Age Changes in the Older Adult Worker

Implications for Injury Prevention

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Musculoskeletal injuries are responsible for a large portion of lost work time. Back problems alone account for over 30% of the claims and $14 billion a year in medical costs.[1,2] Eighty percent of adults in the U.S. will sustain a back injury requiring medical attention, and many affected individuals will experience at least one recurrence of back problems.[3,4] A majority of these injuries occur at two ages, 30 and 55.[5] As baby boomers move into their 40s and 50s, demographic information indicates that the already large number of musculoskeletal injuries will grow unless active prevention is undertaken to reduce the incidence of these types of injuries.

Given such statistics, it is not surprising that the National Institute of Occupational Safety and Health (NIOSH) has identified musculoskeletal injuries as a significant problem and is attempting to develop preventive techniques. Several approaches have been used in industry. The greatest emphasis has been on ergonomic changes. NIOSH has identified several factors that can be modified in an attempt to decrease injury rates, including load weight, frequency of movement, and amount of horizontal and vertical displacement.[6] Educational programs have achieved varying degrees of success in lowering injury rates.[7] Employee exercise and fitness programs have been used to a lesser extent, though little research has examined their effectiveness in preventing job-related injury.[8] Job matching and preemployment screening are now being tried in some industries. However, the legal implications of such programs are still unclear.[9] These approaches, independent or combined, may be useful in preventing job-related injuries. Further research is needed to determine which are the most effective.

NIOSH regards the occurrence of musculoskeletal injuries as a significant problem. Because the work force is aging, it is essential to consider the physiological and functional effects of aging to facilitate development of more precise prevention strategies. The focus of this article is on the aging process and its implications for injury prevention among aging workers.

GENERAL CONSIDERATIONS

No special training is required to observe that there are significant physical differences between older and younger workers. Differences include speed of movement, posture, strength, reaction time, flexibility, and body composition. Such differences do not appear at any specific age. Rather, aging is developmental; normal age changes occur continuously throughout our lives, at different rates for different individuals and, within the individual, at different rates for different body systems. Although one can generalize about the normal aging process,

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there is remarkable variability among aging individuals. People are less alike at age 50 than age 5, not only in personality and social history, but in physiology and functional abilities as well.

Before exploring some of the effects of aging, two other factors need to be examined. First, the effects of normal aging differ from the effects of pathological processes. As one ages, the corresponding rate of acute disease and chronic conditions increases. Second, adults tend to become less active as they age. Many functional changes evident in the older adult population are due to the effects of decreased activity levels, termed "hypokinetics."[10,11]

With these considerations in mind, we will focus on the following question: What are the major normal age changes that should be considered when planning work environments and injury prevention or health promotion programs for older workers? The major body systems to be discussed are the musculoskeletal, neurological, cardiopulmonary, and sensory systems.

NORMAL AGING RISK FACTORS

Musculoskeletal System

Connective Tissue. Connective tissue is found throughout the body and provides support and a "local environment" for various structures. All connective tissues contain collagen, elastin, glycoproteins, and hyaluronic acid. The proportions of each substance vary among the different connective tissue types.[12] Each of these components changes with age.

Collagen, a primary supportive protein, is continuously formed throughout our lives. As one ages, the diameter of collagen fibers increases, resulting in a general increase in the tensile strength of connective tissue.[12] However, vitamin C deficiency and chronic stress may decrease the tensile strength. Older adults and the elderly are vulnerable to both of these situations.[12] The production of elastin, which gives connective tissue the ability to shorten to its original length after having been stretched, decreases, lessening the elastic properties of connective tissue, particularly in the skin, bronchial tree, and arterial walls.[12] Production of glycoproteins, which act as "sponges" to attract fluid to an area, also decreases.[12] Therefore, tissues become progressively dehydrated during the aging process. Friction between cells is minimized by the presence of hyaluronic acid, which acts as a lubricant. Again, hyaluronic acid production also decreases with age.[12]

The result of these changes is that movement gradually becomes more difficult. Flexibility decreases as collagen becomes stronger and elastin is lost, while the relative dehydration and increased viscosity of tissues creates more friction, and hence more wear and tear at the tissue level. Ligaments and tendons lose their normal suppleness due to the increased tensile strength of collagen and relative dehydration, thereby increasing the risk of injury.

The vertebral disc and spine are at particular risk of injury due to age-related changes in connective tissue. Half of lumbar spines show radiographic signs of degeneration by age 60.[10] As the disc loses its normal fluid content due to glycoprotein loss, the disc narrows and degenerative changes occur in the annulus.[13] This can lead to increased pressure on facet joints, with resultant facet degeneration, spondylolisthesis, and/or spinal stenosis.[13]

Articular cartilage throughout all the joints in the body is also at risk. Decreased production of glycoproteins and hyaluronic acid results in a narrowing of the cartilage and a diminution of normal joint lubrication. This in turn contributes to increased wear and tear, which results in even more cartilage loss.[12] As cartilage is lost and discomfort increases, an individual may attempt to minimize use of the joint. But without intermittent compression of the joint, removal of waste products and joint lubrication diminish even further, causing additional joint deterioration and creating a vicious cycle of discomfort and disuse.

Bone. The best-documented age change in bone is decreased density, i.e., osteoporosis, which increases risk of fracture. Although postmenopausal women are at particular risk for significant bone loss, bone density of women begins to decrease as early as the 30s.[14] Bone mineral loss occurs at a rate of approximately 1% per year before menopause, 2-4% per year for 4–5 years after menopause, and 1% per year thereafter. At such rates, total bone mass can be reduced by 30% by age 70.[14] For men, the rate is approximately 0.5% per year, with significant risk of associated fracture usually not occurring until age 80.[14] Decreases in activity significantly accelerate bone demineralization. It has been suggested that, other than the bone loss associated with menopause itself, losses in bone mineral may be due primarily to decreased activity associated with aging.[12] Other factors include levels of bone mass in early adulthood, amount of calcium in the diet, and genetic and hormonal influences.[14]

Muscle. Age-associated loss of muscle strength is well documented. By age 65, there is an approximate 20% loss in strength, and diminished muscle mass due to decreased number and size of muscle fibers.[15] These losses, in both strength and mass, continue as one ages.

Muscles consist of varying proportions of type I and type II muscle fibers. Type I, or slow-twitch fibers, are the first recruited for any activity and are associated with slow contraction velocity and endurance activities. Type II, or fast-twitch fibers, are associated with high force and speed. After age 50, there is selective loss of type II but little loss of type I fibers.[16] These changes are more pronounced in the muscles of the lower extremities than the upper extremities.[16] Other age changes in muscle include fewer capillaries per muscle fiber and decreased mitochondrial volume.[16]

Functionally, there is a loss of isometric strength which begins around age 40 and decreases 25% by age 60.[17] Studies of dynamic strength show marked variability among aging individuals, but there is a general decline in dynamic strength associated with aging and probably a decreased ability to produce torque at high speeds.[17] Overall power and speed of muscle contractions decrease, but muscle endurance shows little deterioration. Although overall performance endurance decreases with age due to decreased maximum Vo_2, if an older person works at the same percentage of maximum Vo_2, no decrease in muscle endurance is found.[17] The functional changes in strength generally noted in the aging population may be due more to decreased activity rather than inherent biological aging processes. In fact, there is evidence that muscle which is used frequently undergoes little structural or functional change.[12]

Neurological System

Perhaps one of the best-documented effects of aging is increased reaction time. This is due to a relatively small decrease in nerve conduction velocity and, more significantly, increased conduction time across synapses.[12] Coordination decreases, perhaps because of increased conduction time and age-associated loss of synaptic connections within the nervous system. Although there is constant loss and remodeling of such connections throughout life, it appears that reconnections are made less readily or effectively in the older population, resulting in more "noise" within the nervous system and less precise transmission of information.[12]

Older individuals have more postural sway and less balance control compared with younger individuals. These differences are probably related to a number of factors including decreased vibration sense, decreased proprioception, changes in the vestibular system, and age-related vision changes[18] (see discussion on sensory changes below). The ability to balance on one leg often begins to deteriorate by age 60; the decrease is more pronounced when the eyes are closed.[18] Given decreased reaction times, normal protective reactions may be slower, and hence less effective in preventing injury when balance is lost.

Cardiopulmonary System

It is extremely difficult to separate the effects of disease and decreased activity levels from normal biological aging of the cardiovascular system. Heart disease is the leading cause of death in older adults. Cerebrovascular disease is the third most prevalent cause of death for those 65–84 years old and second among those over age 85.[19] Given the long-term effects of smoking and exposure to environmental and occupational hazards, as well as specific pulmonary diseases which are more prevalent with age, identifying specific normal age changes in the pulmonary system is difficult.[19] Nevertheless, a few general observations about age changes in the cardiopulmonary system can be made.

While there is little change in resting heart rate with increasing age,[20] maximal attainable heart rate diminishes (although the standard formula, 220 minus age, probably exaggerates the rate of decline for many older individuals).[21] Cardiac output decreases due to changes in both preload and afterload conditions and resting blood pressure tends to rise.[20] A major implication of these changes is that older individuals have less cardiac reserve.

Due to changes in connective tissue (and decreasing activity levels), rib cage flexibility decreases. Connective tissue changes also result in decreased recoil ability of the lungs and increased airway closure during expiration.[22] Vital capacity decreases, and there is residual volume and functional residual capacity increase.[23] Functionally, the work of breathing increases as one ages[22] and breathlessness is reached sooner during vigorous activities.[23]

Sensory System

Some of the most obvious age changes occur in the special senses, yet the implications of these changes are often overlooked. Of particular interest with regard to older workers are changes in vision and hearing. Many of these changes begin in the 40s and 50s. Due to changes in the lens, older adults become increasingly far sighted (presbyopia). The pupils shrink, necessitating increased illumination. By age 80, an individual likely requires 3.5 times more illumination than a 20-year-old.[24] The "yellowing effect" further impairs vision. Pastel colors tend to look alike, and there is a significant decrease in the ability to distinguish between blue, green, and purple;[25] implications for color coding are obvious. Due to the development of cataracts (a normal age change), as well as corneal flattening and increased vitreous humor, blurring and loss of visual detail occur.[25] Glare can functionally blind an individual with cataracts, whether it is from natural or intense single sources of artificial light.[24] Depth perception decreases, as does light/dark accommodation (due to retinal changes) and near/far accommodation (due to stiffening of the lens).[25]

Changes in hearing include a progressive loss of the ability to hear high frequencies. This results not only in difficulty hearing high-pitched environmental noises and voices, but also parts of the spoken word. It is difficult to hear consonants, especially S, Z, T, F, and G.[26] Additionally, it becomes difficult to filter out background noise or locate the source of sounds.[24] Clearly, in many workplace environments, the older worker may be unable to hear what is being said to him or her.

After reviewing the list of normal age changes, one may be discouraged about hiring or maintaining older workers. However, individuals undergo the aging process at markedly different rates, and not all changes are experienced by all individuals. More important, regular activity can counteract many, and perhaps most, of the functional implications of these changes. Study after study has shown that individuals who remain active experience the declines commonly associated with aging to a far lesser extent than sedentary individuals.

EFFECTS OF REGULAR EXERCISE AND ACTIVITY

Despite progressive age changes, the effects of regular activity are extremely beneficial for older adults. In fact, the need for activity increases rather than decreases as one ages. Regular exercise counteracts changes that constitute many of the injury-associated risk factors of aging.[17] Furthermore, trainability (the ability of the body to respond favorably to exercise) persists as one ages, independent of previous levels of activity.[27] Even those with sedentary lifestyles maintain the physiological ability to increase muscle strength, decrease heart rate for a given workload, and increase flexibility when placed on an appropriate exercise program. However, their rates of improvement are slower than those of active individuals of comparable age. Specific benefits of exercise in the older individual are as follows.

Connective Tissue. Regular activity, consisting of movement of all body parts, helps prevent abnormal crosslinks from forming within collagen, i.e. activity keeps it "stretched out." Although the collagen of older adults is less flexible and slower to respond to stretching, it maintains the ability to stretch.[12] Despite changes in joint lubrication due to decreased glycoprotein and hyaluronic acid production, regular (but not excessive) compression is vital for maintaining cartilage nutrition, metabolite removal, and lubrication.[28] Since cartilage has no direct blood supply, it relies entirely on mechanical forces for these functions. New studies suggest that even patients with osteoarthritis or rheumatoid arthritis benefit from regular aerobic exercise.[29] Walking and swimming have been shown to be beneficial for patients with histories of spinal dysfunction.[30]

Bone. While activity level is not the only factor involved in bone loss due to aging, there is a clear relationship between decreased activity and increased bone loss. Numerous studies have shown that proper exercise, including weight-bearing activities for the spine, pelvis and lower extremities, and resistive exercise for the upper extremities not only slows the rate of mineral loss associated with aging, but can actually increase bone mineral content.[15,17] These effects are especially pronounced in individuals with sedentary jobs and lifestyles.

Muscle. There is significant evidence that age-associated losses of strength may be greatly modified or eliminated (at least through the sixth decade and perhaps longer) in individuals who remain active.[17] A Swedish study demonstrated that older manual laborers experienced less disability and required less assistance with activities of daily living than sedentary individuals.[14,22] Maintenance of activity can reduce and in some cases reverse muscle fiber atrophy associated with aging. If a muscle is used fully, little deterioration occurs despite increased age.[12] Older adult muscle remains trainable at least through the eighth decade, although more time is required for the strengthening effect to occur.[31] Increases in strength occur primarily through improved motor unit recruitment rather than an increase in muscle fiber bulk, but the possibility for hypertrophy remains to some degree.[12] Reported exercise gains in strength in older adults and the elderly range from 10–72%.[12] Although older adults will not reach as high a level of strength as younger workers, the percentage increase may be the same. Excessively aggressive strengthening however, may cause injury or actual muscle weakness.[12,15]

Neurological System. Although controlled studies have not clearly demonstrated that balance significantly improves with training, many activities can be designed to try to improve both balance and protective reactions in the older adult.[18] Studies have proven that reaction time improves with training,[32] and coordination may also respond to training, although to date there has been little research in this area.

Cardiopulmonary System. Cardiovascular and pulmonary functions decline in healthy, cardiovascularly fit aging individuals, even master athletes. However, age changes produce little functional difficulty for such individuals.[22,33] In contrast, cardiopulmonary function markedly declines in sedentary individuals, but exercise can greatly enhance their cardiopulmonary performance. With appropriate training, improvement has been documented in maximum Vo_2, and significant improvements in functional abilities have been noted.[33] Finally, aging individuals who participate in regular exercise programs significantly decrease their risk of heart disease.[34]

Psychological Factors. Regular participation in an exercise program increases a person's awareness of health considerations.[22]

Regular exercise is also associated with an improved sense of well being, cognition, perception of health, and self-concept.[22]

IMPLICATIONS FOR INJURY PREVENTION

The physiology of aging has direct implications for the development of injury prevention programs for aging workers, especially with regard to job design and fitness programs.

Exercise Guidelines for the Older Adult Worker

Research on the effects of exercise on specific groups of aging workers is lacking; however, studies done in industrial settings indicate that exercise may be useful in the general working population. For example, Chaffin[35] found that a job-specific decrease in isometric strength was associated with an increase in injury rate. Another study showed a significant difference in injury rates between groups of firemen that did and did not exercise. Although the type of exercise was not controlled in this study, those who did not exercise were 10 times more likely to sustain an injury.[36]

Exercise should receive serious attention along with ergonomic and educational considerations. It is likely that such a multifaceted approach is appropriate for all age groups, but especially for older individuals who are decreasing their activity levels.

However, older workers are also at increased risk of injury from exercise due to normal age changes, as well as the effects of disease and hypokinetics. This does not mean that higher risk individuals cannot or should not participate in exercise programs. Good screening and knowledgeable instructors can help to prevent exercise-induced injuries or problems.

Certain general training principles should be followed when planning exercise programs for older adult workers:

General Considerations

1. Workers over 40 who have not been involved in a regular activity or exercise program for some time should obtain a release from a physician. However, this does not mean that all older workers require stress testing before participating in a training program. Provided that adequate screening is done, exercise can be initiated and progressed at safe levels determined by knowledgeable professionals. Medications should also be checked for possible effects on exercise response.
2. Documented heart disease may warrant participation in a program that monitors for cardiac dysfunction and has equipment available for resuscitation.
3. Musculoskeletal screening is important to assess limitations in joint movements, flexibility, and strength specific to the critical tasks of a particular job. Appropriate screening also provides a baseline for initiating exercise.
4. Obtaining initial or continued participation in an exercise program may be difficult with aging workers because of their slower response to exercise and possible false beliefs about the risks of exercise and the aging process.[27] Education helps to counteract these problems.
5. A fully trained individual—one who is familiar with normal exercise prescription, the physiology of aging, and its implications for exercise prescription—should be in charge of this type of exercise program. This person should be certified in cardiopulmonary resuscitation (CPR).

Exercise Parameters

1. Due to age changes in connective tissue, muscle, and circulation, older adults require longer warm-up and cool-down periods.[12] Additionally, static stretches should be held for up to 30 seconds and must be carefully performed to prevent injury. Con-

tract-relax-contract techniques are an excellent form of controlled stretching.

2. In general, physiologic adaptation is slower in older adults. Exercise programs should begin at levels which are not overly taxing and which progress gradually. Although a system must experience overload for a training effect to occur, in older adults too quick a progression will result in deterioration rather than improvement of the system. This applies not only to the cardiopulmonary system, but also the muscular, skeletal, and connective tissue systems.
3. Exercise should be limited to low-impact activities. Participants should wear proper footwear to reduce shock.
4. Activities should encourage good postural alignment and muscle balance. Activities that encourage balance and coordination without risk of falling may provide additional benefits.
5. The program should include cardiovascular exercise. Participants should understand the safe limits of exercise and should be taught to monitor their pulse.
6. Water is an excellent medium in which to increase strength, flexibility, coordination, and cardiovascular endurance without damaging older workers' bone and joint structures. However, it may not provide adequate stimulation for calcium uptake in bone, especially in the spine and lower extremities. Thus, the program should include some sort of weight-bearing activity.
7. Walking programs combined with adequate stretching and upper extremity resistive exercises may be sufficient if the worker's job does not require high levels of strength.
8. Cross-training stresses different parts of the musculoskeletal system.
9. Older adults should continue to exercise even after achieving a higher level of fitness. Although the beneficial effects of training programs gradually disappear in all age groups when the activity levels are not sustained, older adults lose the benefits of training faster than younger adults.[37]

Environmental Factors

1. The environmental temperature is important when exercising due to decreased thermoregulation in older adults; caution is required when exercising in hot or cold environments.[38]
2. The exercise, locker, and shower areas should include lighting and auditory accommodations that take into account the normal vision and hearing changes experienced by aging individuals.
3. Because older participants may have diminished balance, safety measures, particularly in the potentially slippery area of showers and sinks, must be taken.

Ergonomic Changes for the Aging Worker

Basic ergonomic principles apply when designing work environments for older workers; however, certain areas merit special consideration. For example, the simultaneous needs for increased illumination and decreased glare may be met by installing multiple lighting sources located in several positions.[24] Color-coding schemes must be carefully planned, and care taken to be certain that older workers can see and read any small print or fine detail needed for the safe and effective completion of a job.

Older workers must be able to hear verbal directions, especially in noisy settings. The pitch of safety or warning signals should be examined. Requirements of a task should take into account changes in flexibility, strength, speed, and reaction time in the older worker. Particular attention should be paid to preventing falls. While this is far from an exhaustive checklist of environmental considerations, it stresses the need for environmental adaptation to maintain healthy, productive older workers.

CONCLUSIONS

Older workers make up a growing percentage of the work force. Many of these workers may be at risk of injury because of the normal biological changes which occur as individuals age. Fortunately, steps can be taken to reduce the risks associated with the aging process. Exercise may counteract many age-related changes. Injury prevention is critical for older workers, and may be facilitated by altering their work environment based on the physical changes associated with aging.

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