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Safety considerations for the aging workforce

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Abstract

This paper discusses some of the psychological and physical issues of the aging workforce based on recent literature. Descriptions of physical aging and cognitive aging are presented and the relationship of these factors to worker safety, especially those relevant to the mining industry, is discussed. The authors include suggestions for the integration of this knowledge in the design of appropriate safety and health interventions for older workers.
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Keywords: Aging worker; Cognition; Physical capabilities; Work demands; Ergonomics; Mining

1. Introduction

We are an aging population, an aging workforce. There are over 70 million baby boomers in the US workforce, and one turns 50 every 7 s (Dahlberg, 2004). In the United States, the number of workers 55 years or older will increase by almost 50% between 1998 and 2008, while those between 25 and 54 will increase by only 5.5% (Clifton, 2001). The US Bureau of Labor Statistics predicts that by the year 2015 there will be 55 million workers 45 years of age or older in the United States. This is approximately 40% of the workforce. The most rapid increase in the aging population growth is calculated to occur between the years of 2010 and 2030, when the baby boom generation reaches age 65

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(AARP, 1996; Hopkins et al., 1991). By 2006 in the federal government alone, 493,000 employees in the top 24 federal agencies will be eligible to retire. According to former Sen. Fred D. Thompson, R-Tennessee, agencies without adequate numbers of workers, including enough experienced workers, run the risk of not being able to carry out their missions or deliver services (Federal Employees News Digest, 2001). In light of these statistics, fewer workers will be available and older workers may have to remain working longer than the traditional retirement age of 65.

In many ways the trend of older workers remaining in the workforce is beneficial for the nation's economy. For instance, older workers' expertise is valuable to companies, and many companies prefer to keep their older employees as long as possible. Additionally, older workers have lower non-fatal injury rates. However, when older workers do get hurt they need more time off and suffer fatalities at a higher rate (Kisner and Pratt, 1999). It has been shown that job characteristics such as high stress, repetitiveness, and high physical demand are statistically related to early retirement (Yeatts et al., 1999).

In the mining industry, a disproportionately large number of workers will retire during the next five years. Fig. 1 illustrates the mining workforce by age groups and year, showing the aging trend since 1997. Fig. 2 defines three age groups (18–34, 35–44 and over 45) illustrating the percentage of the workforce in each age group by year from 1997 to 2003. The bottom line trend is an aging workforce with fewer workers to replace those retiring.

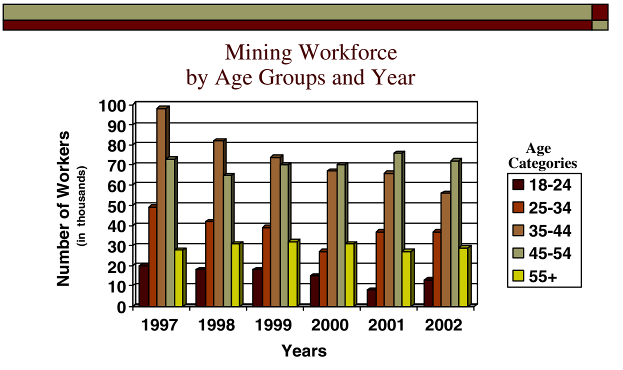

Fig. 1. Mining workforce by age groups and year.

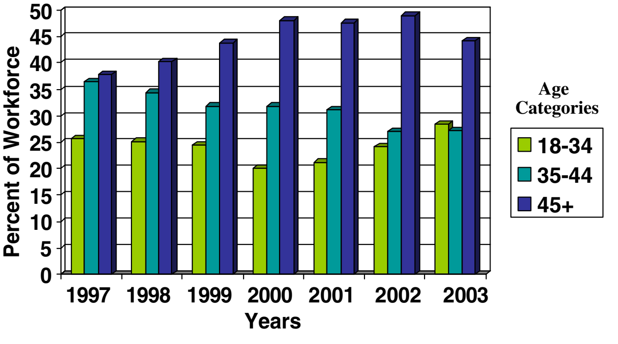

Fig. 2. Three age groups as percent of mining workforce by year.

In fact, the trend toward an aging workforce is amplified in the mining industry due to a boom in the 1970s which necessitated the hiring of a large number of workers, most of whom were in their twenties. In the 1980s and 1990s the mining process became increasingly capital-intensive, with downsizing and layoffs that resulted in a scarcity of younger new-hires over a several-year period. In response to these demographics, the mining industry has prioritized the issue of improved work procedures and training needs for aging workers in order to maintain the workforce and prevent future accidents and injury.

This paper discusses psychological and physical issues specific to the aging workforce and relates the information to the mining industry. Similar to the recommendations suggested by Teiger (1994), this paper integrates research in the areas of epidemiology, ergonomics, and experimental psychology to address the challenges of the aging workforce. The authors propose preliminary recommendations to address the safety considerations for the aging workforce in the mining population.

2. Definition and terminology

The "older worker," as defined under the Age Discrimination and Employment Act (ADEA), is 40 years or older. This group will soon make-up the largest portion of the working population in the United States and should be considered a valuable economic resource deserving special attention.

Gerontechnology, a phrase coined by Graafmans and Brouwers, is "the multi-disciplinary study of aging and technology for the benefit of a preferred living and working environment…" (Fozard, 1997). Gerontechnology is often referred to as using the technology in the fields of ergonomics and gerontology "to compress morbidity and extend functional anatomy (independence)" (Vercruyssen, 1994). Gerontechnologists are interested in developing devices and procedures to allay declines in strength, mobility, flexibility, and other areas of age-related loss (Goldberg and Ellis, 1996). The focus until recently has generally been on providing greater independence for aging persons in their lives. Yet, these same tenets may be applied to helping aging workers in the workplace.

Along with the physical aspects of aging, psychosocial aspects of aging must also be integrated into solutions and recommendations in support of maintaining older workers on the job. With this in mind, the authors purport to use a multi-disciplinary definition of aging to include physical, psychological, and social aspects of the older worker.

Pascal Paoli, Director of Research at the European Foundations for the Improvement of Living and Work Conditions, states that "Aging is a very dynamic process. You can be too old for a job at 30, and too young for a job at 45. It's a continuous process" (Hallett, 1997). For instance, a worker may not have enough experience to perform certain jobs when younger, but may have too slow of a reaction time or not enough physical strength to perform other tasks when older. The ideal work situation is one that matches the demands of the job to the abilities of the employee in order to facilitate optimal worker performance without the employee experiencing any health problems.

Chronological age is often taken as an index for the aging process. Some researchers, however, have attempted to find an index for functional age as opposed to chronological age (Dirken, 1972). Functional age is a measure of how well a person can function in a certain environment (or at a certain job) when compared with other people of the same chronological age. The authors believe this is an important distinction. The usefulness of such a designation is debatable in that the strength of individual differences and wide differences in work tasks complicate generalization. Clearly, though, chronological age is not necessarily a reliable predictor of functional performance because of individual variability. Individuals age at different rates determined by many factors, including lifestyle, genetic make-up, environment, and economic and social support factors. Thus, researchers continue to use chronological categories but define multiple "contributing factors" when making their conclusions.

Finally, several researchers argue that Transgenerational Design, or designing for all generations, is the best way to address ergonomics (Pirkl, 1995; LaBar, 1996; McMahan and Phillips, 1999). This approach is all inclusive and promulgates that better design means better design for everyone, not just older workers.

3. Cognitive and physical attributes of aging

3.1. Cognition

The common belief has been that as humans age there are reduced functions, both physically and cognitively. When researchers refer to cognitive aging, they are usually addressing age-related changes in the fields of memory, attention, intelligence, language, decision-making, learning, and information processing. Cognitive aging has important consequences for one's ability to learn and perform many work-related tasks. Some psychologists believe that the biological processes of aging cause decline in function (Cronholm and Schalling, 1988; Burke and Mackay, 1997; Rabbitt and Lowe, 2000) while others believe that there is an accumulation of knowledge and experience over time that lead to an increase in skill with age (Westerholm and Kilborn, 1997). Still others believe that not enough information exists to determine a definite answer (Colley and Beech, 1989; Bruyer and Scailquin, 1994).

One of the most well-established findings regarding the aging process, which is likely to have implications for work performance, is the decline in information processing speed which accompanies advancing age (Salthouse and Hambrick, 1999). There are other age-related changes in cognition which may affect work performance such as decrements in working memory (Baddeley, 1986), attentional abilities (Craik and McDowd, 1987), and perceptual abilities (Plude and Hoyer, 1985). Declines in working memory may make it difficult to learn new concepts, such as those associated with computer tasks, or recall complex and/or uncommon operational procedures. Nevertheless, while novel problem solving is thought to be more difficult for older workers, some research has shown that experience can offset possible declines in problem solving ability as evidenced in crossword puzzle proficiency (Hambrick et al., 1999).

Declines in attentional capacity may make it difficult for an older person to perform concurrent activities or to switch their attention between competing displays of information. In the psychology literature, this is referred to as divided attention. In many work situations it is necessary to be attentive to relevant signals and to ignore irrelevant signals in order to make decisions on appropriate behaviors to complete the task at hand. Snel and Cremer (1994) found that with increasing complexity of a task, older adults are proportionally slower than young adults. For example, it is known that older adults are less accurate and require more processing time than young adults when stimulus/response relations are indirect or not logical. Thus, older workers also may have problems attending to or selecting target information on complex displays.

With the aging workforce, much research has focused on the adult learner and a number of elements have been identified with the process of learning. For instance, learning skills require perception and comprehension of data, short-term and long-term memory (STM and LTM) store, and active search and retrieval. Age-related changes in memory may deteriorate any of the above mechanisms, leading to comprehension difficulties, lower capacity or greater vulnerability of STM storage, consolidation problems, changes in LTM storage, or search and retrieval problems (Snel and Cremer, 1994; Ference and Vockell, 1994).

Although changes in cognition have been shown to occur across the lifespan, research has also indicated that such changes in laboratory tests (often times novel tasks) do not parallel changes in work performance. For instance, many jobs in which older workers are employed rely heavily on accumulated knowledge that relates to crystallized intelligence. Research has shown that older adults perform well at tasks at which they are expert or in environments in which they are familiar (Park and Gutchess, 2000).

Because novel laboratory tasks may not always predict work performance, newer research has striven to be ecologically valid. Ecologically valid research seeks to generalize results from an artificial (work) situations and thus provides the opportunity to advance theory and practice while solving real-world problems (Czaja and Sharit, 2003).

3.2. Physical aging

The challenges of the physically aging workforce include age-related declines in physical, physiological, perceptual, and motor processes that may limit functioning during aging. Workers' vision, hearing, balance, strength, joint mobility, manual dexterity, reaction and movement times, and endurance all suffer declines with age, and some workers suffer from degenerative joint disease, osteoporosis, cardiovascular disease, and metabolic disorders (Fozard, 1997; McMahan and Phillips, 1999). In general, older people suffer a reduction in the range of visual accommodation, a loss of contrast sensitivity, decreases in dark adaptation, declines in color sensitivity, and heightened susceptibility problems with glare. Visual search skills and the ability to detect targets against a background also decline with age (Kline and Schieber, 1985). Finally, most older adults experience some decline in auditory function. Age-associated loss in hearing includes: a loss of sensitivity for pure tones, especially for high frequency tones; difficulty in understanding speech, especially if the speech is distorted; problems localizing sounds; problems in binaural listening; increased sensitivity to loudness (Schieber et al., 1991).

3.2.1. Reduction in joint mobility and manual dexterity

The most significant changes in our ability to move as we age occur in our joints, particularly small motor movements associated with grasping, gripping, twisting, and turning, and large motor movements associated with walking, bending, sitting, climbing, stooping, and reaching. As our ability to locate and identify textures and surfaces becomes impaired, it is increasingly difficult to grasp, hold, or manipulate small, smooth objects (Pirkl, 1995). Although joint mobility decreases slightly from the ages of 20–60, the incidence of arthritis (inflammation of the joints) increases dramatically beyond the age of 45 (Morgan et al., 1963). Shoulder muscle fatigue, identified as a major concern for older workers experiencing decreased joint mobility, has been associated with jobs requiring elevated arm activities (Herberts et al., 1980). Pressure receptors located deep within our various body parts also seem to decline with age. This decline may inhibit our ability to detect pressure cues associated even with simple tasks such as pressing a switch or button to activate a light or appliance. In addition, our body may be less sensitive to pain caused by thermal stimuli, requiring shielding from heat or cold when accidental or prolonged contact causes injury (Pirkl, 1995).

3.2.2. Changes in muscular strength and reaction times

Muscular strength, in general, peaks between the ages of 25 and 30. There are rough estimates that by age 40, average muscle strength is about 95% of an earlier maximum in the late 1920s; by age 50, it drops to about 85%; by age 65, only 75% of the earlier output is available with further decline thereafter (Vitasalo et al., 1985). Reduction of physical strength with increasing age is generally believed to be potentially hazardous, especially to older workers in jobs requiring exertion of high muscular forces such as lifting, lowering, and carrying of moderate to heavy loads, and pushing and pulling of heavy carts on broken or inclined floors.

With age, behavioral responses also slow down. Davies and Mebarki (1983) found that there were significant decreases in movement time between the ages of 16–25 and 28–56. Tolin and Simon (1968) reported that an average reaction time of older groups (age 66–87) was 30% slower than that of younger groups (age 18–30). Part of this slowing down is explained by the declining efficiencies of the sensory organs and musculoskeletal system.

3.2.3. Aerobic capacity and endurance

Aerobic capacity at age 65 is about 70% of that at age 25. Therefore, aerobically demanding work is more hazardous to older workers than younger workers. Aerobically demanding tasks are also more difficult for older workers due to the reduction in their ability to regulate the temperature of their bodies in hot and cold environments (Goldberg and Ellis, 1996; Kemper, 1994).

The National Health Interview Survey analyzed the ability of older adults to perform work-related activities that involved mobility, endurance, lower and upper body strength, freedom of movement, and fine motor skills (Kovar and LaCroix (1987)). The sample included people 55–74 years of age who had continued to work or returned to work for at least some time during their middle years. The authors found that a large proportion of their sample had difficulty stooping or crouching (28%), lifting or carrying 25 pounds (23%), or standing on their feet for two hours (22%). Fifteen percent of the sample indicated difficulty walking up 10 steps without resting. Very few had difficulty reaching to shake hands or carry 10 pounds. The study also found gender differences, with a greater portion of women experiencing problems with work demands than men. Overall, the data suggest that due to age-related changes in physical capacity older people are less able and less likely to perform tasks which are characterized by high physical demands.

One area in which age seems to play a role is the severity of musculoskeletal injuries that develop over time (often times termed cumulative as opposed to acute injuries). Most studies show that repetitive motion injuries are more prevalent in workers age 40–60 years. The reduced resiliency in the ligaments, tendons, and muscles places older workers at a greater risk of injury, and the lower back seems to be especially prone. Because of these types of changes, older workers' physical work capacities may be lower, leading to the likelihood of overexertion. Finally, some studies indicate that older workers are less likely to return to work after experiencing a disability (Goldberg and Ellis, 1996).

3.3. Decline vs. compensation theory

Despite the above findings regarding the effects of physical and cognitive decreases, some researchers now believe that these declines are neither inevitable nor unilateral. For instance, Lee and Lee (1999) tested older and younger pilots on emergency response skills and found that, although the older pilots were slightly slower in response, there was no statistical difference in performance between the groups. There is also a debate amongst psychologists concerning the degree and type of cognitive decline as the worker ages and the amount and type of intervention that may compensate for those declines in cognitive functioning.

Other researchers suggest that growing older does not have to lead to cognitive slow down. Although the evidence is clear that memory declines with age, studies on how age and practice affect skilled performance assert that older adults can develop techniques to offset the slow down of mental functions (Rabasca, 2000). Other researchers have shown that while aging does result in certain decline and losses, aging also fosters positive characteristics (Quales and Abeles, 2000; Rabasca, 2000). Attributes such as wisdom and emotional maturity improve with age. Geropsychologists are challenging popular theories that aging leads to inevitable decline, with experts suggesting that aging adults can positively adapt to changes in their cognition, mental health, and social relationships.

In a recent study, Westerholm and Kilborn (1997) examined the issues of aging decline and aging compensation. The authors concluded that the difficulty in characterizing productivity, skills, and occupational health of aging workers is an important issue. They believe that there is considerable variation among people in physiological, cognitive, and social functioning and that these differences increase over the human lifespan, necessitating an individual rather than a group approach to aging research. Age-related decline of biological and physiological function is suggested to affect work performance only when work performance is primarily dependent on such functions. It may be relatively difficult for some older workers to adequately perform physically demanding jobs and jobs requiring quick responses to unexpected situations.

The above observations are important for the older worker, indicating that the worker (and/or the employer) indeed can intervene in the aging process to maintain important work skills. As Cavanaugh (Volz, 2000) notes: "The stereotype is that memory is supposed to decline, but that is still an open question." A study by researchers at Georgia Tech (Hambrick et al., 1999) suggested that even though older people may not perform as well in spontaneous activities, they can do the job just at well if they have experience in that field. Salthouse and Hambrick (1999) reported that many older adults successfully perform jobs that are somewhat cognitively demanding. He suggests that experience also results in higher levels of job knowledge or competence which may compensate for declines in abilities.

Psychologists are showing that memory loss can be reversed by personal strategies such as daily memory check and regular mental exercises. Some are designing methods to help people change their behavior in relation to memory to take advantage of increased longevity. A team of Princeton University psychologists found that adults continue to grow new brain cells throughout life. Those late-generated cells may allow older people to bolster their learning and memory capabilities or even to stave off decline (Gould et al., 2000). Peter Martin, Ph.D., a professor at Iowa State University, is quoted as saying, "No matter what your age, the memory is still trainable. You can teach an old dog new tricks," (Volz, 2000). In support of that belief, L.C. Katz, a professor of neurobiology at Duke University, says his easy-to-perform "neurobic exercises" help the brain to not only maintain connections between nerve cells and preserve memory recall, but actually can aid in the development of new connections (Katz and Rubin, 1999).

New research shows that balanced diet can also benefit memory enhancement. Researchers at Tufts University found that men aged 50 and older who had low levels of the B vitamins folate and B12 were not as good at performing memory tests as those with higher levels of vitamin B. Other research in the past several years has linked mental dexterity to vitamins C, D, and beta carotene. These antioxidants may prevent damage to the brain's neuron (Volz, 2000).

From a physical performance standpoint, an older worker's experience may allow him or her to compensate for excessive physical demands. In a study of blue collar workers performing light manufacturing jobs with little physical demand, it was found that older workers may use their experience to compensate for declines in physical stamina (Giniger et al., 1983). The study found that "experience was the primary determinant of job performance." Ashcraft (1992) found that productivity may decline with age when the job relates directly to some physical aspect of reaction time or speed of performance. Similarly, Czaja (1994) noted that experience makes up for cognitive deficiencies while technology reduces physical demands; she believes that together they can improve employment opportunities for older workers.

4. Shift work

Harma and Ilmarinen (1999) refer to the 24-h society in the Scandinavian Journal of Work, Environment and Health. The authors point out that the health and well-being of the aging shift worker is a combination of several job-related, individual, and psychosocial factors. Thus, interventions for the aging worker need to be multi-dimensional. These authors noted that older employees have a need to adjust their work demands to their private lives. Older workers want a life more balanced between job and family. The researchers recommend that increased flexibility for the worker should be set as a general organizational goal to accommodate aging workers. The interval of time off between shifts should be set to allow adequate rest for older workers. Finally, the authors note that older workers benefit from an increased number of breaks during the work shift to compensate for increased fatigue.

Sleep quality after night shifts is a major complaint of aging shift workers. On the other hand, older workers have fewer problems with morning shifts than do younger shift workers. The effect of night shifts on elderly shift workers can probably be reduced by decreasing night work, by reducing the total amount of night work through a redesign of the shift schedule, or the allocation of part of the night shift to younger shift workers (Harma and Ilmarinen, 1999). Finally, the authors suggest that the option of changing the older night shift workers to day work should be considered on an individual basis.

5. Mitigating the effects of aging on the workforce

5.1. Accommodating workers through ergonomics

Broadly defined, ergonomics, as it relates to the working population, is fitting the job to the worker. This entails matching the task, the tools, and the environment, to the needs of the worker with the goal of achieving a healthy, productive workplace (Allie, 1994). Because older workers may struggle with work demands and job requirements, using ergonomics to improve work design, work environment and tool design becomes extremely important. Thus, in order to keep our workers continually adapting to the workplace and being healthy and productive, instead of choosing retirement, it is important to match the physical and cognitive characteristics of the workplace to the abilities of the worker (Moyers and Coleman, 2004). Marshall (2001) discussed results from researchers who studied the relationship between age, quality of tool design, and job performance. The study found that the quality of tool design was unrelated to job performance among younger workers, but that older workers with poorly designed tools had the lowest performance ratings of all groups.

Research shows that changes can be made to help reduce age-related effects and to accommodate older workers' shortcomings. For instance, McMahan and Phillips (1999) recommend three main redesign or work organization objectives that can be implemented by employers and workers to combat musculoskeletal injury (MSD) type problems:

1. Reduce extreme joint movement (keep motions within acceptable range of motion, use distinct textures and shape for controls, minimize twisting and reaching).
2. Reduce excessive force (opting for mechanical assist devices, use padding to reduce pressures, keep cutting edges sharp).
3. Reduce highly repetitive tasks (use power tools, job rotation, variety work).

Other types of corrective action or considerations for older workers include providing larger print, higher levels of illumination, higher contrast, and more physical training (Czaja, 1995).

Often, industries consider an ergonomic approach only as a reaction to increased reporting of MSDs and rising worker's compensation costs. Instead, a proactive ergonomics approach determines job redesign needs based on a sound evaluation of the associated risk factors for MSDs for a particular job. As such, early intervention and prevention of MSDs translates into a lower incidence of worker's compensation claims. A proactive approach requires a keen understanding of the limitations of the workforce and the requirements of the job through careful task analysis. When considering the aging workforce, a proactive ergonomic approach can help to ensure compatibility between the skills and limitations of all workers, regardless of age.

A strategy to design workplaces to fit aging workers was outlined by Getty and Getty (1996):

1. Use and develop techniques to evaluate the capabilities of individuals.
2. Promote continuous improvement of the work processes for all workers and special accommodations for the aging workers.
3. Provide skills training packaged in an acceptable program that is unique to the needs of the individual.
4. Provide a clear description of physical conditioning and the efficacy of how specific techniques apply to individuals.
5. Ensures that the aging worker is accepted and their contributions to the workforce are acknowledged.
6. Ensure involvement of aging workers in all aspects of the process to gain ownership and inputs of their unique capabilities and experiences.

5.2. Training for older workers

In today's 24-7 economy it is imperative that all employees receive training to hone their skills and prevent them from becoming obsolescent. Myths abound, however, when it comes to the topic of aging and learning, and often companies are not sure about the best ways in which to train older adults. Czaja (1995) reported a study finding that training can mitigate age declines in performance. The study found that age accounted only for a small portion of the variance in performance, that job complexity did not moderate the effects of age, and that older workers who had received recent task training performed better than those who had not received recent training. In a later study, Czaja and Sharit (2000) suggested that older people are quite capable of learning new skills, tasks, and procedures, but that training strategies may need to be modified for older people. These training modifications may significantly improve the learning efficiency of older adults. Costs associated with additional training or extended practice may be offset by lower turnover and absenteeism among older people. The authors suggest that training is an investment, not a cost.

Researchers at the National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory (PRL), have addressed these challenges in a recent publication titled, "Safety and Health Training for an Evolving Workforce: An Overview from the Mining Industry" (Kowalski-Trakofler et al., 2004). In this study, PRL researchers suggest that training will be successful if it is based on adult educational needs and sound learning principles. The authors report the findings of Caudron (2000) and Lankard (1995) which suggest that the best adult learning experiences occur through personal experience, group support, and mentoring that allows the learner to participate in an active, rather than a passive, way. With these principles in mind, PRL has developed a program that involves on-the-job-training (OJT) and mentoring or "coaching" for the mining workforce (Mallett et al., 2005). These training materials utilize the expertise of older miners, and they use older workers in the training of new workers. The use of these types of programs to provide continuous on-the-job growth and skill development is strongly suggested for an age-diverse workforce.

There are several types of training that should be considered for the aging workforce, including task-specific, general ergonomics and postural awareness, age awareness, and employee wellness. Task-specific training should occur upon hiring, when a new process or tool is introduced, or when design changes have been made to a process or tool. General ergonomics and postural awareness training for workers and management will help aging workers and those who work with them understand the perceptual, physical and physiological capabilities and limitations of workers. The ergonomics training will also help individuals to recognize risk factors which may lead to injury or illness. Thus, these risk factors can be thought of as indicators and preventative measures can be taken early. Specific age awareness training for managers, people who work with older workers, and the older workers themselves is needed to educate individuals as to the process of aging and how it relates to job design. Information about cognitive, perceptual, physical and physiological declines should also be discussed, and workers should be given an opportunity to devise solutions for their specific work environment.

5.3. Wellness programs

Research has shown us that exercise dramatically increases physical fitness, muscle size, and strength in older individuals (Rowe and Kahn, 1998). Besides rejuvenating muscles, resistance exercise also enhances bond strength, limiting the risk of osteoporosis and fractures of the hip, spine, and wrist. Exercise also improves balance. In addition, there are psychological benefits to exercise that support a sense of well-being. Strength and flexibility training can slow down the aging process and increase worker ability. Physical function is strengthened through conditioning thereby reducing the risk of injury.

Keeping the older worker physically fit has many benefits, including financial benefits that may be realized in the form of reduced insurance costs or lower injury rates. The authors recommend that companies support physical fitness through education and even integration of activities and programs in the workplace. Wellness programs focus on education and prevention, and they can include such programs as disease management, physical fitness, nutritional counseling, stress reduction, smoking cessation, flu vaccinations, cancer screenings, and childrens' nutrition and exercise programs (O'Rourke and Sullivan, 2003). Cost benefits per employee for wellness programs conservatively range from $3.00 to $7.00 (Kelly, 2003). It has been suggested that the benefits from wellness programs include improvement of corporate image, a decrease in employee turnover, gains of productivity, reduced absenteeism and medical costs, improved employee lifestyles and a reduction in industrial injuries (Shepard, 1992; Maniscalco et al., 1999).

6. Applications to mining

Mining is considered to be one of the most physically demanding occupations. Bituminous coal and lignite mining rank second in the nation for the average cost per worker for fatal and all nonfatal injuries and illnesses (Leigh et al., 2004). Within mining, musculoskeletal injuries conservatively make-up nearly 40% of all nonfatal injuries, and they tend to increase and become more severe with age. Currently, the median age for workers in the mining industry is greater than in the civilian labor force. The median mine worker age was 41.8 years in 2003, and it is predicted to increase through the next decade (Bureau of Labor Statistics, 2003; Fotta and Bockosh, 2000). Without recognition of this issue of aging, and targeted age-related ergonomic interventions, the number and severity of injuries to our older mine workers most likely will increase.

Applying the disciplines of psychology, sociology, and ergonomics can be difficult due to the dynamic and physical environment of mining. This work environment includes unpredictable geological anomalies which can change the physical work environment within minutes. The response to such changes requires experience, knowledge, and the ability to make decisions quickly and safely. There are multiple safety and health concerns in the mining environment, such that miners must be mentally aware at all times while performing physically strenuous tasks (Steiner et al., 1997; Scharf et al., 2001). Ergonomic, organizational, and training measures, health and exercise promotion, and the continuous improvement of mining skills through training help to promote work ability, health, and wellness of mine workers. Addressing these training and design issues is needed to give older mine workers a greater opportunity to contribute meaningfully to the industry. Studying and transferring the knowledge and experience of older workers helps to define needs such as operational parameters, training requirements, and new design. This information helps us to develop safer, healthier, and more productive work environments. Also, as new technology is designed and implemented, there can be an initial and even permanent change in mental workload, which can be significant especially for older workers.

Studying technological advancements and their application to mining before implementation becomes critical to an aging workforce.

7. Discussion and recommendations

The authors agree with Clifton (2001), who suggests that employers who underestimate the strengths of older workers may be missing a valuable source of labor in an increasingly tight market. The key to effective accommodation for older workers is through a diagnostic approach that begins with the anticipation of reducing losses for all workers while enabling prolonged healthy work conditions for the aging worker. The mining industry needs to accommodate and utilize the older worker as an important resource.

To achieve and maintain a competitive edge, organizations need to find the most effective training possible for their workforce. A socio-ecological approach is suggested to support the older worker. This approach considers the individual, physical environment, organizational climate, and community. It focuses on the interactions between humans and their environments, including the institutional and cultural context. Work sites are complex systems, comprising multiple social and physical environmental conditions, which jointly influence physical, mental, and social well-being. A socio-ecological approach is comprehensive and focuses on four main components: (1) the individual employee, (2) the physical workplace, (3) organizational dynamics, and (4) the community/culture. Mining companies with foresight will evaluate their programs within these parameters. For example, one of the biggest issues in mining is the low-light environment. Older workers physically have more trouble in low-light conditions and adding lighting ineffectively can result in glare issues. As the senses (hearing, vision) degrade, the environment must be enhanced to accommodate the worker through redundant cues or by highlighting critical information.

Clifton (2001) presents a four-step plan to mitigate the effect of aging in the workplace: pre-loss risk appraisal, pre-loss evaluation, a risk corrections process, and post-loss intervention. The authors believe that this plan, along with a socio-ecological approach discussed earlier, is an appropriate template for the mining industry. Clifton's four-step program is briefly elaborated:

1. Pre-loss risk includes defining the demographics of the workforce including age and job type and evaluation of injuries.
2. Pre-loss evaluation develops interventions to address the broader work environment.
3. The risk corrections process includes modification to the work site, work stations, job functions, and ergonomic education that minimizes potential for injury by accommodating for the physiological impact of aging.
4. Post-loss intervention focuses on a proactive program for addressing medical treatment and return-to-work.

Within the dangerous mining environment, effective safety and health programs can be the difference between life and death. Laflamme and Menckel (1995) concluded that "the safety problems of older workers may well be restricted to activities that are specifically "age-impaired". The authors recommend research in the area of specific mining injuries that may be age-related. More research is also needed to determine job skills and task requirements as they relate to age so that we might determine what can be done to minimize the age-related effects. These data would be beneficial to the industry in planning interventions for this population and for ensuring healthier work environments and procedures for all workers in the future.

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