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Abstract Occupational low back pain (LBP) is an immense burden for both industry and medicine. Ergonomic and personal risk factors result in LBP, but psychosocial factors can influence LBP disability. Epidemiologic studies clearly indicate the role of mechanical loads on the etiology of occupational LBP. Occupational exposures such as lifting, particularly in awkward postures; heavy lifting; or repetitive lifting are related to LBP. Fixed postures and prolonged seating are also risk factors. LBP is found in both sedentary occupations and in drivers as well as those involved in manual materials handling. Any prolonged posture will lead to static loading of the soft tissues and cause discomfort. Standing and sitting have specific advantages and disadvantages for mobility, exertion of force, energy consumption, circulatory demands, coordination, and motion control. The seated posture leads to inactivity causing an accumulation of metabolites, accelerating disk degeneration and leading to disk herniation. Driver’s postures can also lead to musculoskeletal problems. Workers in a driving environment are often subjected to postural stress leading to back, neck, and upper extremity pain. This exacerbates the problems due to the vibration. Prevention is by far the treatment of choice. Improved muscle function can be preventative. Poor coordination and motor control systems are as important as endurance and strength. Fixed postures should be avoided. Seats offering good lumbar support should be used in the office. A suspension seat should be used in vehicles whenever possible. Heavy and awkward lifting should be avoided and lifting aids should be made available. Workers should report LBP as early as possible and seek medical advice if they think occupational exposure is harming them. The combined effects of the medical community, labor, and management are required to cause some impact on this problem.
INTRODUCTION

Occupational low back pain (LBP) is a great burden for industry and medicine. Kelsey & White (1) found 2% of workers in the United States have a compensable back injury. LBP is the most expensive United States health problem in ages 20 to 50. The greatest expense is from 25% of the cases, and as the LBP duration increases, the total cost accelerates. LBP is responsible for 21% of all compensable work injuries and 33% of the cost. Medical costs are 33% of the total and disability payments are the remainder (2).

In this article, we examine the epidemiologic relationships between LBP and physical loading of the spine and the biomechanical etiology.

RISK FACTORS

General

We emphasize ergonomic factors, but other factors result in LBP and especially LBP disability. Psychosocial factors can influence LBP disability (3). According to Karasek et al. (4), work stress and ill-health are related to work load and clarity and conflict at work, but the effect of these work-related characteristics is moderated by control (decision latitude), career development opportunities, and social support at work. The combination of high demands and low control at work is supposed to be stressful and related to adverse health effects. It is now being recognized that there is a symbiotic relationship between psychological and physiological stress. Psychosocial stress during activity such as lifting under stressful conditions increases muscle activity and leads to increased spine compression and lateral shear (5).

Other important patient factors are obesity, physical fitness, smoking history, height, and pregnancy (6). Specific personal factors affect tissue tolerance (i.e., age and gender). These are important factors to take into account with an aging and diversified work force.

Muscle Function

Chaffin et al. (7) found that LBP was three times more prevalent in workers who had less strength than needed for their jobs and that one third of the workforce
is required to exert at their maximum strength [NIOSH (National Institute of Occupational Safety and Health) 1981]. Chaffin et al. (8) suggest industry use placement programs based on strength performance. Isometric testing is the most common, but it may be unrealistic and unsafe (3). In isokinetic tests, the lift velocity is constant. In isodynamic tests, the velocity varies but the resistance is preset, which is a realistic functional test, but has not been tested prospectively. The purpose of job simulation is to see if the worker can perform the job required. Strength testing should be as specific as possible to the job for practical, ethical, and legal reasons.

More subtle muscle functions such as motor control are also important. Cholewicki & McGill’s (9) model showed that the spine can buckle during a minor task with low muscle forces where a small motor error causes over-rotation of a functional spinal unit and loading of the soft tissues. Magnusson et al. (10) found that muscles do not respond quickly enough to protect the soft tissues. Krajcarski et al. (11) found that preactivation of trunk extensor muscles may serve to reduce the flexion displacements caused by rapid loading. The abdominal oblique muscles, especially external oblique, will rapidly increase their activation levels in response to rapid loading. When preactivation levels are low, there is a lower initial trunk stiffness and spine compression force. Adams & Dolan (12) found that soft tissues fail with bending moments of 60 Nm, which could be the torso weight when bending over with no muscle support. Some injuries occur because of motor control errors. These are random events, but are more likely in people with poor motor control systems (13). Thus, a back injury can occur in a simple task if there is insufficient warning of an overload.

Endurance is important because workers fatigue with repetitive tasks (14). McGill et al. (15) noted that people differ in their ability to hold a load in their hands and breathe “heavily.” This may be significant because the muscles required to be continuously active to prevent buckling of the spine are also used to breathe. Thus, those with compromised lung elasticity (i.e., smokers) may be at risk when the muscles are relaxed. McGill et al. (15) have identified inappropriate muscle sequences in subjects loaded while breathing 10% carbon dioxide to elevate breathing. Potvin & O’Brien (16) made the important observation that fatigue results in a change in the recruitment patterns of trunk muscles: Muscles serving as antagonist and trunk stabilizers during prolonged axial twist exertions increased their force levels in response to fatigue.

The stability of the spine can be considered to consist of three subsystems: the passive musculoskeletal, the active musculoskeletal, and the neural feedback subsystem. All systems act together. In recent years, more attention has been given to the neural feedback system. Proprioception is an important factor in stabilization of the joints and throughout the spine. It is probable that proprioception deficits are associated with LBP and low back injuries. Proprioception decreases with aging, with lack of exercise, and in those with LBP. A system with feedback has been successfully used to rehabilitate those with chronic LBP. With prolonged exposure to lifting or excessive postures such as full flexion, the viscoelastic structures of the
Lumbar spine will become stretched out due to creep. Gedalia et al. (17) reported that laxity in the viscoelastic structures desensitizes the mechano-receptors within and causes loss of reflexive stabilizing forces from the multifidus muscles. The first 10 minutes of rest after cyclic loading results in fast partial recovery of muscular activity; full recovery is not possible even with rest periods twice as long as the loading period. This may increase the risk of instability, injury, and pain in the spine.

Lifting

LBP is associated with lifting, but instructions for the “proper” technique have been controversial. The principle is to hold the object as close to the body as possible, which is more important than keeping a straight back (18). Brinckmann et al. (19) reported that spinal loading during forward bent posture results in a height decrease or deformation of lumbar vertebrae. Other things affect the way we lift. Chen (20) showed that when muscle fatigue occurs in the arms, the lifting strategy becomes more stressful on the back, and whole-body lifting should be avoided in order to reduce the risk of injury to the lower back. The worker should use smooth lifting technique without jerking to minimize the effect of dynamic loads on the spine. Davis & Marras (21) concluded from an extensive literature review that the ability of the individual to perform a task “safely” may be compromised by muscle coactivity during dynamic exertions, e.g., trunk motion outside the sagittal plane. Fathallah et al. (22) established that lowering of a load gives consistently lower trunk muscular activities than lifting. Asymmetric lifting is associated with an increased risk of low back disorders according to Kingma et al. (23); small deviations of a lifting movement from the sagittal plane can increase risk of low back disorders. Antagonistic cocontraction affects spinal stability and spinal compression. For antagonistic cocontraction to be beneficial, stability must increase more than spinal load. Antagonistic cocontraction is beneficial at low trunk moments typically observed in upright postures (24). Granata et al. (25) found that weight, task asymmetry, and job experience (level of experience) affect the magnitude and variability of spinal load during repeated lifting exertions.

Gagnon & Smith (26) also point out that slower lifts with reduced acceleration when lifting moderately heavy work may present less of a risk to low back disorder. With regard to our aging workforce, bending and lifting activities generate loads on the spine that exceed the failure load of vertebrae with low bone mineral density. This yields a high factor of risk (ratio of load on spine to failure load of bone) (27).

In critical tasks with twisting, it is important to have the worker turning with the feet to reduce the torsional loads on the intervertebral discs. The relative merits of back-stooped posture versus knee lifts are debated. However, lifting a bulky load with an erect back increases the intradiscal pressure (IDP) compared to the back-stooped posture because of the increased moment arm and the vertical component of body weight and hand forces. However, shear forces are greater when lifting with the back flexed and the articular capsule and the posterior ligaments may be overstrained. Workers may lift loads with their backs rather than their legs to
maximize the available energy. IDP is similar with back lift and leg lift if the load moment arm is constant. Intra-abdominal pressure (IAP) has been proposed as a major source of column support. Asmussen & Poulsen (28) report a maximum limit of 150 mm Hg for highly trained individuals and 90 mm Hg for the normal population. Krag et al. (29) established that increasing IAP actually increases muscle activity and thus spinal load.

### Pulling and Pushing

Pushing and pulling activities can cause occupational LBP. Magora (30) found increased LBP in those whose jobs involved reaching and pulling, and NIOSH reported that 20% of injury claims for LBP involved pushing or pulling loads. Damkot et al. (31) measured pushing exposure by multiplying the weight of pushed objects by the number of pushing efforts required each day. Those with severe LBP have five times as much weight-day units as those without LBP. White & Panjabi (32) have shown that high spine loads result from pulling activities (see Figure 1a). Ayoub & McDaniel (33) found that body posture plays an important role in the force capability in both pushing and pulling and is probably very important in the etiology of pulling or pushing LBP injuries. Friedrich et al. (34) found that combined walking and pushing under vertical space constraints was associated with increased lumbar flexion and thoracic extension. The latter increase was due to an attempt to enhance abdominal muscle strength. The health care professions are at a high risk of LBP, and pushing-pulling activities are no exception. Lavender et al. (35) found the most hazardous tasks performed by emergency medical technicians included pulling a victim from a bed to a stretcher, the initial descent of a set of stairs when using the stretcher, and lifting a victim on a backboard from the floor.

### Posture

The posture at work can cause LBP. We have already mentioned the antagonistic muscle activity and the effect on spinal loading. McGill et al. (36) pointed out that anterior shear load on the lumbar spine increases the risk of LBP. Bending forward allows the spine to fully flex; this changes the line of action of the largest extensor muscles and reduces their effectiveness to support anterior shear forces. In fact, in this position, the muscles become inactive and the person is hanging by their soft tissues. McGill et al. (36) found that fully flexing the spine renders the lumbar extensor muscles ineffective for supporting anterior shear forces. Anterior shear load on the lumbar spine is highly related to the risk of back injury. Jobs such as seated warehouse shipper, gardener, and construction worker require such postures. Potvin et al. (37) also pointed out that during lifting, the risk of injury to the spine may be increased more by the degree of lumbar flexion than the choice of stoop or squat technique. McGill & Brown (38) measured creep response of the lumbar spine from nine min of full flexion posture. Full recovery took ~30 min. Many workers have to work in extreme postures. Gallagher et al. (39) found that the effect of the kneeling posture, used in construction and mining, is increased
Figure 1  Forces in (a) pulling and (b) pushing activities.
Figure 1  (Continued)
lumbar compression. Adams & Dolan (40) point out that the risk of bending injury to soft tissues due to posture will depend not only on the loads applied to the spine, but also on loading rate and loading history.

The quantification of potentially harmful postures has been an enigma. One approach to record potentially stressful postures is referred to as posture targeting. A worker is observed at random times during the workday and the angular configuration of various body segments is recorded with the aid of a body diagram. This procedure is useful in evaluating workplace layouts when combined with worker reports of localized musculoskeletal pain obtained at several intervals during a workday. Another technique has been to use a trunk goniometer as shown in Figure 2.

SITTING LC According to Magora (41, 42), there is increased risk of LBP in sedentary jobs. There is also an increase in symptoms in those with LBP who sit for prolonged periods. In sitting, body weight is transferred to supporting areas by the ischial tuberosities and the soft tissues. Some body weight will be transferred to the floor, the backrest, and armrests. IDP when sitting with no lumbar support is 35% higher than standing (43). Increased IDP in sitting occurs due to (a) increased trunk moment when the pelvis rotates backward and (b) disk deformation caused by the lumbar spine flattening. Inclination of the backrest backward and increased lumbar support reduce IDP because (a) body weight is transferred to the backrest and an increased backrest inclination is beneficial, and (b) lumbar supports increase lordosis and reduce disc deformation. In addition to the advantage of backrests, armrests offer support that unloads the spine.

Sitting postures are usually classified as anterior, middle, or posterior. In the middle posture, the center of mass is directly above the ischial tuberosities and is unstable due to them acting as a pivot. The lumbar spine is either straight or in slight kyphosis. The anterior (forward leaning) posture is used when deskwork is performed. The center of mass is in front of the ischial tuberosities. In the posterior (backward leaning) posture, the center of mass is behind the ischial tuberosities. The posterior posture is obtained by a backward pelvic rotation resulting in lumbar kyphosis. The seated posture depends on factors such as the chair design, sitting habits, the task, seat height and inclination, backrest position, shape and inclination, and other supports. The chair should permit easy adjustment because continuous sitting in one position is a risk factor for LBP. Writing decreases IDP when the arms are supported by the desk, whereas typing and lifting a phone increase IDP because of larger load moments. However, there are physiologic reasons to change one’s working posture to improve both disc nutrition and soft tissue tone. Griffing (44) noted that postural fatigue, sickness, and absence decrease when postural changes are required.

STANDING LC Pope et al. (6) have reported the positive relationship between prolonged standing and LBP. However, there is no information that prolonged standing increases IDP unless accompanied by twisting, lifting, or other risk factors.
Muscular activity is required to maintain an upright posture, but as long as the body segments are well aligned with respect to the center of gravity, the activity is small. Any shift in the center of gravity of the trunk requires active counterbalancing by muscle force to maintain equilibrium. Muscle forces are also required to counterbalance the moment caused by an outstretched arm, an external weight, or any other force applied to the trunk, head, and upper extremities. The combined effect of all these forces upon the lumbar spine produces a moment that must be counterbalanced by the spinal muscles to maintain equilibrium.

It was first reported by DePuky (45) that the height of the human spine decreases during the day and increases at night while resting. It has been shown, by use of a precise height-measuring device called the stadiometer (Figure 3), that the overall height decreases with loading but increases in the hyperextended posture. Thus, creep occurs throughout the day.

Awkward Positions LC Muscle force, and thus IDP, is increased in postures involving lateral bending or twisting (46). A much more complex situation occurs when asymmetry prevails. In postures such as lateral flexion, rotation, and combinations thereof, other appropriate muscles will contract. In rotation and lateral bending, high levels of activity occur contralateral to the direction of postural asymmetries, whereas the activities on the ipsilateral side are small. The asymmetry in muscle activity can lead to unequal stress concentrations on the different component structures of the spine. Electromyographic (EMG) studies demonstrate the antagonistic activity and resulting higher IDP in awkward postures. Antagonistic cocontraction of trunk muscles was beneficial in improving stability at low trunk moments observed in upright postures (24). Antagonistic cocontraction was less in high trunk moments and more in low trunk moments.

Troup et al. (47) and Frymoyer et al. (48, 49) found twisting to be related to LBP. Basmajian (50) reported antagonistic EMG activity of the deep trunk muscles during axial rotation. Thus, the high level of muscle activity and the resultant IDP may explain the relationship between twisting and LBP. Sudden loading and awkward postures occur from slipping, tripping, and falling and range from 36% to 70% of LBP injuries (51, 52, 53). Grieve (54) pointed out that slipping is often accompanied by lifting. Measurement of slip resistance is not difficult. Strandberg (55) listed over 60 different methods to measure the frictional characteristics of the floor. If the slip resistance is greater, a worker is less likely to slip.

Whole Body Vibration (WBV)

Extensive reviews of the literature have been made by Hulshof & van Zanten (56) and Bovenzi & Hulshof (57), and it has been concluded that there is a positive relationship between LBP and WBV. There are a few studies with dose-response relationships. From a survey of occupational drivers (of many types), Schwarze et al. (58) concluded that, with increasing dose, it is probable that LBP is caused by exposure to WBV. Fritz (59) found the risk from exposure to WBV increases
Figure 3  Stadiometer system for measuring in vivo vertical creep of the seated subject.
with age. Interestingly, Hinz et al. (60) suggested that a person with a low vertebral strength may be more at risk to degenerative changes in the lumbar spine during repetitive exposures to moderate transient whole-body vibrations. Magnusson et al. (61) measured WBV while the drivers were traveling on their usual routes according to the recommendations set out by ISO (International Standards Organization) 2631 E (62, 63). Male bus drivers and lorry drivers were age matched to a cohort of sedentary workers. There was a significant difference between length of time off work due to LBP between the three occupations. Bus drivers took more time off work than truck drivers in both subjects in Sweden and the United States. Of the bus drivers, the Swedes were exposed to higher vibration levels, whereas the United States truckers were exposed to higher vibration levels than the Swedish truck drivers. Swedish city bus drivers experienced more vibration exposure than did the United States long-haul bus drivers. This is probably due to the difference in bus types, road conditions, and driving demands. The United States truck drivers were vibrated more than anyone in the study, possibly due to travel on poorer roads and less vibration attenuated seats and driver’s cabs.

With mounting epidemiologic evidence associating LBP with WBV environments there has been an increasing focus on the mechanical effect of occupational vibrations on LBP. WBV has many, and quite varied, effects on the human. Mechanical studies have focused on the resonant frequency, transmissibility, impedance, spinal muscle activity, and effects on the spinal tissues. When the spinal system is excited at the resonant frequency, there are major mechanical consequences because the associated stress can lead to the structure’s mechanical failure. Failure can occur because the structure oscillates at the maximum excursion, creating the greatest possible strains on the tissues. The natural frequency of a single degree of freedom structure can be determined by two means: driving point impedance and acceleration transmissibility. In impedance studies, the driving force is divided by the resultant velocity. Resonance occurs when both the driving force and resultant velocity are in phase and the impedance versus frequency curve reaches a maximum. They found resonant frequencies to occur between 4 and 6 Hz when the upper torso vibrates vertically, and between 10 and 14 Hz when there is a bending vibration of the upper torso with respect to the lumbar spine. Studies also report resonant frequencies of standing and supine subjects, and resonant frequencies of seated subjects as affected by side to side or fore to aft vibrations. The effect can also be characterized by a transfer function, describing the relationship of input acceleration and measured output acceleration at a point in the body. In frequency ranges where attenuation is low, resonance occurs causing increases in the transfer function magnitude. In sitting subjects, resonance occurs at the shoulders at 5 Hz and also, to some degree, at the head. A significant resonance from shoulder to head occurs at approximately 30 Hz.

The acceleration transmissibility method determines the output acceleration caused by a given driving acceleration. Transmissibility is defined as the ratio of the output acceleration, $A_{\text{out}}$, as measured on the body to the input acceleration, $A_{\text{in}}$, as measured on the system. At resonance, $A_{\text{out}}$ exceeds $A_{\text{in}}$. Using accelerometers
implanted in the lumbar vertebrae and an impact introduced by a pendulum (Figure 4). Pope et al. (64) showed that the resonant frequency was 4.5 Hz. These studies demonstrated that much of the dynamic response is due to the combined rotation and vertical compression of the pelvis-buttocks system. The frequency response of a tested subject is influenced by posture. Lateral bending and rotation of the trunk, which have a higher risk of disc herniation, also lead to a greater transmission of vibration. Due to fatigue during whole body vibration, there is a significant increase in EMG response of paravertebral lumbar muscles to a sudden unexpected load applied to the upper trunk. Thus, truckers who unload their truck right away after longer driving have a high risk of soft tissue or muscle injury. Of concern to the spine is the fatigue life of the tissues. This can occur with relatively small stresses

Figure 4  Impact system to test the frequency response in seated or standing subjects.
compared to those required for a static stress failure. A tissue’s fatigue life depends on the range of stress imposed. We have found that an intervertebral disc can fatigue and herniate and can develop a tracking tear due to cyclic vertical vibration. This is increased if the vibration is asymmetric or the specimen is preloaded.

Forklift drivers, farmers, and construction workers are exposed to long periods of twisted posture. The twisted posture in a vibrational environment has been shown to cause increased energy consumption compared to twisted posture or vibration as single exposure variables (65). Seated whole body vibration in a position that ensured muscular activity of the erector spinae muscles caused faster and more pronounced muscular fatigue in the lumbar erector spinae muscles when compared to the absence of vibration (66). Both static sitting and seated whole body vibration caused increased height loss in subjects, suggesting increased spinal load (67).

PREVENTION

General

Because LBP disability is due to more than ergonomics, it is advisable to consider them in a prevention strategy. Psychosocial factors can influence LBP disability, so it would seem to be advisable to improve this aspect of the working environment. A conflict-free workplace is probably healthier. Personal fitness programs aimed at obesity, physical fitness, and smoking history are also likely to be beneficial. Such programs should take into account the role of age and gender.

Muscle Function

LBP is more prevalent in workers who have less strength than needed by their jobs, and thus, it makes sense to build up the trunk strength of these workers. Screening or placement programs based on strength performance are problematic unless clearly legal in that jurisdiction. Emphasis should also be placed on endurance, motor control, and proprioception.

Lifting

The NIOSH guide, which is a very useful and important contribution, is only applicable to smooth lifting, two-handed symmetrical lifting in the sagittal plane, and the lifting of moderate-width objects. However, Dolan et al. (68) report that spinal loading during lifting, which is controlled by muscles from the trunk and fascia, depends as much on the speed of movement as the size of and position of the object lifted. Gagnon & Smyth (26) showed that rapid lifting increases moments and forces in the spine and the musculature. NIOSH also prescribes that the standing postures should be unrestricted, there should be good handles on the object, favorable environmental conditions, and no other activities going on at the same time. If any of these other provisions do apply, then the load should be reduced even further. When the object is large and heavy, it is desirable to make available
a hoist or crane to assist in its movement. Obviously, this must be conveniently placed, otherwise the worker will not use it. The load acting on the lumbar spine during lifting is a combined result of the object weight, the upper body weight, the back muscle forces, and their respective lever arm to the disc center. Therefore, the distance of the object from the body is a very important ergonomic factor. This distance should be considered in designing a container or other things that are often lifted. If a container is compact, a worker can minimize the spinal load moment by keeping the object’s center of mass close to the body. If the container must be lifted from the floor, and it is too large to pass between the knees, it requires the person to lift the object in front of the knees. This causes a larger spinal load moment than would be the case if the object could be lifted between the knees. Any object larger than approximately 30 cm cannot easily be lifted between the knees, thus increasing the horizontal distance. Thus, the admonition to lift by the knees and not by the back is nonsense—it depends entirely on the load shape and size! Most likely, what is of importance is the pelvic orientation. Delitto & Rose (69) reported that trunk muscle activity occurring with the anterior tilt position of the pelvis may ensure muscular support for the spine while handling loads. Granata et al. (25) found that box weight, task asymmetry, and job experience (level of experience) affect the magnitude and variability of spinal load during repeated lifting exertions and may be responsible for LBP. Low lifting-index values were observed by Kee & Chung (70) for relatively high L5/S1 compressive forces from the EMG-assisted model. This suggests that the 1991 NIOSH lifting equations may not fully evaluate the risk of dynamic symmetric lifting tasks. Marras et al. (71) found that the position from which the worker lifted a box on a pallet affects spine loads with the lower level of the pallet being the greatest. Thus, the effects on spine loading can be controlled depending on its position on the pallet. Handles on the box also reduce spine loading.

Commissaris & Toussaint (72) suggest the absence of load knowledge, and hence overestimating the load to be lifted, may lead to an increased spinal load and to an increased risk of losing balance in lifting tasks. Underestimating the load mass to be lifted may lead to similar problems. Thus it is important to label objects with the weight and to encourage testing of the load by the worker.

Pushing and Pulling

To avoid high compressive forces in the disc, the pulling or pushing hand force should be below 225 N. Several factors such as vertical handles that can be grasped at various heights, large low-friction rubber wheels, and two wheels that easily pivot are important. The workplace floors must be clean and free of hazards. The floors and shoes must be clean and dry and be high friction. Pushing or pulling force requirements should be made low, below 225 N, and the hands should be between the hip to waist level so as to minimize spine load moments. The floor surfaces and areas where pushing and pulling activities occur must be kept clean and dry and workers should be instructed to use shoes with traction.
Posture

SITTING The posture of a seated person depends not only on the design of the chair, but on sitting habits and the task to be performed. The height and inclination of the seat of the chair, the backrest, and other types of support all influence the resulting posture. The chair should also permit regular and easy alterations in posture. Inclination of the backrest backward from vertical results in decreased IDP. Support of the lumbar spine via a backrest towards lordosis reduces the deformation of the lumbar spine and resultant IDP. Van Dieen et al. (73) suggest that sitting is a risk factor for LBP due to the prolonged and monotonous low-level mechanical load imposed by a seated posture. Spinal shrinkage was increased in a fixed rather than dynamic chair.

STANDING To maintain low muscle stresses on the spine when standing, an upright symmetric posture should always be advocated, and all material should be handled as close to the body as possible. It is often reported that a compliant mat under the feet will reduce subjective complaints of back fatigue in standing workers. These mats may attenuate impact to the discs. Alternating between sitting and standing is also a good idea.

AKWARD POSTURES Muscle force and thus disc pressure is increased in postures involving lateral bending or twisting (46). In most cases, these postures can be avoided by redesign of the workplace to ensure axially symmetric postures. Workplaces should be kept clear of hazards that workers must walk around, and parts must be delivered at a convenient height in front of the worker.

Whole Body Vibration

In a vehicle, the primary source of WBV is the interaction of the vehicle and the ground surface, but any component of the vehicle could be a source. In some cars, driving 100 km h\(^{-1}\) over California expressways and the joints in the concrete slabs, which are placed at 5 m intervals, cause resonance of the spine. Thus, the terrain, speed, and vehicle characteristics can all be of importance.

There can be a considerable muscular effort associated with driving due to the forces necessary to maintain posture and to control the vehicle and resist its movements. The components of vibration and shock may not be enough to cause acute injury, but lateral thrusts may add to the spinal stress. Thus, there may be a symbiotic effect of vibration and posture. The seat itself is only one part of the sitting workplace. Cyclic loading should not exceed ISO 2631 E (62, 63) requirements. Vibration isolation seats should be used where possible, and firm cushions with lumbar support should be employed. If possible, support of the arms and the feet should also be used. The posture should permit the backrest to be used where possible. One method of reducing whole body vibration is to reduce the vibration input. This can only be done by the choice of vehicles, by training
drivers to choose the vehicle that they drive, and to reduce vibrations by changing their driving speed and style. Much of this is within the control of the operator and can be influenced by training.

Other factors to bear in mind are that a hazardous exposure to WBV can be found in various forms including driving off-road too fast or over a rough route and driving on badly paved surfaces in vehicles with poor suspension. Exposure to WBV is not the only cause of back pain. Other factors that can cause or increase back pain include general posture; poor design of controls, making them difficult to operate; and poor driver visibility, making twisting and stretching necessary when driving. The employer should assess the health risks to workers from WBV and identify what is needed to control those risks and should ensure that the equipment the employer provides for his employees has been designed or adapted to minimize WBV.

SUMMARY

Occupational LBP is of major importance both economically and in terms of disability. The problem is getting worse each year and major steps should be taken toward prevention. LBP has been called the albatross of industry and the nemesis of medicine. LBP is one of the most important disabling health problems facing industrialized societies. The medical, industrial, and socioeconomic costs of LBP are immense. In the United States, LBP is the leading cause of industrial disability payments and the second most common medical cause of work loss in industry. In the United States, the total cost of LBP currently comes to nearly 80 billion dollars per annum (74) and can be anticipated to be far more in the future. Occupational exposures such as lifting, particularly in awkward postures; heavy lifting; or repetitive lifting are related to LBP. Fixed postures and prolonged seating are also risk factors. Any prolonged posture will lead to static loading of the muscles and joint tissues and, consequently, cause discomfort. The human being’s natural behavior is to change posture often. Even during sleep, there is a need for posture adjustments. No single position should be maintained for a long period of time without considerable discomfort. LBP is found in both sedentary occupations and in drivers, as well as those involved in manual materials handling. The seated posture leads to inactivity that may itself be injurious. Lack of motion leads to an accumulation of metabolites, which probably accelerates the degeneration of the disks and increases the probability of disk herniation. Drivers postures can also lead to musculoskeletal problems in the neck, shoulder, and arm. At the workplace, standing and sitting are the two basic forms of postures. These postures have their specific advantages and disadvantages for mobility, exertion of force, energy consumption, circulatory demands, coordination, and motion control. Workers in a WBV environment are often also subjected to postural stress, whether they are seated or standing.

Although it can be a problem, prevention is by far the treatment of choice. Epidemiologic studies clearly indicate the role of mechanical loads on the etiology of occupational LBP. Methods are available for characterizing the mechanical environment of the worker. This information can be used to adapt the workplace to
prevent injuries. It is probable that mechanical risk factors along with psychosocial factors combine as to total risk for LBP disability. Workers should be made aware of the importance of personal factors such as level of general fitness, obesity, smoking, and leisure pursuits. Workers should report LBP as early as possible and seek medical advice if they think occupational exposure is harming them. The combined effects of the medical community, labor, and management are required to cause some impact on this problem.

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