Back injury control measures for manual lifting and seat design

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Abstract

Back injuries account for a high proportion of lost workdays in the mining industry and are a leading cause of disability in mine workers. Two risk factors for low back injuries are manual lifting and whole-body vibration exposure when operating mobile equipment. Recent research has shed light on possible mechanisms through which low back injuries may occur, and the results of these studies can be used to improve the design of lifting tasks and seats to decrease injury risk. This article discusses recent research results and how this knowledge can be leveraged to reduce the risk of low back pain.

Introduction

The mining industry has long been associated with a high incidence of low back disorders and pain (Klein et al., 1984; Leigh and Sheetz, 1989; Brinckmann et al., 1998). It is believed that the higher incidence of these injuries among miners is the result of high exposures to postural demands, heavy manual work and exposure to whole-body vibration (WBV). Recent work indicated that miners involved with heavy lifting (especially in restricted spaces or on uneven ground) or who have been exposed to whole-body vibration in undamped seats experience noticeable changes in their spines, consistent with degeneration of the intervetebral discs of the spine (Brinckmann et al., 1998). As described here, there is increasing evidence that disc degeneration plays a large role in the development of low back pain, particularly chronic back pain.

Figure 1 shows the rate of back injuries for various industrial sectors in the United States from 1992 through 2001 (NIOSH, 2004). One can see a general decline in the rate of back injuries for all sectors over this timeframe. During the first half of this period, mining was typically the fourth highest sector (out of nine) in terms of back injury rate. During the latter half of the period, mining shows some improvement in relation to other industry sectors and was among the lowest sectors in terms of back injury rate in 2001. However, it should be noted that mining was the third highest sector in the preceding year. Clearly, some improvement can be seen over this time period. However, back injuries remain a leading cause of lost time and represent a tremendous cost to the U.S. mining industry.

Back injuries are also a significant international issue in mining. In Australia, for example, workers compensation statistics for the state of New South Wales from 1998 to 1999 found that 30 percent of all workplace injury claims involved the back. The mining industry was the second worst industry in terms of incidence of male back injury, with 40.6 claims per 1,000 wage and salary earners (Stewart et al., 2003). Back injury rates among miners in Scotland (Lloyd et al., 1986) and degenerative changes to the spine in German coal and salt miners (Brinckmann et al., 1998) have all been found significantly elevated with respect to comparison populations. These statistics highlight the need for solutions to reduce back injury risk in the mining industry to better control costs and reduce disability among mine workers.

Causes of back pain

Until recently, medical doctors generally assumed that back pain was the result of muscle strain, ligament pain or so-called "trigger points" (Bogduk, 1997). However, research supporting these mechanisms of pain has been scant. There are three mechanisms that have shown high associations with back pain in controlled scientific studies:

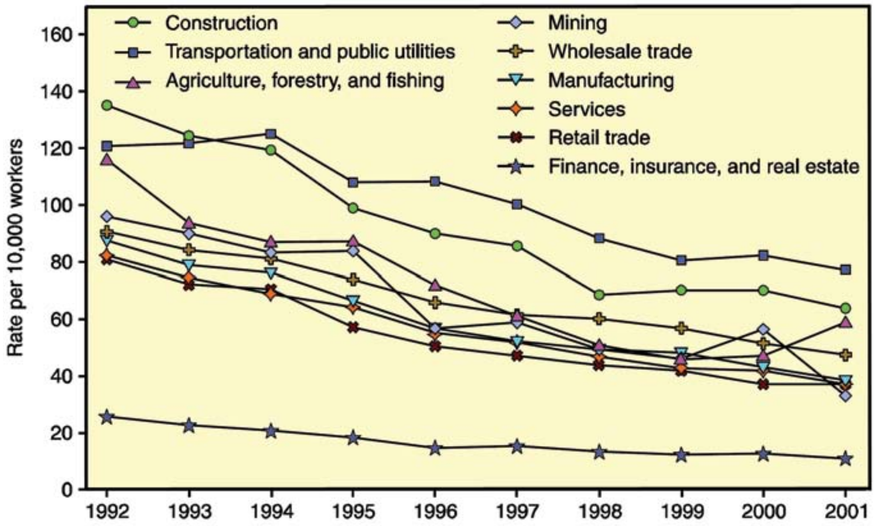
- sacroiliac pain (present in 13 percent of back pain sufferers) (Maigne et al., 1996),
- facet joint pain (present in 15 percent of back pain sufferers) (Schwarzer et al., 1994) and
- disc disruption and degeneration (present in 39 percent of chronic back pain sufferers) (Moneta et al., 1994).

The latter mechanism, which bears the highest relationship to back pain that has yet been shown, will be the focus of this section.

Scientists now believe they know how back pain may develop in cases involving disc disruption and degeneration (Bogduk, 1997). When the spine experiences a sufficient load, the first structure to fail is the vertebral endplate, a structure that attaches the disc of the spine to the vertebral body and that is important in disc nutrition (Fig. 2). The body's response to the fracture is to attempt to heal the fracture by "mortaring" the fracture with scar tissue. Unfortunately, the scar tissue impedes the flow of nutrition to the disc itself (discs are dependent on nutrition from blood vessels in the vertebral bones), and if

FIGURE 1

Back injury rates for major United States industrial sectors, 1992-2001.

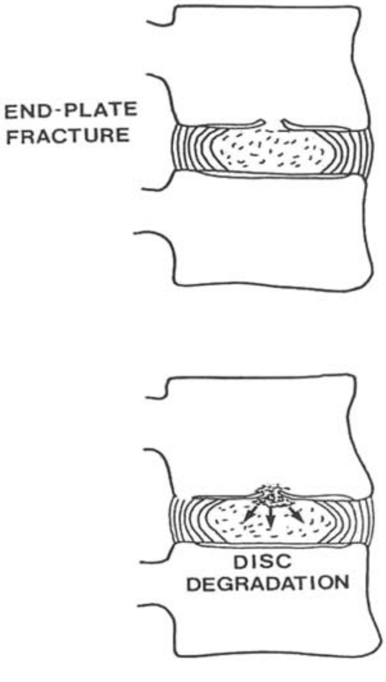


the supply is reduced sufficiently, the disc will start to degenerate. As this degeneration process proceeds, fissures or tears in the fibers of the disc start to develop from the inside out. If any of these tears is a Grade 3 fissure (Fig. 3), an inflammatory response occurs in the disc, which will lead to the well-known sensation of low back pain (Peng, 2006).

The best approach to preventing this degenerative process would appear to be minimizing the likelihood of the initial endplate fracture. Endplate fractures can occur in two ways. The first is that the endplate's strength may be exceeded by one very large load placed on the spine. This may occur in the case of a fall or an extreme jolt when riding in a vehicle. However, most experts believe that endplate fractures may occur more commonly due to fatigue failure. In this process, a load (perhaps when lifting) will result in a small fracture in the endplate. Subsequent loading (e.g., repeated lifting) will cause this small fracture to expand, ultimately leading to a full-fledged fracture. In this way, repeated sub-maximal loading can lead to an injury that is equivalent to an injury experienced in a one-time overload of the tissue strength (Brinckmann et al., 1988; Gallagher et al., 2005).

FIGURE 2

Disc degeneration is thought to be initiated with an endplate fracture, which inhibits disc nutrition leading to disc degeneration (Bogduk, 1997).



An important implication of the effect of repetitive loading is that people can be performing tasks that they believe are safe, such as lifting a 23-kg (50-lb) bag, because they have done so before without pain, but in reality each lift may be leading to a slight amount of damage. The resulting accumulation of weakness in the spine may lead to an injury that may result from what seems like a fairly innocuous task (such as bending down to pick up a pencil), but which is really the result of damage that has accumulated over time. Two things that can result in such repetitive spine loading are manual lifting and exposure to whole-body vibration. The purpose of this paper is to describe methods by which the risks of back injury may be reduced in the mining industry for workers so exposed.

Controlling low back risks associated with handling materials

A comprehensive approach is needed to reduce the risks associated with back pain resulting from handling materials. This approach includes factors such as proper layout of facilities and supply handling systems, development and/or use of appropriate equipment or aids and, when manual lifting is necessary, proper design of lifting tasks. Harsh mining environments can sometimes make aspects of this approach difficult to implement. However, there are usually methods that can be used to improve the design of supply handling systems at any mine site.

Facilities layout. Transportation of materials is costly in terms of space, machinery and energy. It does not add value to the object being moved and it exposes workers to numerous hazards. In fact, given that transportation costs for materials typically account for 30 percent to 75 percent of the total operating cost, there is a strong economic incentive to improve the efficiency of materials handling systems (Kroemer, 1997). However, some may view the reduction of risk to the workers by redesigning, improving or eliminating transportation barriers to be a more compelling motivation. Fortunately, ergonomic design of materials handling systems can benefit the health of the worker and the bottom line.

Efficient material flow is associated with few transportation moves, whether on the surface or underground. Analysis of current materials handling practices is a critical step in the proper design of existing and planned facilities. When existing facilities are present, it is often difficult to change the building or the layout. However, improvements in material flow can often be realized. It is more efficient to design new facilities for the ergonomically best transport than trying to improve a design that is faulty (Kroemer, 1997). For this reason, it is important to include an ergonomist in the team planning the construction of a new facility.

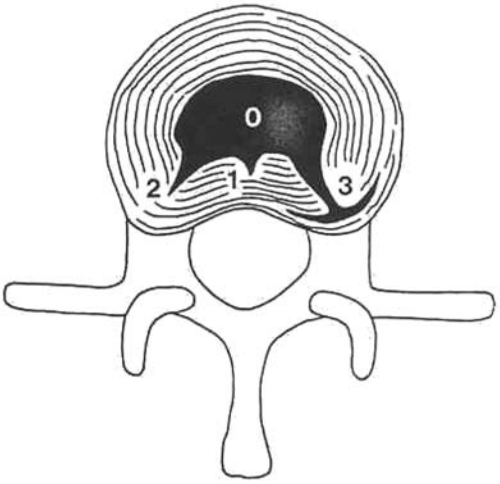
For existing facilities, generalized checklists have been developed that can help identify problem areas for typical materials handling operations. Problem areas may include (Kulwiec, 1985):

- crowded operating conditions,
- cluttered entries and supply areas,
- poor housekeeping,
- delays or backtracking in the flow of material,
- obstacles in the flow of materials,
- manual handling of loads weighing more than 20 kg (45 lb),
- excessive storage times for materials,
- single items being handled as opposed to unit loads,
- underutilizing materials handling equipment where appropriate,
- excessive time required to retrieve stored parts or supplies and
- multiple handling of the same item.

It is often helpful to describe the flow of materials using a diagram or flowchart that shows the sequence and location of materials handling activities or that represents a listing or table of steps associated with movement of a specific material (Gallagher et al., 1990; Kirwan and Ainsworth, 1992). This type of analysis can be helpful in identifying unnecessary materials handling activities and other inefficiencies associated with the supply handling system. An example is shown in Fig. 4. Obviously, such an analysis has the potential to reduce unnecessary manual materials handling, which, in turn, will reduce the repetitive loading on the spine that leads to low back pain.

FIGURE 3

Grade 3 disc fissures have been strongly associated with chronic low back pain (Bogduk 1997).



Use and development of mechanical-assist devices

Use of hoists for materials handling. One technique that has met with considerable success in the mining environment is the implementation of standard hoist mechanisms (in the mine and on the surface) to assist with handling timber, track and other bulky materials, as shown in Fig. 5. Several mines have reported that installing hoists at central destination and delivery points can eliminate a significant amount of manual handling of heavy objects (Selan et al., 1997).

Development of specialized vehicles. Another technique that mines have had success with is in the devel-

FIGURE 4

Example of flowcharting of materials handling practices for concrete blocks at two mines. The procedure at Mine A involves more steps and several manual transfers of the block, which are inefficient and hazardous to the worker. Mine B accomplishes the delivery of block in fewer steps and entirely by mechanical means.

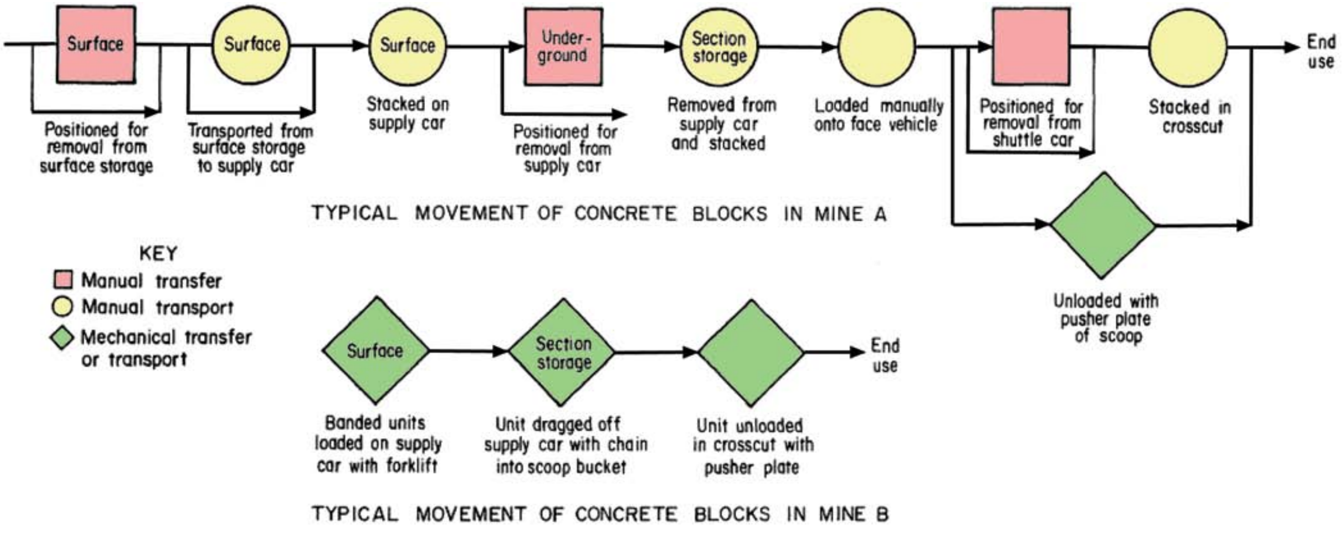


FIGURE 5

Installing hoists at central destination and delivery points can eliminate a significant amount of manual handling.

opment of vehicles to perform specialized functions. In many cases, such vehicles have been built entirely out of salvaged parts and supplies, making these solutions quite cost-effective. Figure 6 shows a materials-handling cart called the "Zipmobile" (named after the miner who developed it). This cart rides on the handrails of the longwall conveyor and transports supplies along the longwall face. Instead of manually moving supplies beneath the longwall shields, miners can simply load up the cart and pull the supplies down the longwall face (Selan et al., 1997).

Another example of a specialized mining application is the belt car shown in Fig. 7. The belt car was made from a recovered supply car, but it was modified to allow it to carry a 150-m (500-ft) roll of conveyor belt. The modifications consisted of cutting a hole in the bottom of the car (to allow for a larger roll of belt) and installing a pair of stanchions to hold the roll. Using this cart allowed the mine to have a roll of belt mechanically loaded on the car, which could then be driven next to the tailpiece. This allowed miners to splice 150 m (500 ft) of belt without having to do any manual handling of the belt other than pulling it off of the roll to perform the splice.

Developing specialized mining tools. One problem identified by many mines is that there are a limited number of tools specifically designed for mining tasks. To address this problem, several mines have made efforts to develop in-house tools for specific mining applications. Figure 8 shows an example of a tool used to help remove conveyor belt rollers. This tool, which has a two-handed handle on one end and a prong that fits into a hole on the belt roller on the other end, provides leverage to facilitate the removal or installation of belt rollers and prevents the miner from directly handling the roller (which can get quite hot). Many other tools have been developed for mining applications. These tools largely rely on innovative ideas developed by miners familiar with the demands of the jobs they perform everyday (Selan et al., 1997). It should be clear that many opportunities exist for reducing the physical demands of mine workers through development, adaptation or use of mechanical-assist devices in the mining environment.

Design of lifting tasks

When the manual handling of materials cannot be eliminated through more efficient system design or through the use of appropriate mechanical assist devices, it is often possible to reduce the demands associated with manual lifting through appropriate design of lifting tasks. Unfortunately, manual lifting tasks are often considered unavoidable, and thus, not much thought is put into principles that can significantly decrease the load on the low back. However, there are some fairly straightforward design criteria that can reduce the loads experienced by workers during lifting tasks. The following sections briefly describe some principles that can help this goal.

Reduce the moment. A moment of inertia (or moment) acting about the spine is defined as a force (e.g., the weight of a lifted object) times the distance from the spine to the object's center. This distance has a multiplying effect on the force requirements of lifting a load. Thus, an 11 kg (25 lb) load being held 0.9 m (3 ft) away from the body will result in approximately twice the moment about the spine than a 18 kg (40 lb) load held just 0.3 m (1 ft) in front of the body (Fig. 9). In this way, lighter weights can actually cause greater low back stress than heavier loads. Recent research has shown that the load moment (the weight of an object multiplied by its distance to the spine) is one of the best predictors of the likelihood that someone will experience a low back injury (Marras et al., 1999). This means that not only can reducing the weight of an object decrease spinal stress, but reducing the horizontal distance to the load being lifted plays a vital role as well. Some ways of reducing the distance to the center of the load include eliminating physical barriers that prevent the worker from getting close to the load, pulling objects close to the body before lifting and reducing the size of the object.

Reduce bending. Recent studies have shown multiple hazards related to bending the trunk forward when lifting. Bending forward creates an additional moment about the low back due to the weight of the torso, which the spine muscles must counteract through increased contraction. Spinal tissues have been found to fail more quickly when this additional load is imposed (Gallagher et al., 2005). In addition, it was recently found that when spine ligaments get stretched in sustained or repeated forward bending, the spinal muscles (through a feedback mechanism) actually lose strength and are more prone to muscle spasms (Solomonow et al., 2003). Recovery from the effects of even a brief period of ligament stretching can take 24 hours or more (Solomonow et al., 2003). While restricted spaces in underground mines often limit what can be done to limit forward bending, easier changes are often possible in other areas or facilities. One of the most effective design changes that can be made is to simply limit the number of items that must be manually lifted off the floor. Ideally, items should be stored about waist height and should be stored no lower than knee height and no higher than shoulder height.

Seating design and whole-body vibration (WBV) exposure

WBV refers to mechanical energy oscillations that are transferred to the body as a whole, usually through a supporting system such as a seat or platform. Typical exposures in the mining industry include operation of equipment such as haul trucks or front-end loaders in surface operations and shuttle cars or mantrips in underground mines. A comprehensive NIOSH review of epidemiologic results concluded substantial evidence of an association between exposure to WBV and back disorders (Bernard et al., 1997). Clearly, the repeated bouncing and jostling of the body experienced when driving over rough haul roads can be expected to impart significant loads on the lumbar spine, which may accelerate the degenerative changes detailed in previous sections of this paper. In addition, the development of vibration standards (e.g., ISO 1997) demonstrates that exposure to WBV may negatively impact worker safety, comfort, working efficiency and performance.

There are two basic types of vibration: sinusoidal and random. Sinusoidal vibration is characterized as a waveform that is repeatable at regular intervals. It is most often employed in laboratory studies. On the other hand, random vibration is irregular and unpredictable. It is the type of vibration most often encountered in the work environment (Sanders and McCormick, 1993). Furthermore, the term damping is associated with attenuation and is simply the dissipation of vibration energy with time or distance (Griffin, 1990).

Vibration exposure can affect the human body in various ways determined by the characteristics of vibration that include frequency (the number of oscillations per second), magnitude (or amplitude) and duration of exposure. The direction of vibration (vertical, lateral and fore-aft), along with the mass and body part locations, also contributes to the effects of vibration exposure to the human body. Moreover, vibration transmitted to the human body can be either amplified (magnified, increased) or attenuated (reduced, lessened) according to posture, frequency and seating type (Sanders and McCormick, 1993).

Different parts of the body have different natural frequencies (frequencies at which the structure will naturally vibrate). When an external force excites the body part at its natural frequency, vibration of this body part will occur at maximum amplitude, which is larger than the original vibration. This condition is called resonance (Sanders and McCormick, 1993). The large oscillations that occur create potentially harmful stresses within the body part.

It is also important to consider the level or magnitude of vibration during WBV exposure. Reactions to various levels of vibration have been noted for passengers using public transportation: 0.32 m/s^2 is not uncomfortable, 0.8 to 1.6 m/s^2 is uncomfortable and greater than 2.0 m/s^2 is extremely uncomfortable (ISO, 1997).

Figure 10 shows the perceived effects of WBV exposure according to various vibration frequencies. At different frequencies of exposure, subjects increased the vibration magnitude to a level that if increased further would surely result in damage. They responded according to where they sensed pain or discomfort in their bodies (Magid and Coermann, 1960). Back pain in this figure is perceived to occur between 8 to 12 Hz. Whereas, general discomfort of the whole body was shown to occur from of 4 to 9 Hz. Typically, a mine shuttle car has a natural frequency between 1.5 to 2.5 Hz for full-load and no-load conditions, which is below the frequencies of concern shown in Fig. 10. Nevertheless, a terrain-induced jar/jolt (mechanical shock) could could produce the frequency of a denoted part of the body part since a jar/jolt contains multiple frequencies.

Thus, the repeated exposure in a vibration environment exhibiting frequencies found in Fig. 10, coupled with magnitudes greater than 2.0 m/s^2, should be avoided to reduce the potential risk for damage to the back and other parts of the body.

Probably the best approach to protect against the health effects of whole-body vibration is to isolate the person from the vibrating source with an adequate suspension system, either on the seat or in the vehicle being operated or both (Tong et al., 1999). It should be noted that simply providing a seat cushion to the operator is not necessarily a good solution, because a soft cushion may not protect against WBV exposure (the person bottoms out) and may even amplify vibration — the ratio of output to input transmitted vibration is greater than 1. In addition, overall RMS (root-mean-square) acceleration has been shown to decrease with increasing cushion density (Gagliardi and Utt, 1993). However, proper seat design

FIGURE 6

This cart rides on the handrails of the longwall conveyor, facilitating movement of supplies along the longwall face.

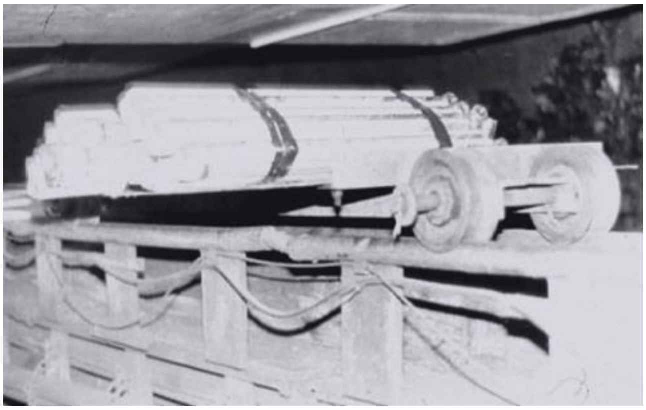


FIGURE 7

The belt car allows miners to splice 150 m (500 ft) of belt without having to do any manual handling of the belt other than pulling it off of the roll to perform the splice.

FIGURE 8

Use of this specially developed tool provides leverage to remove belt rollers and prevents having the miner to directly handle the roller.

can play an important role in enhancing worker health and safety. Understanding the vibration environment is an important part of designing a safe, comfortable seat.

Seat design considerations

Improving seated postures in mining equipment. Mine workers who operate heavy mining equipment or vehicles may assume different seated postures depending on the design of the vehicle workstation or operator compartment. For example, in underground low-seam coal mines, shuttle car operators must assume partially or, in some cases, fully reclining seated work postures due to mine environment, operational or equipment design constraints. These conditions have risks of worker injury through reduced visibility, increased fatigue from poor seating conditions or awkward postures and reduced work performance.

On the other hand, large surface mining equipment provides the vehicle operator better opportunity to assume proper-seated postures. Vehicles in surface operations are generally thought to provide ample space within a workstation. While this may not always be the case, these vehicles would at least have greater vertical clearance or headspace compared to an underground vehicle constrained by a vehicle canopy. The increased vertical clearance can be used to add a seat suspension system that requires limited travel (or stroke) in the vertical direction.

The seated posture for mine vehicle operators, particularly in the context of a vibration environment, is crucial as it defines the initial configuration of the body and that of the spine in particular. Kittusamy and Buchholz (2004) noted that two important risk factors for developing MSD in construction equipment operators are exposure to WBV and nonneutral body postures. Construction equipment is essentially the same as those operating at surface mines with some exceptions. Thus, this would also apply to surface mining equipment operators.

A key objective is to ensure that vehicle operators have an optimum seat that includes energy absorption properties to minimize the risk factors from WBV exposure. A seated posture also affects the worker performance as the upper body muscles and ligaments work to maintain the body in the seat. Kazuhito and Hanai (1999) showed that during vibration exposure, a small change of posture (such as bending the knees or back) can noticeably affect the transmission of vibration energy to the body.

Coltman (1983) studied increasing the effectiveness of energy-absorbing seats through improved design and qualification test criteria. Some major findings were:

- measurement of spinal force and moment provided the most reliable means of relating test performance to spinal injury,
- seat pan acceleration is not a good indicator of test severity or injury potential and
- placement of the feet can significantly influence seat and occupant response to load on the occupant.

In view of the above, important seat features should include adjustability and vibration attenuation features in three directions, adjustability of the suspension system to accommodate operator differences and, in particular, adjustability of low back support. Because designing a suitable and effective seat is application specific (and ideally requires measurements to quantify the vibration environment), the following are offered as general guidelines to consider:

- minimize vibration transmitted to the body, preferably with seat attenuation capabilities in three directions (including a seat suspension primarily for vertical vibration) and energy absorbing foam padding;
- allow for proper spinal alignment to minimize disc pressure with foam padding (that provides comfort in addition to energy absorption) and with an adjustable backrest;
- minimize muscle activity associated with main taining proper postures (the appropriate seat mechanisms, e.g., padding, backrest and lumbar support will do the work to maintain proper posture instead of the muscles);
- maximize circulation to buttocks, thighs and knees with proper seat height, seat cushion dimensions and seat pan angle (SAE, 1988);
- be adjustable for individual differences;
- provide supportive cushioning or padding;
- not interfere with visibility;
- allow for movement of the head or other body parts; and
- provide easy access to controls and monitors.

Finally, the mine engineer/purchaser of new equipment or seats should consult with the equipment dealer/manufacturer as to the availability of seats that include the above features.

Reducing transmissibility of vibration

Minimizing transmitted vibration through the seat to the vehicle operator is an important goal of mine health and safety researchers. This is accomplished by suspending first the vehicle, primarily at the wheel units (near the forcing source of the vibration) and secondarily by suspending the seat and workstation. In underground mining vehicles, wheel suspensions are not the norm. However, in larger off-road surface mining vehicles, this is often the case. When wheel suspension systems are neither possible nor practical, the next option is isolating or suspending the vehicle seat and, if possible, the operator cab/deck. For example, vibration isolators have been used on farm tractors for the operator cab/deck.[1,2] A properly designed suspension system of the vehicle and operator workstation will lessen the required level of vibration isolation at the vehicle seat.

In addition, a major U.S. manufacturer of mine shuttles (Joy Mining Machinery) offers wheel and seat suspensions and NIOSH-design seats. The four-wheel independent suspension system consists of eight elastomeric struts,[3] which is an available option on select shuttle car models (*Coal News*, 2005). In addition, this manufacturer provides the NIOSH-design seats (for low-coal models) and foam padding options as standard equipment on all new shuttle car low- and mid-coal seam models. The low-coal shuttle car seat includes low back support with an adjustable lumbar pad and easier adjustment in the fore-aft direction.

Moreover, the seat design with the most efficient isolating and damping properties should include seat padding and a suspension system with optimized stiffness and damping parameters. Ideally, this would be accomplished with an active seat suspension designed to provide adaptive optimization through changes in seat stiffness and damping properties as a function of vibration frequency and level of magnitude (Amirouche et al., 1997). In turn, this can result in lower accelerations and power absorption of the human body and thus, lower the risk of operator injury and illness.

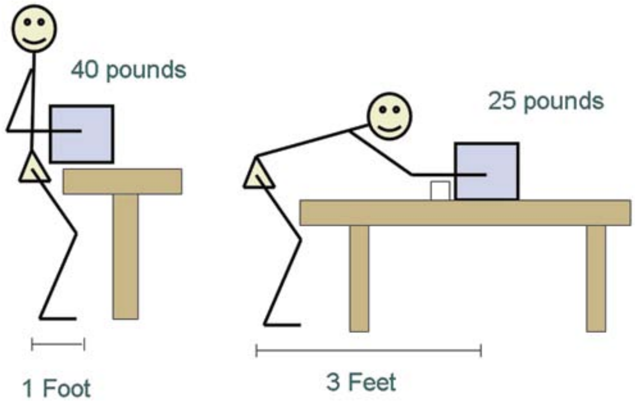
Unique mining issues affecting seating

Harsh underground mining conditions make it difficult to design an effective and reliable seat with a reasonable life. Because mud and water are often present, an underground mine vehicle seat must be made to withstand this punishing environment. Components must be rugged enough to hold up under the large forces and loads that can be generated during operations from the coal, rock and other heavy equipment. Seat cover material should be used that features a tough vinyl material and when punctured, does not tear. Mayton et al. (2005) described such seat designs using unique viscoelastic foam padding on mid-coal seam and low-coal seam mine shuttle cars. The results of this NIOSH study showed lower energy absorption to the body for all of the NIOSH-designed shuttle car seats with unique viscoelastic foam padding. The padding combination best suited for the low-coal shuttle car (owing to constraints with vertical clearances) included 76-mm- (3-in.-) thick pad consisting of one 25.4-mm (1-in.) layer of Sun-mate Pudgee (from Dynamic Systems Inc.) [4] set below two 25.4-mm (1-in.) layers of Sun-mate extra-soft. The mid-coal seam model shuttle car seat padding options included two 127-mm- (5-in.-) thick options. The first option consists of five 25.4-mm (1-in.) layers of Sun-mate extra-soft, and the second option consists of three 25.4-mm (1-in.) layers of Sun-mate extra-soft stacked below one 25.4-mm (1-in.) layer of Sun-mate Pudgee and a fourth 25.4-mm (1-in.) layer of Sun-mate extra-soft on top of the Pudgee.[4]

Considering the seat cushion, operators should notice when the cushion cover is cracked, worn or damaged with padding exposed or protruding from the cover. This is a sign that seat cushioning needs to be repaired or replaced. Another indication for replacing the seat cushion or foam padding is when "bottoming out" occurs, which means that the seat is no longer supporting the vehicle operator.

FIGURE 9

Low back stress in lifting is a function of the weight of the load times the distance to the base of the spine. A lighter weight object lifted at a distance (25 lb * 3 ft = 75 ft-lbs) can create greater back stress than a heavier weight lifted closer to the body (40 lb * 1 ft = 40 ft-lbs).



Furthermore, seats and their components installed on off-road heavy surface mining vehicles should also be designed with durability in mind. This would include the spring (mechanical or air), damper (shock absorber) and seat cover material (made from durable fabric instead of vinyl because vinyl causes sweating).

Prevention and control. Attention to proper roadway maintenance can reduce the WBV load experienced by equipment and haul-truck operators and should be given due consideration in any program to control operator exposures. Moreover, the preferred approach to controlling or preventing WBV exposures and injury risk for the vehicle driver/operator should be engineering controls that emphasize workstation and job design or redesign (Kittusamy, 2002). Administrative controls such as switching out mining vehicle operators during breaks and lunch can also limit the WBV exposures that involve awkward work postures. However, controls of this sort should only be considered as an interim solution until better engineering controls are available to minimize injury risk to vehicle operators.

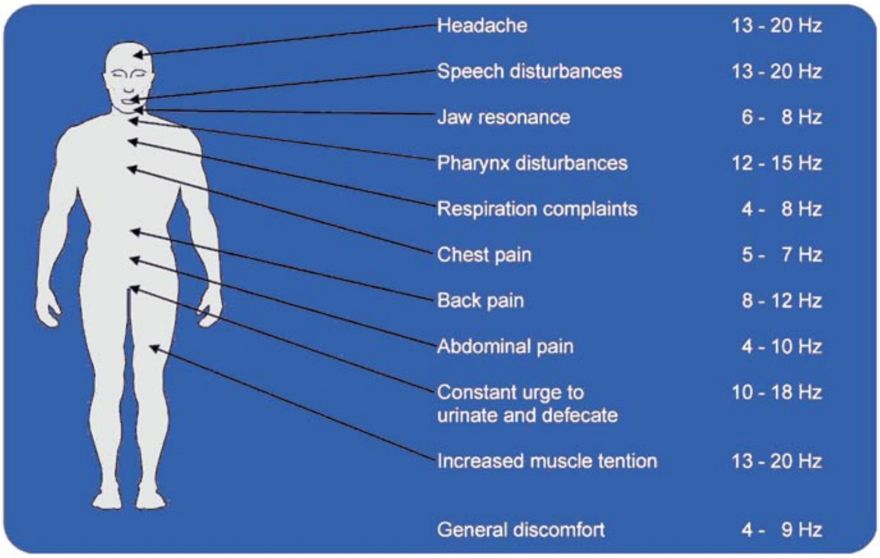
Summary

Low back pain remains a significant and costly problem in the mining industry. Research indicates that disc degeneration resulting from endplate fractures may be a common cause of pain. Prevention of endplate fractures requires reducing the loads experienced by the spine due to lifting and due to exposure to wWBV. Development of more efficient supply handling systems, innovative approaches to supply handling problems and proper design of manual lifting tasks can greatly reduce the risk of back pain, as can attention to proper design of seating.

Engineering controls that emphasize workstation and job design or redesign are first preferences for controlling or preventing WBV exposures and injury risk to vehicle drivers/operators. This type of control is preferred be-

FIGURE 10

How WBV exposure at different vibration frequencies can affect different parts of the human body (Magid and Coermann, 1960).



cause it deals directly with the issues of WBV exposures and injury risk. Administrative controls such as switching out mining vehicle operators during breaks and lunch should only be considered as interim solutions until suitable engineering controls are available. Because they do not address WBV exposures and injury risk directly, administrative controls are less preferred measures. Some important guidelines to consider for a vehicle seat are to minimize vibration transmitted to the body with energy absorbing foam padding, provide a seat suspension (as appropriate and practical), provide adjustable back support (especially for the low back) and accommodate individual user differences with adjustability.

Footnotes

[1] https://www.deere.com/en_AU/equipment/ag/tractors/5025_series/pf_cab.html

[2] http://www.macdon.com/products/9000seriestractor/9000seriesspecs.html

[3] http://www.joy.com/jmm/products/pdf/Haulage_Brochure_Joy.pdf

[4] Sun-mate Pudgee and extra-soft can be obtained from Dynamic Systems Inc., 235 Sunlight Drive, Leicester, NC 28748 (http://www.sunmatecushions.com/).

Disclaimers

Mention of any company or product does not constitute endorsement by NIOSH. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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