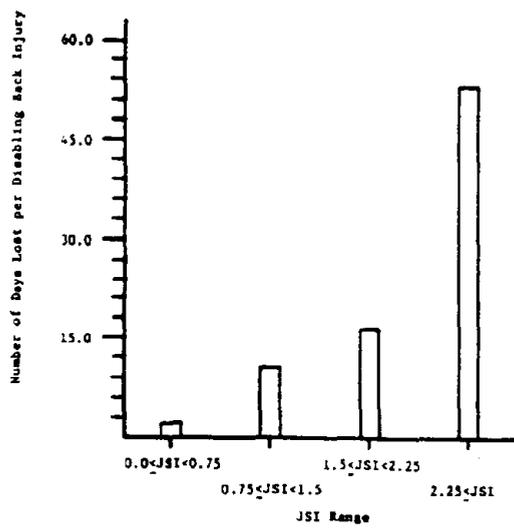
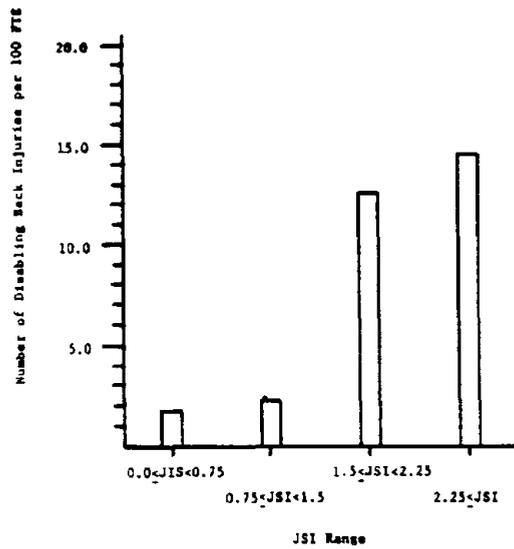


Figure 2.7: Incidence and severity of disabling back injuries caused by lifting versus job severity index (JSI) (Ayoub et al., 1983).

stresses to the spine and other body joints, and (iii) significant workplace risk factors are minimized. The basic premise is that both the frequency and severity of musculoskeletal and back injuries can be minimized if the job is not hazardous to a large percentage of the worker population.

It is widely believed that the most effective control for musculoskeletal injuries, and low-back injuries in particular, is the ergonomic job design (Chaffin and Park, 1973; Snook et al., 1978; Rowe, 1983; Ayoub et al., 1983; Liles et al., 1984; Herrin et al., 1986). Snook et al. (1978) reported that a worker was three times more susceptible to low-back injury if the worker was performing a job which less than 75% of the working population could perform without overexertion. The authors suggested that the ergonomic approach would be more effective if the jobs were designed so that they were within the physical capability of 90% of the working population. Liles et al. (1984) also reported that the disabling back injury rate (worker missed at least one day) increased with an increase in the percentage of overstressed workers (Figure 2.8). Ayoub et al. (1983) also reported a relationship between the job severity index (JSI) and the frequency and severity of back injuries (Figure 2.7).

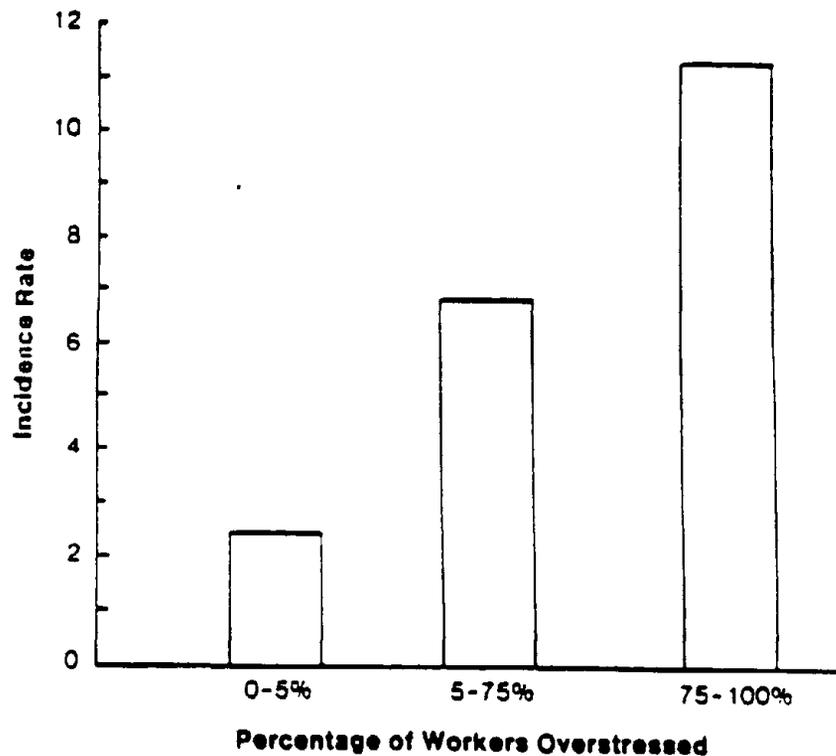


Figure 2.8: Incidence rates of back complaints (per 100 full-time employees) versus percentage of employees overstressed (from Jensen, 1988 based on data from Liles et al., 1984).

Chaffin and Park (1973), based on data involving 103 jobs in five manufacturing plants, reported that a job with even one highly back-stressing lifting task could appreciably increase the risk of back pain complaints (Figure 2.3). The authors also found a correlation between the compressive force on the L₅/S₁ disc and the incidence rate of low-back pain. Jobs with a compressive force over 6236 N (636 kg) had an 8 times greater low-back pain incidence rate than jobs having values below 2673 N (273 kg). Herrin et al. (1986) based on a study involving fifty-five industrial jobs in five industries showed a consistent increase in low-back incidence rate with an increase in compressive force on the L₅/S₁ disc (Figure 2.9). The jobs were classified only on the basis of the most stressful task. The study reported similar findings when the jobs were evaluated using strength requirements instead of compressive force. The study concluded that overexertion injuries can be related to physical job stress and that, in addition to compressive force, the percentage of the population capable of performing the most stressful element of the job is perhaps the best single index. This index can be based upon either isometric strength or psychophysical strength (maximum acceptable weights and forces).

Rowe (1983) believes that the real objective is to minimize disability, and ergonomic job design can significantly reduce



Figure 2.9: Incidence rates of back complaints (per 200,000 hours) versus compressive force on the lower back (from Jensen, 1988 based on data from Herrin et al., 1986).

disability. Adequate job design so that all work falls within the physical capabilities of the majority of workers may allow the workers to continue to work regularly with backache because it would have the same effect as placement in lighter work (Rowe, 1983).

SUMMARY

Low-back pain and back injuries are of such a complex nature that any one criterion cannot be applied by itself to give a valid assessment of the risk associated with manual materials handling jobs. There is no question that low-back pain is an extremely significant cause of disability and has a major socioeconomic impact. Many different personal and job factors are associated with the incidence and prevalence of low-back complaints. There is a need for ongoing systematic investigations of the multiple risk factors that may be causally related to low-back pain and may possibly be preventable. Knowledge of workplace and individual risk factors is far from complete. Prospective studies are needed so that factors contributing to the development of low-back pain can be separated from factors resulting from low-back pain.

It is difficult to relate low-back pain to the workplace because it is found quite often in workers employed in sedentary occupations. However, the incidence, severity and potential for disability are all related to the physical demands of the job. In this regard, jobs involving lifting, lowering, pushing, pulling, carrying and holding; body movements such as frequent bending, twisting and sudden movements; and working in bent-over postures appear to have a significant potential for producing low-back pain. A combination of lifting, bending and twisting appears to be the most hazardous. It is concluded that heavy load lifting contributes to the increased frequency and severity rates for low-back pain. This is true regardless of whether the lifting is performed over a short period or throughout the day and whether it is performed a few times per day or repetitively. If, however, such lifting is performed repetitively, the medical hazard extends beyond low-back problems to other musculoskeletal strain/sprain injuries and fatigue related injuries, particularly for weaker workers.

In this latter regard, gender, age, anthropometry and previous history of back pain are known to modify these risks for populations of workers. The inherent variability between workers and within any worker over time preclude the use of such factors to assign risk to any particular individual. Strength testing, however, is supported as one means for identifying high risk workers who need to perform manual materials handling. Studies are needed to carefully validate the effectiveness of this form of selection procedure. At present, ergonomic job design offers the most potential for preventing low-back pain and other musculoskeletal injuries.

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