EFFECTS OF STRETCH PROGRAMS ON MUSCULOSKELETAL INJURIES

by

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ABSTRACT

Musculoskeletal disorders (MSDs) describes conditions that affect the musculoskeletal system, which includes the nerves, tendons, muscles, and supporting structures of the body and physical symptoms that result from repeated trauma or strain. MSDs accounted for 357,000 injuries in workplaces across the United States in 2006 (United States Bureau of Labor Statistics [US BLS], 2007). Although trending data indicate that MSDs have decreased for the past 5 years, the impact on the worker and the company is immense (US BLS, 2008).

The muscle is a complex structure that produces force through contraction. The basic contractile unit of the muscle is termed the sarcomere (Llewellyn, Barretto, Delp, & Schnitzer, 2008) and is comprised of actin and myosin filaments. The actin filament provides the structure of the sarcomere, similar to the skeletal system in the human body. The muscle is highly adaptable and responds to increased workloads through a compensatory hypertrophic response (Adams, Cheng, Haddad, & Baldwin, 2004).

Effects of injury and stretching on the microscopic level of the muscle are still not well understood. While stretching has been a foundation of exercise for many years (Black, Freeman, & Stevens, 2002), the research suggests that it has mixed results in application (Bazett-Jones, Gibson, & McBride, 2008; Herbert & Gabriel, 2002; LaRoche, Lussier & Roy, 2008; Pope, Herbert, Kirwan & Graham, 2000; Shrier, 1999; Thacker, Gilchrist, Stroup, & Kimsey, 2004; Witvrouw, Mahieu, Danneels, & McNair, 2004). Warm-up and calisthenics prior to exercise

have proven to have more positive outcomes prior to muscle activity (Cé, Margonato, Casasco, & Veicsteinas, 2008; Woods, Bishop, & Jones, 2007).

In the occupational setting, MSDs are a leading cause of injury and incur significant costs. The occupational and environmental health nurse (OEHN) plays a critical role in the reactive and proactive assessment and intervention of MSDs. To affect the incidence of MSDs in the workplace, programs with primary, secondary, and tertiary prevention methods must be implemented. As a proactive measure, and after a hazard assessment of the area, a pre-work warm-up program can be implemented to further reduce the impact of MSDs.

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CHAPTER I

INTRODUCTION

Musculoskeletal disorders (MSDs) in the workplace accounted for approximately 357,000 injuries in 2006 (US BLS, 2007). Trending data indicate that the number of workplace-caused musculoskeletal injuries has been on the decrease. The incidence of MSDs accounts for 30% of the injuries and illnesses with days away from work in 2006, the same percentage as in 2005 (US BLS, 2007). The impact to both the injured worker and the employer can be tremendous, as conservative estimates of the imposed economic burden as measured by compensation costs, lost wages, and lost productivity, are between $45 and $54 billion annually (National Academy of Sciences [NAS], 2001). The aging of society will further impact MSDs both inside and outside of the workplace, as United States Census Bureau data report that Americans over the age of 65 will increase from 13% to an estimated 20% by 2030 (He, Sengupta, Velkoff, & DeBarros, 2005).

To decrease these injury types and create a safer, healthier workforce and workplace, the occupational and environmental health nurse must understand all aspects of the problem. As Gordon (1949) stated, the process "includes first an epidemiologic analysis of the particular situation, an establishment of causes, the development of specific preventive measures directed toward those causes, and finally a periodic evaluation of accomplishment from the program instituted" (p. 504). In simpler terms, in order to prevent an occurrence, it must first be understood and once understood, a plan can be created to change it.

From a broad perspective, injury is caused by a combination of three forces: the host (the worker), the agent (the work, tool, load, etc.), and the environment (Gordon, 1949). Each variable, though intimately connected and influenced by the other, can be individually addressed to lessen the likelihood and severity of injury. The variables to this model of injury causation are similar to a three legged stool analogy; if one leg of the stool is shortened or removed, the stool will be out of balance and fall. An occupational and environmental health nurse's focus would be to remove or affect the legs (cause) of the problem and thereby reduce or eradicate causal factors resulting in reduced injury rates. Many studies have documented the physical (ergonomics), chemical (hazardous materials) and biological (bloodborne pathogens) agents that influence injuries, as well as identifying various environmental factors that both positively and negatively effect injury outcomes. This paper will examine both the host and the agent and the effect stretching has on musculoskeletal injury in the workplace.

Understanding the complexities of injury to the musculoskeletal system and more specifically, skeletal muscles and associated tendons, will increase the knowledge of how to decrease and prevent injuries. Muscles come in various shapes and sizes, adapted by the body to perform different actions, whether through contraction or relaxation. The work that the muscles perform on the microscopic level is similarly influenced by the factors described above such as repetition, load, vibration, or temperature extremes. Work is defined as the transfer of energy (Work, n. d.). When a human body performs work, the musculoskeletal system provides the framework to physically move through the contraction and relaxation of muscles and the structure of the skeletal system. All aspects of work require the use and variable effort of the musculoskeletal system, from typing on a keyboard to lifting heavy loads. Muscle injury is expressed most often through inflammation, delayed onset muscle soreness (DOMS), and decreased range of motion.

Personal medical factors as well as the physical and psychological demands of the workplace can place the workforce at risk of injury to the musculoskeletal system. MSDs are defined by the United States Department of Labor (US DOL) as an injury or disorder of the muscles, nerves, tendons, joints, cartilage or spinal discs (US BLS, 2007) and typically do not include disorders caused by slips, trips, falls, or motor vehicle accidents. As the definition states, MSDs can be a broad category that includes any bodily injury to the soft tissue. The defining health outcome resulting from an MSD is the occurrence of pain or discomfort. MSD injuries in the workplace can be acute or chronic in nature and typically relate to upper extremity and back conditions. In the occupational setting, MSDs are one of the leading causes of occupational injury and disability in the industrially developed and developing countries (Choobineh, Tabatabaei, Mokhtarzadeh, & Salehi, 2007).

One of the preventive measures utilized to reduce workplace-initiated MSDs is the implementation of a workplace stretch program. Stretch programs typically are tailored to specific job tasks and focus on increasing flexibility and decreasing injuries. Multiple studies have been completed that support utilizing stretch programs as a way to limit occupational injury and severity (Emery, Rose, McAllister, & Meeuwisse, 2007; Woods, Bishop & Jones, 2007), but some evidence suggests that stretch programs have minimal effect on these outcomes (Herbert & Gabriel, 2002; Pope, Herbert, Kirwan & Graham, 2000; Shrier, 1999; Thacker, Gilchrist, Stroup, & Kimsey Jr., 2004). This paper will review the current data on musculoskeletal injuries and preventive programs to address what measures industry can take to decrease the impact of MSDs.

CHAPTER II

LITERATURE REVIEW

Definitions

Muscle

"Skeletal muscle is an elongated, contractile tissue that generates force and shortens when activated to contract by stimuli" (NAS, 2001, p. 200). Skeletal or striated muscle is comprised of myofilament subunits, actin and myosin. These subunits, or groupings of actin and myosin myofibrils are termed sarcomeres, which are arranged in series to form a chain that comprises a muscle fiber. There are three major types of myofibers: type 1, which are slow myofibers that are resistant to fatigue; type 2A, which are fast myofibers that are resistant to fatigue at an intermediate level, and type 2B, which are also fast myofibers but are not resistant to fatigue (Huard, Li, & Fu, 2002). The average person has a mixture of slow-twitch and fast-twitch motor units in every skeletal muscle (NAS, 2001). The myofiber is surrounded by a cytoplasmic substrate called sarcoplasm which contains a cellular matrix and organelles, including the Golgi apparatus, mitochondria, sarcoplasmic reticulum, lipids, glycogen, and myoglobin (Huard et al., 2002). These various structures and organelles are necessary to produce movement through contraction and relaxation of the myofiber and to support the regeneration process that occurs after injury (Huard et al., 2002).

Single muscle fibers are grouped together to form bundles, called fascicles, and these bundles are grouped together and in series to form muscle. Muscle is connected to attachment points on the bone, called processes, by tendons which forms the musculotendinous unit. Skeletal muscle represents the largest tissue mass in the body, constituting up to 45% of the total body weight (Huard et al., 2002).

Sarcomere Components

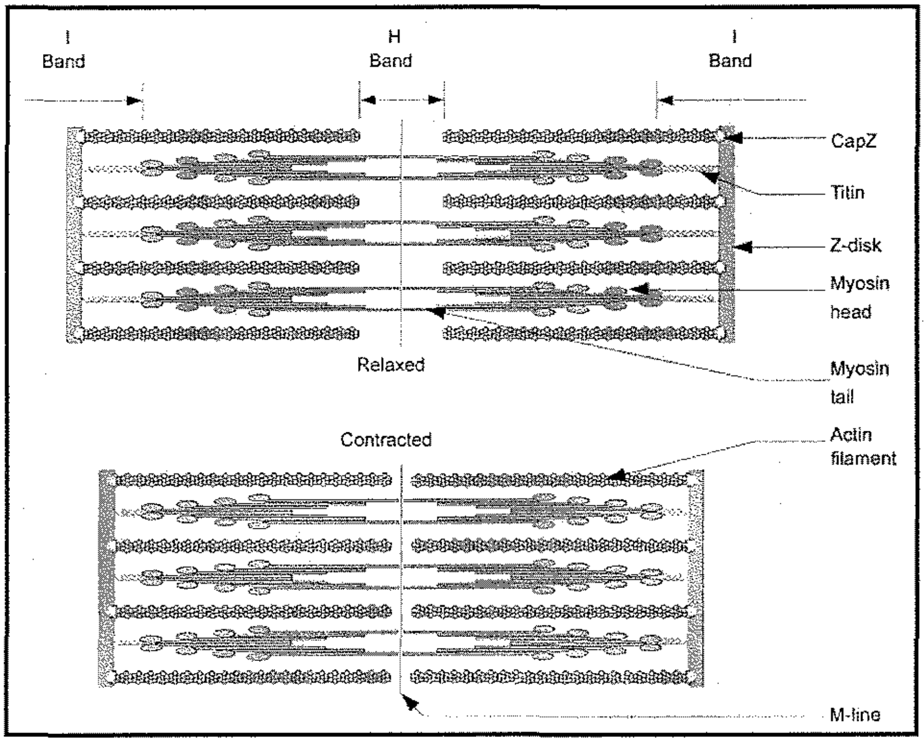
Skeletal muscle has a highly structured architecture (NAS, 2001) and the basic contractile unit of striated muscle is the sarcomere. A single muscle cell from the biscep can contain approximately 100,000 sarcomeres. These hundreds of thousands of sarcomere units acting together create a synchronized muscle contraction. The sarcomere unit is made up of the protein filaments actin and myosin and is defined by its borders at the Z-disk (Figure 2.1). Actin is described as a thin filament and is within the sarcomere in a parallel arrangement. Myosin is a thick filament, also in parallel and in between the actin myofibers.

Myosin is attached to the sarcomere superstructure by the protein titin. Titin is a very large, highly elasticated protein (also known as connectin), and it spans from the Z-disk to the M-line. Titin provides passive force to the sarcomere structure when stretched and also plays an important role as a molecular scaffold for myofilament formation during tissue re-generation (Fukuda, Granzier, Ishiwata, & Kurihara, 2008). Actin filaments and titin molecules are cross-linked in the Z-disc.

Actin filaments are major components of the I-band and extend into the A-band, which is between the I-bands. Myosin filaments extend throughout the A-band and are thought to overlap in the M-band. During muscle contraction, the I-bands and the H-bands shorten due to the interaction of the myofilaments.

FIGURE 2.1

SLIDING FILAMENT MODEL OF MUSCLE CONTRACTION



Source: Richfield, 2007.

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Muscle Force Generation

Skeletal muscle generates force during contraction for movement of the limbs (Cutlip, Baker, Hollander, & Ensey, 2008). Force generation as a concept was first introduced by Huxley in 1954, where he termed it the sliding filament theory. The theory describes the interaction between the myosin and actin filaments within the sarcomere and serves as the basis for describing the generation of contractile force. The sliding filament model states that the lengths of the filaments remain essentially constant but that the overlapping arrays of filaments slide past each other (Huxley, 1969). The actin filaments provide the structure around which the myosin acts as the motor. Each myosin filament is anchored at its head-end by titin, which provides a tether to the outer portion of the sarcomere at the Z-disk. The myosin tail section bridges across the H-Band to attach on the far Z-disk. Myosin has surface heads that act as molecular force generators and are activated via a biochemical process and attaches to the actin filament. When the myosin head attaches to the actin filaments, they form a cross-bridge. The actin filaments are sandwiched between and around the myosin filaments and provide attachment sites for the myosin heads to grip and pull the structure together. Myosin functions as the motor of the sarcomere unit, whereas actin supplies the support structure, similar to the relationship between muscle and bone in the musculoskeletal system.

When the myosin head becomes activated, it then binds in a "swing-roll-lock" mechanism described by Ferenczi et al. (2005). The model suggests that the myosin heads exhibit a two-step force generation that begins when the myosin head becomes activated and swings toward the actin binding site. The head then rolls onto the site and locks into place, compressing the sarcomere structure by moving both myosin filament head-ends toward their respective Z-disk. The myosin head rolls onto the actin "before locking into a specific orientation, which fixes the orientation of the lever arm relative to the actin filament" (Smith, Geeves, Sleep, & Mijailovich, 2008, p. 1630). The myosin head acts like a magnet on the end of a string, dangling until a metallic object comes close enough, at which point it attaches and pulls the string taut. After the roll and lock of the myosin head, the second force generation is a lever arm tilt that slides to further interdigitate the myofilaments (Ferenczi et al., 2005).

From a biochemical perspective the main components in the sarcoplasm that play a role in contraction are calcium (Ca^{2+}), adenosine triphosphate (ATP), and myoglobin. Ca^{2+} is supplied by the sarcoplasmic reticulum and when added to the myofilaments, causes contraction (Mazzarello, Calligaro, Vannini, & Muscatello, 2003). ATP hydrolysis is the source of energy for muscle contraction and is coupled to both steps of the force generation process (Ferenczi et al., 2005). Addition of ATP to the myosin crossbridge releases the lock and the filament is free to slide further up the actin protein (Steffen & Sleep, 2004) and is provided by the cellular mitochondria. Myoglobin is a mobile carrier of oxygen, which supplies the mitochondrial demand for oxygen during ATP production and to a larger extent, muscle contraction (Wittenberg & Wittenberg, 2003).

Actin and myosin form a lattice framework with a variable orientation depending upon the type of muscle and location on the body; for instance vertebrate striated muscle forms a two-dimensional lattice and in fast muscles, the filament lattice is triangular with three myosin filaments around each actin filament (Smith et al., 2008). The muscle shortens through the action of the myosin head on the actin filament and during contraction, "the sarcomeres are shortened to about 70% of their uncontracted, resting length" (Lodish et al., 2000, para. 6).

Muscle tissue is extremely plastic, acting to both cushion the body from external forces and to enhance the force production capacity of the muscles while generating movement (Wilson, Murphy & Pryor, 1994). Muscle plays a role in both creating movement and reducing the actions of movement. It is also known to be extremely elastic, which means that it will regain its original shape when the load is removed (NAS, 2001). Skeletal muscle can produce loads on other tissues such as tendons, joints, and nerves, and can also generate heat for the body (Cutlip et al., 2008).

Muscle Movement

As previously discussed, muscles provide the motor to move the body, while the skeletal system provides the structure. Muscles are arranged throughout the body to perform specific tasks, sometimes in isolation, but many times in series and paired or grouped with other muscles. In any movement of a joint controlled by an agonist/ antagonist muscle pair, one will be shortening and the other will be lengthening (Allen, 2001). Agonists refer to muscles that cause the movement to occur through contraction. Antagonists act in opposition to the movement generated by the agonists and are responsible for returning the limb to its initial position (Huard et al., 2002). Additionally, several muscles may be involved in a specific movement through immobilizing a joint or acting as force couple to prevent undesirable movement (Huard et al., 2002) such as the hamstring muscle limiting knee extension when the hip is flexed (Garrett, 1990). The three primary muscle actions are isometric, concentric, and eccentric.

In isometric contraction, the force generated by the muscle is equal to the resisting load and, therefore, the length of the muscle does not change (Huard et al., 2002). The isometric contraction produces tension while the muscle remains essentially the same length (Fridén & Lieber, 2001), such as when a person holds a bag of groceries in a fixed position, the bicep exhibits isometric contraction or tension. During an isometric contraction the contractile component contracts as the musculotendinous unit extends (Wilson et al., 1994).

In concentric contraction, the force generated by the muscle is larger than the resisting load and causes the muscle to shorten (Huard et al., 2002), similar to the action of the bicep during a dumbbell curl. During concentric action the muscle produces tension while shortening.

Eccentric contraction, defined by Patel, Das, Fridén, Lutz, & Lieber (2004), is forced lengthening of activated skeletal muscle. In eccentric contraction, the resisting load is larger than the force generated by the skeletal muscle and causes the muscle to lengthen (Huard et al., 2002). Morgan and Proske (2004) stated, "in common terms, the muscle is being used as a brake, not a motor" (p. 541). The muscle acts as a shock absorber to slow the action of the movement rather than contracting to cause the movement. Morgan and Proske

(2004) stated that "energetically, the muscle is absorbing work, not performing it" (p. 541). Conceptually, the myofilaments are generating force and in the process of contracting, but are actually lengthening, which absorbs the energy from the activity. Eccentric contraction is an important function of muscle, occurring during activities ranging from lowering a load to walking down hill.

Cause of Muscle Injury

"Damage to skeletal muscle invariably occurs as a result of external forces that exceed the tolerance limits of the muscle's passive (connective tissue) and active contractile structures" (NAS, 2001, p. 200). Studies have shown that muscle injury can be caused by unaccustomed exercise, particularly eccentric exercise (Clarkson & Hubal, 2002). Fridén and Lieber (2001) stated that eccentric exercise has been established as the most damaging form of exercise and the NAS reports that eccentric contraction "offers the greatest risk for structural damage to fibers" (p. 206). Due to the balance of all the forces at work, the tension generated during eccentric action is shown to be higher than that of the other muscle actions (Fridén & Lieber, 2001).

However, there is no consensus on the exact mechanical failure that causes the injury. The NAS (2001) stated that the muscle mass of each person has its own endurance limits, creating variations in each person's injury threshold. Lieber and Fridén (2002) hypothesized that, mechanically, the weak link of the sarcomere seemed to be the Z-disk, where both the actin and myosin filaments are tethered to the sarcomere structure. McHugh, Connolly, Eston, and Gleim (1999) described muscle injury as a mechanical failure similar to material fatigue, which is caused by cumulative tensile stress as opposed to a failure caused by the application of a single stress that exceeds the material's ultimate tensile strength. This statement shows the hazardous effects of cumulative trauma on the musculoskeletal system over time, as opposed to a single, acute event.

One of the theories of stretch-induced muscle damage is described by the "popping sarcomere hypothesis", which results from a non-uniform lengthening of sarcomeres when active muscle is stretched beyond its inherent optimum length (Morgan & Proske, 2004). Optimum length is defined as the point at which the myosin and actin filaments no longer interdigitate and is fixed with each sarcomere. It has been demonstrated that lengthening a muscle beyond 140% of its optimum length places an unaccustomed mechanical strain on the muscle (Clarkson & Hubal, 2002). Any contraction of the muscle outside of its optimal length range creates a greater risk of structural damage, in addition to reducing force generation (NAS, 2001). When the sarcomeres are stretched beyond their optimum length, the weakest sarcomere(s) will stretch more rapidly than the others in the series, until the crossbridges are forcibly detached and the myofilaments no longer overlap. Studies have shown that while some of the sarcomeres recover from this detachment, others remain "popped" (Proske & Morgan, 2001).

Because the weakest sarcomeres are not at the same point along each myofibril, this non-uniform lengthening leads to shearing of myofibrils, exposing membranes, and deformation of the muscle unit. Patel et al. (2004) provided support for this theory, which showed that mechanical injury to muscle is directly related to the sarcomere strain imposed on the sarcomere lattice. Clarkson and Hubal (2002) theorized that the sarcomere "pops" when the muscle tension is sudden or of high force. Morgan and Proske (2004) proposed that as the muscle is lengthened, weak sarcomeres are stretched to a length until rising passive tension of the overall microstructure compensates for falling active tension in the myofilament overlap. Currently, there is no unified theory that describes how muscles become injured.

Effect of Injury on Muscle

Injury to the muscle causes a disturbance of the muscle's homeostasis, which can involve loss of active force generation, inflammation, necrosis, hemorrhage, and connective tissue tearing (NAS, 2001). Additional insult to the tissue can occur after the mechanical strain injury, and acute inflammation in tissue is an early post-injury response (MacIntyre, Sorichter, Mair, Berg, & McKenzie, 2001). Butterfield and Herzog (2005) theorized that injured sarcomeres exhibit evidence of subcellular disruption, dependant on the magnitude of fiber strain. Huard et al. (2002) reported that after injury, muscle undergoes a distinct set of healing phases, consisting of degeneration, inflammation, regeneration, and fibrosis. It is generally accepted that delayed onset muscle soreness (DOMS) is a function of the healing phases.

Morgan and Proske (2004) stated that the muscle will get worse before it gets better as the local inflammatory response will further degrade the muscle tissue during the ensuing hours after the initial injury. It seems that the initial impact of the exercise, possibly due to the popping sarcomere, creates an insult to fibers which results in damage to the ultrastruture, extracellular matrix, and possibly to capillaries (Clarkson & Hubal, 2002). The degradation is due to neutrophils and macrophages being released during the acute inflammation causing further damage to the muscle tissue due to their hydrolytic action (MacIntyre et al., 2001). This "remodeling" takes from days to weeks to complete, and during the period, the muscle is working in an inefficient manner (NAS, 2001). Ultimately, inflammation is an important biological process as it clears debris from the injured area in preparation for regeneration to occur (Clarkson & Hubal, 2002). The formation of scar tissue, or fibrosis, begins between the second and third weeks post-injury. Fibrosis appears to be the end product of the muscle repair process, and until the scar tissue is removed, complete regeneration of the muscle tissue cannot occur (Huard et al., 2002).

An important indicator of damage after a period of eccentric exercise is the drop in active tension within the muscle (Proske & Morgan, 2001). Active tension is defined as prolonged strength loss after eccentric exercise, and is considered to be one of the most valid and reliable indirect measures of muscle damage in humans (Clarkson & Hubal, 2002).

Nonsteroidal anti-inflammatory drugs (NSAIDS), used as a standard treatment option after soft tissue injuries, have demonstrated remarkable recovery compared with nontreated groups initially, but then showed a significant decline in muscle torque generation after 28 days (Lieber and Fridén, 2002). Use of nonsteroidal anti-inflammatories in study groups showed a short-term benefit by long-term detriment in terms of torque and force generation.

Muscle Adaptation

Repeated Bout Effect

Repeated bout effect refers to the lessening of soft tissue symptoms, such as muscle pain, soreness or stiffness, after the initiation of new activity to muscle groups. The first "bout" of eccentric exercise can frequently cause some level of muscle damage. Repeated bouts of similar exercises results in less damage and is referred to as the 'repeated bout effect' (McHugh et al., 1999). There is significantly less muscle soreness and recovery of strength is faster after the second bout of exercise, when compared with the first. The first bout in some way produces an adaptation so that the muscle is more resistant to subsequent exercise (Clarkson & Hubal, 2002). In response to an increased demand, skeletal muscle adapts via an increase in myofiber size and alteration in the composition of the metabolic and contractile proteins (Adams et al., 2004).

As with muscle injury, there is little consensus of the actual mechanism that causes the repeated bout effect. It is suspected that the weakest link in the muscle, or stress-susceptible fibers, develops over time as a natural phenomenon. These links are theorized to be removed and replaced after the injury with a stronger sarcomere, ultimately making the muscle more resistant to damage from similar activity. In this way, some amount of sarcomeres that the body creates is non-optimal and after exercise of the muscle is replaced with optimal sarcomeres. Other studies suggest that the repeated bout effect is due to altered motor unit recruitment, an increase in sarcomeres in series, a blunted inflammatory response, and reduction in stress-susceptible fibers (Clarkson & Hubal, 2002).

Compensatory Hypertrophic Response

The relationship that resistance exercise plays in "building" muscle is a form of muscle adaptation. It is a long held belief that in order to build muscle, it must first be "broken down" by stressing it through resistance exercise, termed the compensatory hypertrophic response. Hood, Irrcher, Ljubicic, and Joseph (2006) found that increased contractile activity resulted in an improved resistance to muscle discomfort and fatigue. The NAS (2001) reported that "it is well recognized that loading is required to maintain tissue integrity" and without loading, the tissues atrophy and impaired function will result (p. 184). Other studies have shown that increasing the load imposed on skeletal muscles "elicits adaptations that result in increased muscle size and changes in contractile characteristics" (Haddad & Adams, 2002, p. 394). A person need not experience the "negative" symptoms in order to obtain results. Folland, Irish, Roberts, Tarr, and Jones (2002) studied high fatigue versus low fatigue resistance training and found that muscle building can be effective without severe discomfort and acute physical effort. Additionally, Haddad and Adams (2002) stated that "the principles of resistance training implicitly assume that multiple bouts of exercise, imposed within an appropriate time frame, must stimulate and reinforce cellular and molecular processes that lead to a compensatory hypertrophy response" (p. 395). The compensatory hypertrophic response occurs when "the structural and functional properties of skeletal muscle are generally matched to the current level of demand placed on individual muscles" (Adams et al., 2004, p. 1613). Miyazaki and Esser (2008) reported that the muscular response to increased mechanical tension is due, in part, to an increased rate of protein synthesis related to release of local growth factors.

It is apparent that muscle is a highly adaptable tissue that responds to increased stress loads. However, the lack of scientific consensus on key actions of the muscle hampers comprehension of how stretch affects the muscle, how injuries occur, and the best way(s) to protect the muscle tissue from damage. Is the repeated bout effect a mini-injury or is it a means for the muscle to "delete" non-optimal sarcomere strains from the overall myofiber? The "pain is good" theory for muscle building has been considered a given for years, but what differentiates a "good" popping sarcomere that ultimately builds muscle from a "bad" popping sarcomere that ends in muscle injury? Herbert and Gabriel (2002) disagree that discomfort is a sign of muscle building, but believe it is a key precursor to muscle injury.

Stretching

Definition and Reasoning

Stretching elongates the muscle fiber to increase flexibility, improve performance, and ultimately decrease the incidence of delayed onset muscle soreness (DOMS) and injuries. As MacAuley and Best (2002) stated, "[s]tretching is long established as one of the fundamental principles in athletic care" (p. 451) and is commonly performed by athletes as part of their warm-up routine (Samuel, Holcomb, Guadagnoli, Rubley, & Wallmann, 2008). Stretching can be dynamic, static, passive, or active.

Dynamic stretching involves moving parts of the body and gradually increasing the reach, speed of movement, or both. It consists of controlled movements that take the muscle groups to the limits of range of motion. Dynamic stretches can include both proprioceptive neuromuscular facilitation (PNF) and ballistic stretch. PNF stretch has many techniques, but is most often characterized by first contracting the muscle up to 20 seconds, then relaxing, followed by a stretch. Ballistic stretch consists of bouncing or swinging the area being stretched, but "has been shown to cause injury and should be avoided" (Hess & Hecker, 2003, p. 336).

Static stretching involves slowly elongating a muscle group and holding the position for a certain amount of time (President's Council on Physical Fitness and Sports, 2000). This form of stretch is most often associated with pre-exercise activity. As Hess and Hecker (2003) stated, it is simple to perform and very effective.

Passive stretching is a technique where the subject is relaxed and there is no contribution from the subject to the range of motion. In a relaxed state, the passive muscle tension provides the resistance to the stretch. The stretch is created by an outside force, usually by manual or mechanical means.

Active stretching is a technique where a position is assumed and held without assistance other than using the strength of the agonist muscles. Active stretching increases active flexibility and strengthens the agonistic muscles (Winters et al., 2004).

Effects of Stretching on Muscle Tissue

During stretching, on the microscopic level, the muscle fibers are forcibly elongated. The sarcomere units of the target muscle stretch to accommodate the lengthening fiber and cause the areas of overlap in the sarcomeres to decrease. However, the muscle will contract in response to stretching within the muscle, this resistance is termed the "stretch reflex".

The extent to which the muscle stretches is dependant on the number of sarcomeres in series along the muscle fibers, and some portion of the stretch can be attributed to the tendon to which the muscle is attached. For example, Muramatsu et al. (2001) have shown that the Achilles tendon is stretched to 5% of its initial length during plantar flexion.

Many studies have been conducted in the past 15 years on the effect of stretching on muscle; however there were multiple studies published in the previous 12 months indicating a continued interest in the area of muscle injury, injury prevention, and stretching. Researchers have studied the flexibility and performance changes that occur with stretching (Table 2.1) and the effects of stretch on injuries (Table 2.2).

Stretch Studies Relating to Flexibility and Performance

The studies relating the effects of static stretching on flexibility and performance had mixed results. Two studies that reviewed static stretching described positive outcomes such as enhanced flexibility, although the effects only lasted 3 minutes (DePino, Webright, & Arnold, 2000) and increased

TABLE 2.1

SUMMARY OF STRETCH STUDIES: FLEXIBILITY & PERFORMANCE

Year / Author(s)	Sample Characteristics	Subject	Conclusions
2000 DePino et al.	n=30, male military cadets	Effects of static stretching on flexibility	1. 4 consecutive 30 sec stretches enhanced hamstring flexibility * The effect only lasted 3 min
2004 Guissard et al.	n=12 women & men aged 21-35	Effect of static stretch on plantar-flexor muscles	1. Increased flexibility 2. Stretch did not impair the force/ speed capacities of muscle
2008 Bazett-Jones et al.	n=21, division III women's track and field athletes	Effects of chronic static stretch on spring and vertical jump performance	1. 6 weeks of static hamstring stretching did not improve knee ROM or sprint/ vertical jump performances 2. Authors suggest static stretch be restricted to post activity 3. Chronic static stretching does not have a positive or negative impact on athletic performance
2008 LaRoche et al.	n=29, males age 18-60	Effects of chronic stretching on muscle force, power & optimal length	1. 4 weeks of stretching had little effect on muscle strength, power, work or length-tension relationship 2. Authors suggest that routine stretching be completed following exercise & passive stretching of the muscles be avoided prior to activities requiring high muscle force/ power
2008 Torres et al.	n=11, track and field athletes	Effects of stretch on UE muscular performance	1. No decrease in UE performance after static stretching 2. No increase in UE performance after dynamic stretching
2004 Shrier	Literature review	Effects of stretch on force & jump height	1. Acute bouts of stretching immediately prior to exercise negatively impacts force and jump height 2. Regular, consistent stretch activities appears to improve performance and decrease injury, as long as the stretch is not immediately before exercise
2004 Power et al.	n=12, males	Static stretching effects on force & jump performance	Findings suggest that static stretch may impair isometric force production for up to 120 min
2004 Behm et al.	n=16	Effect of acute static stretching on force, balance, reaction time & movement time	An acute bout of stretching impaired the warm-up effect achieved under control conditions with balance and reaction/movement times
2008 Robbins et al.	n=20, 10 collegiate athletes & 10 recreational athletes	Effects of acute static stretching on vertical jump performance	1. Acute stretch significantly decreases vertical jump height 2. Static stretching decreased explosive power production and vertical jump performance 3. Lower volumes of acute static stretching can be performed without significantly compromising maximal force production.
2007 Fletcher et al.	n=18, experienced sprinters	Acute effects of static & dynamic stretch on sprint performance	1. Passive static stretching decreases sprint performance when compared to a solely dynamic stretch approach 2. Authors suggest that active, dynamic stretches & mimicking specific components of the sprint cycle should be performed rather than static stretch
2008 Cè et al.	n=15, relatively fit males	Effects of stretching on maximal anaerobic power	1. Stretching inhibited the effect of active warm up (AWU) 2. AWU increased vertical jump performance compared to passive warm up (PWU) 3. Passive stretching seemed not to negatively influence vertical jump performance 4. AWU more appropriate than PWU to improve muscle performance prior to brief & powerful effort

TABLE 2.2

SUMMARY OF STRETCH STUDIES ON INJURIES

Year / Author(s)	Sample Characteristics	Subject	Conclusions
2007 Emery et al.	n=920 high school basketball players	Prevention strategy to reduce the incidence of injury in high school basketball	1. A basketball-specific balance training program was effective in reducing acute onset injuries 2. Trend in reduction of all, lower-extremety and ankle sprain injury
2007 Woods et al.	Literature Review	Review of stretching protocols & results	Warmup and stretch does provide positive outcome to injury results
2006 Fradkin et al.	Literature review of 5 studies	Warm-up effects of sports injury	Insufficient evidence, however the weight of evidence is in favor of a decreasd risk of injury.
2004 Thacker et al.	Literature Review	Stretching effects on injury risk in sport	Not sufficient evidence to endorse or discontinue routine stretching before or after exercise
2000 Pope et al.	n=1538 male army recruits	Preexcercise stretching effects on lower-limb injury prevention	Muscle stretching protocol did not produce clinically meaningful reductions in risk of exercise-related injury
2002 Herbert et al.	Systematic review of 5 studies	Pre and post exercise stretching effects on muscle soreness and risk of injury	1. Stretching before or after exercising does not confer protection from muscle soreness 2. Stretching before exercising does not seem to confer a practically useful reduction in the risk of injury
1999 Shrier	Literature Review	Stretching effects on injury	Stretching before exercise does not reduce the risk of injury
2004 Witvrouw et al.	Literature Review	Stretching and injury prevention	Conflicting data, although concludes: 1. Activity involving "explosive" muscle use (high jump, sprint) benefit from stretching as prophylactic measure 2. Activities involving low impact movements may have no beneficial effect from stretching

flexibility that did not affect muscle speed and force capacities (Guissard & Duchateau, 2004). Other studies revealed neutral findings from static stretching: Bazett-Jones et al. (2008) reported that 6 weeks of stretching did not improve range of motion (ROM), or sprint and vertical jump performance; LaRoche et al. (2008) suggested that 4 weeks of stretching had little effect on muscle strength, power, work, or length-tension relationship; and Torres et al. (2008) found no increase or decrease in upper body performance after stretching.

However, multiple studies showed negative outcomes from stretching. Power, Behm, Cahill, Carroll, and Young (2004) found that static stretch impaired isometric force production for up to 120 minutes; another study showed that stretching impaired the warm-up effect in regard to balance and reaction/ movement times (Behm, Bambury, Cahill, & Power, 2004); Robbins and Scheuermann (2008) revealed that stretch "significantly decreases vertical jump height" (p. 784), and decreased explosive power production and vertical jump performance. The study also showed that acute static stretching could be performed without significantly compromising muscle force production. Two additional reports showed that static stretching had a negative effect on sprint performance (Fletcher & Anness, 2007; Shrier, 2004). Cé et al. (2008) studied the effects of stretching on maximal anaerobic power and reviewed stretching, active warm-up and passive warm-up strategies. They found that active warm-up was more beneficial than passive because it increased vertical jump performance. Interestingly, they also revealed that if performed sequentially, stretching inhibited the positive effects of the active warm-up.

Stretch Studies Relating to Muscle Injury

Studies relating stretching and warm-up activities to muscle injury had conflicting results, but were somewhat clearer. Two studies associated positive results from warming up and stretching related to injury outcomes. Emery, Rose, McAllister, and Meeuwisse (2007) implemented a prevention strategy among high school basketball players which was effective in reducing acute-onset injuries, specifically lower-extremity and ankle sprain injuries. Woods et al. (2007) concluded that warm-up and stretch provided positive outcomes to injury results.

Two studies showed mixed results. Fradkin, Gabbe, and Cameron (2006) concluded that there was insufficient evidence to show positive or negative results due to stretching before activity. However, the review stated that the weight of evidence was in favor of a decreased risk of injury from stretching. Thacker et al. (2004) researched the effects of stretching on injury risk in sport and concluded that there was insufficient evidence to endorse or discontinue routine stretching.

Pope et al. (2000) reviewed stretching effects on lower-limb injury prevention on Army recruits and did not find any statistically meaningful reductions in risk of exercise-related injury. One report provided a systematic review of pre- and post-exercise stretching effects on muscle soreness and risk of injury, and did not find any positive results (Herbert & Gabriel, 2002). They concluded that stretching before or after exercise did not have an effect on muscle soreness and did not reduce the risk of injury. Shrier (1999) also performed a literature review and stated that stretching before exercise does not reduce the risk of injury.

A literature review by Witvrouw et al. (2004) found conflicting data on stretching but revealed that if the activity involved "explosive" use of the muscle, then stretching was beneficial. Conversely, for low impact exercise, they stated that stretching may not be beneficial.

Flexibility

Stretching provides an increased level of flexibility and decreases active tension in the muscle. Increasing muscle flexibility decreases the active tension present over time through "re-setting" the stretch reflex; it relaxes and establishes a new baseline for muscle tension. The increased flexibility gives the muscle and attributed joint a greater range of motion. However, the lasting effects of the flexibility are limited (DePino et al., 2000).

Injury Prevention through Stretching

In addition to flexibility, studies have pointed to other positive effects attributed to stretching, such as preventing injury. Black et al. (2002) stated, "passive stretching is widely accepted in athletic circles as a means of injury prevention" (p. 137). Emery et al. (2007) examined the effect of a "sport-specific balance training program in reducing injury in adolescent basketball players" and were able to demonstrate a "protective effect" in their interventions through decreasing acute onset basketball injuries (p. 17). Other studies have mixed results, showing stretching has little to no effect on injury occurrence (Fradkin et al., 2006; Herbert et al., 2002; Pope et al., 2000; Shrier, 1999; Thacker et al., 2004).

Another well-established physiological effect of stretching is range of motion improvement (Power et al., 2004). Stretching relaxes the muscle fibers through increased blood flow and thermal energy, and decreases muscle stiffness to facilitate lengthening. Some studies posit that ROM gain is not due to muscle lengthening, but due to "increased laxity of joint passive stablilizers" such as ligaments (da Costa & Vieira, 2008, p. 326). Additionally, stretching is commonly utilized for the treatment of various muscle ailments and for acute relief of muscle cramps.

Stretching as a Precursor to Muscle Injury

Other studies paint a different picture on the effects of stretching on muscle. Herbert and Gabriel (2002) found that stretching before or after exercising has no effect on delayed onset muscle soreness, a key precursor to muscle injury. Bazett-Jones et al. (2008) reviewed the effects of six weeks of a static hamstring stretching protocol and found that it did not improve knee ROM or sprint and vertical jump performances in the athletes. They further stated that "it does not seem that chronic static stretching has a positive or negative impact on athletic performance" (p. 25). Pope et al. (2002) found "no significant effect of pre-exercise stretching on…soft tissue injury risk" (p. 271).

Thacker et al. (2004) reported that little evidence exists between increased flexibility and reduced incidence and injury. They found that stretching might not increase the pliability of the muscle, but may increase the person's ability to tolerate the discomfort of the muscle lengthening. Proske & Morgan (2001) found that stretching causes micro-damage to the underlying muscle structure and additionally produces an analgesic effect, which could ultimately mask any injuries that occur.

Muscle Performance Changes

LaRoche et al. (2008) showed that a stretch program had little effect on muscle strength and power and recommended only stretching post-exercise to maintain flexibility. They further speculated that the muscle is affected because the act of stretching saps the muscles' ability to store energy. Torres et al. (2008) agreed and recommended limiting static stretching before an event in which "optimal strength, power and speed are required" (p. 1284). Therefore, activities that utilize fast twitch muscle fibers benefit the least from stretch. Power et al. (2004) addressed duration of these negative effects from stretching and showed static stretching may impair muscle force production for up to 120 min. Rubini, Costa, and Gomes (2007) found that "there appears to be substantial evidence suggesting a decrease in strength following stretching" (p. 221). In addition to muscle force, Behm et al. (2004) found that moderate stretching can adversely affect performance tests of static balance, reaction time, and movement time.

Muscle Injury

The effects of being at the extremes of the stretching spectrum appear to have undesirable consequences, as some studies have found that hypo- and hyperflexibilility of the muscle are at increased risk of injury. Thacker et al. (2004) linked injuries to too much or too little flexibility, and "in some instances, increasing flexibility may actually increase the rate of injury" (p. 372). This reinforces the belief that persons who are in a poor state of physical health are most likely to suffer a physical injury such as an MSD, but including them in the same risk group as hyperflexible individuals need additional study.

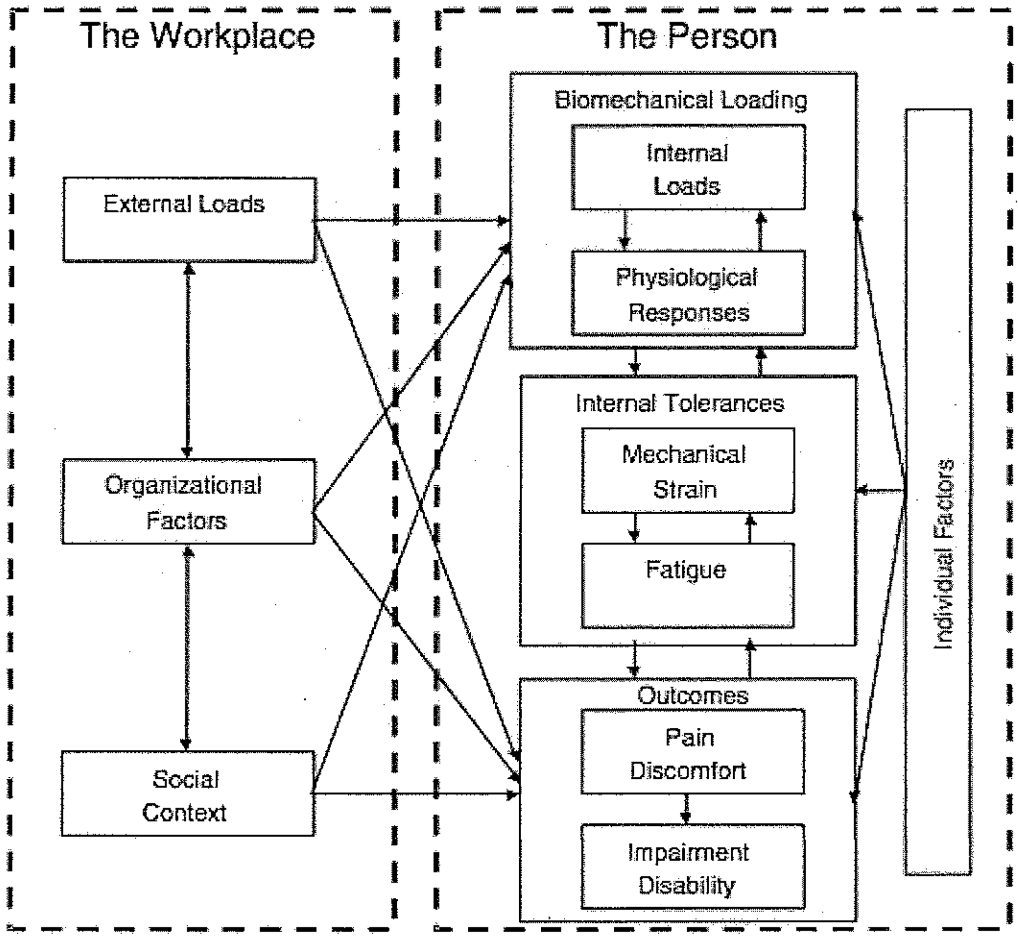
Musculoskeletal Disorders (MSDs)

Rogers (2003) defines musculoskeletal disorders as work-related conditions that generally affect the musculoskeletal system, which involve the nerves, tendons, muscles, and supporting structures of the body, and physical symptoms that result from repeated trauma or work strain. In the occupational setting, MSDs are one of the leading causes of occupational injury and disability in the industrially developed and developing countries (Choobineh et al., 2007) and over 20 million Americans per year sustain injuries severe enough to limit activity in the workplace (Sparling, Owen, Lambert, & Haskell, 2000). The MSD category is broad, but common occupational MSDs include strain, sprain, tendonitis, tenosynovitis, bursitis, myositis, arthritis, and repetitive strain injuries (see Appendix for definitions). Any injury occurring from an acute event such as slips, trips, falls, or motor vehicle accidents are not considered an MSD (US BLS, 2007).

The primary symptom of MSDs is pain. MSD injuries in the workplace can be acute or chronic in nature and typically relate to upper extremity and back conditions. The contributing factors are the work environment and the individual, and how both interact to influence the development of musculoskeletal disorders (Figure 2.2).

FIGURE 2.2

NIOSH Conceptual Model for the Development of MSDs



Source: National Academy of Sciences, 2001, p. 3.

MSDs can also be affected by factors such as age, gender, general fitness level / BMI, and cigarette smoking. Kenny, Yardley, Martineau, and Jay (2008) stated that "functional work ability declines with age beginning in the third decade and becoming much more pronounced in the sixth and seventh decades" (p. 621). Since physical demands can remain the same in the occupational setting over time, the aging worker is confronted with the reality of either increased physical output or decreased production. One study showed that high levels of physical stress over a prolonged period may lead to chronic musculoskeletal injuries (Kenny et al., 2008). Treaster and Burr (2004) found "that women do have significantly higher prevalence than men for many types of [upper extremity MSDs]" (p. 495).

Musculoskeletal injuries are caused by many different activities. Choobineh et al. (2007) studied workers in an Iranian rubber factory and reported that activities such as heavy load lifting, repetitive tasks, and awkward working postures contributed to MSDs. Grooten, Mulder, Josephson, Alfredsson, and Wiktorin (2007) stated that manual handling, working with hands above shoulder level, and working with vibrating tools significantly influenced outcomes in work-related MSD injuries. Other causes include underuse, overuse, forceful exertions, sustained pressure, and various environmental conditions.

MSDs can have a large impact on the workplace because they reduce work productivity, increase costs (workers' compensation costs, time away from work) and influence the overall workplace safety statistics. Symptom persistence has been linked as a risk factor for reduced productivity (Boström, Dellve, Thomée, & Hagberg, 2008).

Incidence

"MSDs have accounted for a significant proportion of work injuries and workers' compensation claims in Western industrialized nations since the late 1980s" (Barbe & Barr, 2006, p. 423) and in 2006, MSDs accounted for 30% of the total injuries and illnesses (The American Federation of Labor and Congress of Industrial Organizations [AFLCIO], n.d.). The US BLS (2007) data reported that of the more than 1,233,791 total MSD cases in 2006, 357,160 cases (about 29%) involved days away from work. The number of MSD cases in 2005 was slightly higher at 1,264,260. The overall incidence rate for all MSD cases was 39 per 10,000 workers in 2006 (US BLS, 2007) and the median time off work was nine days. MSDs continue to create a considerable source of worker pain and discomfort, both physically and mentally, as well as potential long-term disability and high economic toll (Barr & Barbe, 2002).

MSDs have been on the decrease over the past ten years, both in total number, decreasing more then 500,000 cases from 2001 to 2006 (US BLS, 2007), and decreasing in percentage of total injuries, 34% in 2002 to 29% in 2007 (Table 2.3). Whether attributed to increased awareness by workers and employers, OSHA's proposed ergonomic standard, or to more comprehensive safety programs in the workplace, MSDs have decreased steadily over time. From 2002-2007, the median time off work was relatively consistent at 8-10 days per case,

TABLE 2.3

MUSCULOSKELETAL DISORDERS FROM 2002 TO 2007

Musculoskeletal disorders (MSDs), 2002-07						
	2002*	2003	2004	2005	2006	2007
Total number of MSDs	1,598,204	1,440,516	1,362,336	1,264,260	1,233,791	1,122,750
MSDs involving days away from work	487,900	435,180	402,700	375,540	357,160	333,760
Percent of total injuries with days away from work	34%	33%	32%	30%	30%	29%
Median days away from work	9	10	10	9	9	9

Source: United States Bureau of Labor Statistics, 2008.

*Note: Beginning with the 2003 reference year, the 2000 Standard Occupational Classification (SOC) Manual is now used to classify occupation. Prior to 2003, the survey used the Bureau of Census occupational coding system. For that reason, US BLS advises against making comparisons between 2003 occupation categories and results from previous years.

which indicates that even though the total number of MSD cases are decreasing, the severity of the injury remains the same (US BLS, 2007).

According to US BLS (2007), the trunk of the body, including the shoulder and back, was most affected by work incidents. A recent report issued from the National Occupational Research Agenda (NORA) stated that "the low back and the upper extremities are the parts of the body most subject to risk associated with work" (Marras, Cutlip, Burt, & Waters, 2008, p.16). Reviewing the 2007 US BLS (2008) data on MSDs, the top three causes by nature of injury or illness were sprains, strains, tears (74%), back pain (6.9%), and soreness or pain excluding the back (6.7%). Carpal tunnel was the fifth largest nature of injury with 3.5% of the distribution.

Risk Factors

Multiple risk factors are associated with the cause or exacerbation of workplace MSDs, including physical, biomechanical, individual predisposition, and psychosocial conditions (Barbe & Barr, 2006) and any combination of factors greatly increases the risks. Grooten et al. (2007) stated that simultaneous exposure to at least two of the risk factors was associated with increased or prolonged symptoms. Physical and biomechanical stressors include repetitive actions such as gripping, twisting, and reaching, use of excessive force, presence of awkward postures or fixed postures for long periods, effects from vibrating machinery and hand tools, and cold temperatures. Individual predisposition can include morphology of the body, such as carpal canal size, and disease states that can directly or indirectly affect the musculoskeletal system. Psychosocial risk factors in the workplace can be influenced by "job satisfaction, monotonous work, social support at work, high work demands, job stress, and emotional effort at work" (NAS, 2001, p. 287). The extent to which these factors actually affect MSD outcomes is not currently understood.

Common solutions to counteract associated risk factors include frequent changes of position, neutral postures of head, upper body, arms and legs, avoiding positions that require a joint to be used for extended periods of time at the limit of its range of motion, and providing workstations that fit the worker (Alberta Human Resources and Employment, 2000).

Risk Assessment

Risk assessments analyze work environments and tasks to determine injury exposure and root cause. The targeted assessment will determine musculoskeletal hazards, if any, within a job/task, which area/part of the worker's body is at risk, the root cause of these hazards, and if the risks are considered hazardous and require control measures. A basic risk assessment questionnaire can be administered to the workers, with questions that inquire about their experiences while performing certain jobs or tasks, such as:

1. Where in your body are you sore/tired at the end of a hard day?
2. What part(s) of the job/task causes you to feel sore/tired?
3. What changes could be implemented to reduce this soreness/fatigue?
4. How long have you had these symptoms? Have there been any recent changes in job tasks or procedures? (Safe Work Manitoba, 2007)

After identifying a hazard, an ergonomic analysis can be conducted at the worksite to review the mechanics of the task and how the individual or group interact with the work environment. Changing the work environment to reduce the physical hazards of the job by raising work to waist height, reducing lifting loads, or redesigning work areas to accommodate the group can be implemented to decrease MSD occurrence.

Diagnosis

MSDs are typically diagnosed based on the symptoms and the results of a physical examination (Diagnosis, n.d.). Medical providers utilize a differential diagnosis, which examines the underlying causal factors and comparisons are drawn to known pathologies (Moore, 2001). Cone and LaDou (2004) break the initial clinical approach into a quick survey followed by a detailed questioning based on an initial suspicion.

The survey obtains a general outline of the problem based on the worker's complaints. The detailed questioning involves questionnaires, which review work history and hazard exposure, review of the questionnaire by the physician, and symptom review. Symptom review includes discussing onset and duration of symptoms, reviewing actions that make the discomfort subside/increase and subjective symptom description (for example: discomfort, pain, tingling, burning). As Cone and LaDou (2004) stated, "the most important tool for the diagnosis of occupational illness is the occupational history" (p. 7). The physical examination identifies objective data based on the medical providers' assessment of the muscle group and associated joint movement through passive and active range of motion.

Diagnostic tests are utilized for some issues; for example, those involving the nerves (such as Carpal Tunnel Syndrome) require the use of nerve conduction tests to positively identify the condition.

Treatment

Treatment of MSD injuries are based on the diagnosis, but generally consist of rest, ice, elevation, nonsteroidal anti-inflammatory drugs (NSAIDS) and after a certain period, exercise. According to Letz, Christian, and Tierman (2004), "[rest] has dramatic analgesic effects for most musculoskeletal conditions and often is the only treatment necessary (p. 26). Ice is a therapeutic application utilized to reduce inflammation, muscle spasm, and discomfort through local heat removal (Nadler, Weingand, & Kruse, 2004). It is typically prescribed for use intermittently during the acute phase of the injury to reduce swelling. Elevation of the affected limb assists with reducing inflammation through effects of gravity. NSAIDS provide both analgesic and anti-inflammatory benefits, depending on patient tolerance and compliance to recommended dosage and frequency (American College of Rheumatology, 2008). After the acute phase of the injury, exercise can be utilized to increase mobility, range of motion (ROM), strength, and cardiovascular fitness (Letz et al., 2004). Some MSDs require surgical intervention, whether to release pressure on the soft tissues or repair torn tissues. Surgical intervention is a last resort and is considered an option when acute treatments are ineffective or due to the initial severity of the injury.

During the acute phase of the injury, the medical provider may prescribe days away from work. Health care providers can play a key role in encouraging a timely and safe return to work for injured workers (Williams & Westmorland, 2002). When deciding whether an absence from work is warranted, the medical provider often utilizes the "Grocery Store Test", where they ponder the question, "if this patient owned a 'mom and pop' corner grocery store and had no one to cover for her or him while out of work, would this patient be able to find a way to get to work and be safe there?" (Letz et al., 2004, pp. 25-26) If the patient is able to return to work, then the medical provider can restrict certain tasks or movements while at work. The workplace must evaluate the restrictions to determine accommodation.

Interventions

MSDs comprise a complicated injury group due to the multi-factorial relationship of the work environment(s) and worker population. Standard exposure control theory mandates that the Occupational and Environmental Health Nurse (OEHN), along with other members of an interdisciplinary team, plan and implement engineering solutions, administrative practices, training, personal protective equipment, and medical management for preventing and lessening the impact of MSDs.

Morken, Magerøy, & Moen (2007) showed that fewer MSDs were associated with those that had a physically active lifestyle both at work and home. Newton, Morgan, Sacco, Chapman, and Nosaka (2008) demonstrated that resistance-trained men were less susceptible to muscle damage induced by exercise than untrained subjects. If prevention were a simple matter of conditioning, then the optimal solution would be to have an employer sponsored fitness center with mandatory use by all workers through a set exercise regimen. In fact, literature reviews have shown that worksite physical activity programs can reduce the risk of musculoskeletal disorders (Proper et al., 2003).

Effect on Work

As previously mentioned, the median number of days off work for MSD cases in 2006 was 9, and MSDs with days away from work totaled 357,160 (US BLS, 2007). The total MSD cases with job transfer or restriction in 2006 was 281,192. For all MSDs, this totals 638,609 cases with days away from work, job transfer, or restriction in 2006 (AFLCIO, n. d.).

Injuries at work that result in restricted duty or time off work negatively impact the workplace and the injured employee both economically and psychologically. Work efficiency is reduced due to the loss of a trained employee, time off the floor for medical visits, and meetings associated with the injury. The employee's morale is reduced as he/she is not working and able to contribute to the work of the team; likewise, the team's morale is affected because they must work harder to cover the injured employee's absence. The psychological effects of the injury, loss of work (or modified work), and resulting discomfort can create symptoms of depression, anxiety, heightened job stress, and anger, further affecting the healing process and morale of the employee (Barbe & Barr, 2006). Employers face a dilemma as they must decide whether to absorb the reduced output or incur the cost of hiring a replacement worker until the employee returns to work.

However, many of the negative aspects associated with work absence also act as a stimulus to return the employee to work. There is strong evidence that injured employees get back to work more quickly when they are included in a return to work program (McCluskey, Burton, & Main, 2006). Benefits of a return to work program include increased self-esteem for the injured worker, improved morale among all workers, contribution to a faster recovery, maintaining social contact with co-workers, and reduction of the negative financial impact to the injured worker (The Injured Workers' Insurance Fund [IWIF], 2001). Setting up processes to facilitate the employee's return to work reduces time off work, decreases employee stress, increases recovery time, decreases costs to the employer, returns the worker to full pay, and re-connects the worker to the work team. Briand, Durand, St-Arnaud, and Corbière (2008) reported the essential components of a successful Return to Work (RTW) program included: "a centralized coordination of the worker's return to work, formal psychological and occupational interventions, work environmental interventions, and contact between the various stakeholders" (p. 207). It is important that employees be able to work when they are symptomatic as complete pain relief does not occur until resuming normal activities (Nguyen & Randolph, 2007).

Impact on the Workplace

"In 1999, nearly 1 million people took time away from work to treat and recover from work-related musculoskeletal pain or impairment of function in the lower back and upper extremities (NAS, 2001, p. 1). Compared to other diseases, MSDs consume a substantial proportion of healthcare resources and are among the major outpatient services by volume and cost (Osborne, Nikpour, Busija, Sundararajan, & Wicks, 2007). Williams and Westmorland (2002) agreed, "work-related musculoskeletal injuries represent a major source of work disability" and annual disability costs can range from 8 to 15% of a company's payroll (p. 87). Furthermore, conservative estimates of the economic burden imposed, as measured by compensation costs, lost wages and lost productivity, are between $45 and $54 billion annually (NAS, 2001).

Reducing MSDs

There are many programs and processes, both reactive and proactive in nature, that a workplace can implement to reduce MSDs. Reactive programs focus on controlling the incident once it has occurred. Efficient notification, treatment, and safety injury reviews reduce the impact of the injury (both to the worker and the employer) and provide data to further increase the effectiveness of the injury prevention program. Proactive programs are designed to plan for and minimize MSD occurrence in the workplace.

Proactive programs must address both the person (the aging workforce, education level, literacy) and the environment (postures, repetition, force, fatigue, noisy or cold work areas). Aspects of a comprehensive proactive program include a problem identification process, training programs, ergonomic evaluations, process review, and some form of stretch program. For all the listed programs, support of management is paramount as it reinforces and solidifies the importance of the program and increases its effectiveness. As the International Ergonomics Association (2000) stated, "any intervention will only be as effective as the commitment of the employer and training of the people implementing it" (para. 8). Involving employees in the array of safety programs at the worksite, including problem identification, solution implementation, and program evaluation will not only decrease the burden of operating the programs, but also increase the effectiveness and commitment of the workforce.

Process review by occupational and environmental health and safety professionals (OEHN, ergonomist, safety, industrial hygienist) prior to implementing new work practices and toolsets will minimize future hazards. Having an engaged team working with manufacturing and associated engineering groups to design workstations and operations will provide solutions prior to negatively impacting employees.

The OEHN must be involved in area walkthroughs to address issues and concerns, maintain a robust reporting structure to inform management of current data and trends, complete functional job descriptions for work areas, and implement screening evaluations for high risk job groups. Ergonomic evaluations of the worker in his/her work environment help uncover systemic issues while developing a custom work process for the individual.

Ergonomic evaluations may be performed annually or after MSD symptoms have been reported. It is important for the OEHN to understand the core concepts of ergonomics in analyzing the worker and the physical environment. However, standardizing work will not necessarily guarantee safety or similar risk of injury for all workers (NAS, 2001). As da Costa and Vieira (2008) reported, it is important to highlight that the objective of ergonomics is to make tasks, jobs, products, environments, and systems compatible with the needs, abilities, and limitations of people, as opposed to making the people 'compatible' with the work characteristics and demands.

Once the team has identified physical hazards present in the workplace, a corrective action plan must be implemented. Changing the work area can include "alterations in tools, equipment, workstations, materials handled, tasks, work methods, work processes, and work environment, based on their contributions to the identified stresses" (NAS, 2001, p. 302).

Workplace stretch programs aim to reduce injury rates through reducing tension by counteracting mechanical stress on the body, increase blood flow and oxygen to the muscles, and minimize muscle soreness (Lowe, 2007). If the incidence of MSDs is prevalent in specific areas of the work environment, a job analysis coupled with pre-employment screening will reduce injuries through ensuring that workers are physically able to perform the job tasks on a regular basis.

CHAPTER III

RELATIONSHIP OF WORKPLACE STRETCH PROGRAMS AND EFFECTS ON MSD INJURIES

Stretch Programs

Most programs in the workplace focus on general stretches to promote increased flexibility with the benefit of ultimately decreasing workplace injuries. As discussed in this paper, stretching will physically spread the myofibrils within the sarcomere, resulting in increased flexibility and range of motion. It is not understood whether stretching the muscle length facilitates improved muscle function. As stretching leads to increased flexibility of the muscle and joint, at a certain point stretching beyond normal range can lead to hyper-mobility and instability (Joffe, 2007). Conversely, hypo-mobility can lead to higher injury rates, due to the increased resistance of the muscle. Programs should strive to provide normal muscle and joint range, and focus on the hypo-mobile individual. Some programs strive to improve the fitness level of the participants, as studies have shown that individuals with low fitness levels are at increased risk for injury (Newton et al., 2008).

Most muscle injuries occur during an eccentric contraction within the normal range of motion, as previously described. Implementing a stretch program that increases the range of motion of the participants would not address the core issues of MSD injuries. So the question must be asked: do the benefits from stretching, namely increased flexibility and increased ROM, truly influence injury to the muscle?

Pre-activity stretching could produce an indirect, positive effect through the increase of blood flow to the targeted muscles, which adds oxygen and provides heat to increase the elasticity of the fibers. If this is the true benefit, then "activating" the muscles prior to exercise should be the desired focus of prevention programs in the workplace, not increasing ROM. The muscle tissue must be prepared and fortified for the activity at hand, whether it is lifting heavy objects, cutting meat, or typing.

Current Studies on Stretch Programs in the Workplace

Kietrys, Galper and Verno (2007) conducted a randomized control trial of a work exercise program. Participants were randomized into 3 groups: resistance exercise, stretching, and control. The resistance and stretching group differed from the control group by reporting that the exercises helped reduce discomfort in the back and neck.

Reese (1998) conducted a retrospective study of a workplace that implemented a stretch program to prevent sprains and strains due to the frequent twisting and bending of the workforce. A 50% reduction in strains and sprains was reported after 6 months of implementation of the stretch program.

Trujillo and Zeng (2006) reviewed a software program called "Stop and Stretch" and its effects on workers with high amounts of computer usage. They found that the automated program for data entry workers was met with acceptance, but due to the small size of the study few results could be drawn.

van den Heuvel, de Looze, Hildebrandt, and Thé (2003) evaluated neck and upper-limb injuries among computer workers. A software program was implemented to remind workers to take regular breaks and perform physical exercise. While no effect was seen on the frequency and severity of complaints, it revealed that computer workers with complaints who used the software program perceived more recovery than those who did not use the program.

Jepsen and Thomsen (2008) studied the effects that stretching had on upper limb symptom prevention in computer operators. The participants from two divisions of a company were divided into control and study groups, and were asked to fill out pre-study and post-intervention questionnaires and have a physical exam. The control group did no stretching while the study group was instructed to participate in an upper limb-stretching course at least three times weekly over a six-month period. The study group reported fewer upper limb symptoms compared to the control group.

In 2001, Christenssen conducted an experimental study on an exercise program's effect on arm and upper body musculoskeletal pain. The subjects were divided into two groups and the experimental group was trained in a stretch program and had monthly interviews over 12 weeks. The experimental group reported positive feedback on the stretch program and although there was not a significant decrease in musculoskeletal symptoms, the study found that the experimental group had become "far more conscious of their own physical well-being" while working (p. 137).

A literature review by da Costa and Vieira (2008) uncovered 7 studies that met their criteria of stretching for prevention of work-related MSDs. They found that while some studies showed a protective effect from stretch programs, "most of the tasks performed in the workplace do not involve high intensity [activities]" (p. 326).

As da Costa and Vieira (2008) reported, these highlighted studies show some positive results from stretch programs, but the limited scope and sample size minimize the findings. Several studies showed positive effects through stretching, either by reducing physical symptoms or through greater feelings of self-efficacy. Only one study (Reese, 1998) showed a reduction in strains and sprains, but the information was pulled from a retrospective review of an implemented stretch program; the data reflected the input from the administrators of the program and may have been biased.

There have been few studies on workplace stretching programs. Hess and Hecker (2003) reviewed this topic and found only eight studies that met their criteria, even when going back to 1977. They found that the studies showed "equivocal findings pertaining to flexibility and injury" (p. 336). Their findings, however, do not conclude that workplace stretch programs are without benefits. Most of the studies request future data on stretching and what effects stretching has on injuries, but conclude that stretching can be a part of a successful injury reduction program when included with an ergonomically friendly setting and a sufficiently trained workforce.

Reviewing studies on stretching and its effect on injury has been difficult as most of the published studies focused on one type of study group, namely collegiate or professional athletes, performing one type of strenuous activity. The modern workplace contains a highly dynamic employee population with multiple contributing and non-contributing risk factors such as gender, age, ethnicity, frame size, BMI, disease processes, and education level. Additionally, the physical and environmental hazards that can cause MSDs such as lifting loads, bending, repetitive movements, vibration, fine motor tasks, or cold environments are not specifically addressed in the studies. A MSD prevention program must be general in design to encompass all the risk factors of the workforce, but also specific to the hazards in the work area. As Joffe (2007) reported, it must address the person, the task, and the place.

Current Guidelines for Workplace Stretch Programs

Workplace stretch programs can be implemented for various risk factors, worker populations, and many different industries. For example, worksites that have computer intense workloads (and associated MSDs) can utilize software which prompts and coaches the user to perform stretching exercises on a regular basis. The programs can be installed on the worker's personal computer. Some of the software products use keystrokes or mouse click counts to determine when to have the user perform stretch exercises and other programs utilize a timer to cue the user. Most software platforms can be purchased and customized to address specific needs, such as hand, wrist, or forearm issues. Current software prices range from $15-$50 per unit/user, and have many custom options.

Worksites with a production labor force that have little to no computer access or those in need of a fully customizable program can implement a group stretch program, typically facilitated by a stretch leader. Costs for group led programs vary widely, as the initial work of identifying the ergonomic issues, writing the program, and resources to train the stretch leaders encompasses many hours, personnel, and sometimes outside experts. Once the work area and exercises have been selected and the workers have been educated on the program, the indirect costs of using production time for stretching must be added. Other ongoing costs include annual training and audits to ensure proper technique. Figure 3.1 is an example of a return on investment calculation for implementing a stretch program for a worksite of 100 employees, excluding initial start up costs.

Root Cause of Work-Related MSDs

MSDs occur due to a variety of factors including physical (loads, motions, vibration, and thermal exposures), psychological stressors (monotonous work, social support, work demands, job stress, and emotional effort), and personal factors (age, sex, BMI, presence of personal medical conditions). Any number of these factors can contribute to the occurrence of MSDs. The employer, along with the OEHN, must identify hazards and intervene with corrective actions. A hazard identification process, input from the workforce, and injury trend analysis will help identify the specific risk factors. Root cause analysis post-injury can be evaluated, tracked, and communicated to business partners and management. Once the root cause has been established, the data can be utilized to gather the appropriate resources, followed by intervention and hazard correction.

Recommendations

Implementing a stretch program without managing the primary risk factors is shortsighted and not cost effective. A process that addresses the root cause of

FIGURE 3.1

RETURN ON INVESTMENT FOR A STRETCH PROGRAM

- 5 minute program = (3 min stretch + 2 min prep/finish)
- 5 minutes represents approximately 1% of base payroll
- 5 minutes/480 minutes in workday = 1.04% of workday for one session
- 10 minutes/480 minutes in workday = 2.08% of workday for two sessions
- If employee makes $10/hour and is paid for 2,080 hours plus 30% for benefits, then the cost for this one employee for one daily session is:

  Cost = [($10/hour x 2,080 hours) +
  (0.3)($10/hour x 2,080 hours)] x 1.04%
  = $281.22 each year per employee
- Add on 30 minutes of orientation at 0.5 hour x $10 = $5.00 per employee
- If you have 100 employees, then your annual cost is:

  100 employees x ($281.22 + $5.00) = $28,621.60
  for a single session each or
  100 employees x ($281.22 + $281.22 + $5.00)
  = $56,743.60 for two sessions/day

To determine return on investment (ROI):
ROI = (∑ reduced workers' comp cost x probability of success) ÷ (direct cost)
=($100,000 x 10%) ÷ $28,621 x 10% = 35%

For every dollar spend, your ROI is $.35.

Source: Joffe, 2007, p. 3.

Illustrates the ROI of an example program cost for a company of 100 employees and it excludes the investment for program development and initial leader training.

the injury must be a priority. Stretch programs should optimally be part of a comprehensive safety and wellness program, and implemented only when the physical factors have been corrected as no amount of stretching will protect the body from injury due to poor area design or lack of appropriate tooling.

McGorry and Courtney (2006) reviewed worksite stretch programs and reported that there is insufficient evidence to "support the use of worksite exercise programs as a sole intervention" (p. 25) for MSDs. Several stretch studies (Bazett-Jones et al., 2008; LaRoche et al., 2008; Torres et al., 2008) found that there is no clear consensus on the benefits of static stretching, but many professionals seem to agree that warming up the muscles prior to activity produces positive results (Cé et al, 2008; Woods et al., 2007). The scientific evidence shows that warming up the muscle group(s) increases blood flow to the area, which causes a thermal increase and increased oxygen availability to both the muscle and the musculotendinous junction. This results in an increase in muscle pliability without the observed negative effects of a static stretch (Proske, Morgan, & Gregory, 1993).

Hess and Hecker (2003) recommended criteria for a workplace stretch program based on their literature review and current American College of Sports Medicine (ACSM) recommendations (Figure 3.2). The ASCM criteria suggests that static or PNF stretches be done least 2-3 days per week.

As Malm (2008) stated, "[p]hysical exercise is necessary for maintaining normal function of skeletal muscle" (p. 233). The findings in this paper propose a

FIGURE 3.2

CRITERIA FOR AN EFFECTIVE WORKPLACE STRETCHING PROGRAM

- Warm up for 5 minutes prior to stretching
- Exercises should be tailored to commonly performed job duties
- Stretch regularly: 2-3 days/week, minimum
- Perform stretches correctly:
    - Use static or PNF stretches
    - Hold stretch 15-30 seconds
    - 3-4 repetitions per muscle group
    - Stretch bilaterally, emphasize tight muscles
- Intensity should be to a position of mild discomfort
- Trained instructors should lead and monitor classes
- Compliance should be monitored
- Stretch at appropriate work times throughout the day
- Company commitment to work time and program overhead costs

Source: Hess and Hecker, 2003, p. 336.

daily, pre-work warm-up consisting of active, dynamic movements prior to initiating work. The goal of the program includes increasing blood flow, warming up, and activating the muscle without increasing the risk of injury. A sample warm-up should mimic the job task activity; the employee would perform the job task movements at sub-maximal effort for 5-10 minutes prior to working. This warm-up would be tailored to the area. For example, a warm-up for workers who lift heavy loads could be calisthenics that incorporate back movements, such as side bends, trunk rotations, full back and abdominal stretches, and squats. This warm-up would prepare the major leg and torso muscles for lifting.

If the risk factor is cumulative trauma from keyboarding work, then a forearm, wrist, and hand warm-up would be a priority. Exercises for this group of workers would include arm flexion and extension, rolling the wrists, and flexing and extending the fingers. It is also important that the warm-up include both agonist and antagonist muscle groups.

As the literature review pointed out, most of the data on stretching comes from elite athletes (Bazett-Jones et al., 2008; Fletcher & Anness, 2007; Torres et al., 2008) and army recruits (DePino et al., 2000; Pope et al., 2000), and cannot be directly correlated to the typical workplace. However, the negative results that were found may not be applicable. The studies showed that stretching could decrease performance attributes such as power output (Cé et al., 2008; Fletcher & Anness, 2007; Robbins & Scheuermann, 2008), which is not applicable to the workforce. Since the typical worker uses sub-maximal effort and repeated muscle movements over the course of a workday, there may be a concern about a stretch program reducing power output.

Stretch programs have not been shown to directly cause or increase the severity of injuries. If the workplace must choose between a stretch program or nothing, then some activity with stretching is better as the secondary effects of stretching will have positive results. However, comparing the results of the warm-up to the static stretch, although in a much less homogenous sample group than the normal workforce, the warm-up appears to be the superior program in terms of protective effects.

Warm-up programs should ideally focus on the group performing the work as well as the work itself. Once the physical environment has been reviewed, assessed, and modified to reduce MSD injuries, the use of a warm-up program would be beneficial. A warm-up program as the sole solution to the problem would be less than successful. Data indicate that warming up the muscle prior to activity is a safe and effective means to prepare the muscle for work (Bishop, 2003; Cé et al., 2008; Woods et al., 2007).

Another option is to focus on increased fitness and health, which encourages and supports health habits through dietary choices, exercise facilities, and through the involvement of management without the implementation of a formalized stretch program. This program would dovetail with other corporate health initiatives to impact obesity, diabetes, cardiovascular disease, and stress in the workplace, as well as positively influence work-related injuries including MSDs.

Implementation of a Warm-Up Program

To initiate a warm-up program in the workplace, the OEHN must ensure management support. As the program encompasses many departments on many levels, working with a team of supportive individuals including management, benefits, finance, safety, and workers will assist with dividing up tasks, creating solutions to problems, and ensuring a successful program. The program must be tailored to the work environment, workers, and exposure hazards.

After analyzing the work areas and activities, the team must develop the appropriate activities to meet the goals of the program. Once the activities have been determined, a deployment plan is enacted to communicate the program and educate the participants to ensure success. Regular audits must be performed to ensure program compliance, as well as regular training and monitoring for the group and leaders.

CHAPTER IV

OCCUPATIONAL AND ENVIRONMENTAL HEALTH NURSE (OEHN) ROLES

The role of the OEHN in MSD care and prevention is critical to the workers and company. As Marinescu (2007) stated, OEHNs "are well positioned to assume leadership roles in their organizations by coordinating efforts and programs across departments that offer health, wellness, and safety benefits (p. 75). The OEHN can affect MSDs by developing an ergonomics program, coordinating and leading an ergonomics team, educating employees to report symptoms early, instituting appropriate referrals, planning and implementing a return to work program which would lead to a healthier workforce and a more efficient and profitable workplace. The OEHN must be an advocate for worker health and safety through affecting corporate policy and occupational hazard identification and correction. From a global perspective, the OEHN will influence MSDs through primary, secondary, and tertiary prevention levels and by utilizing the assessment, planning, intervention, and evaluation method. The primary focus of the OEHN in MSDs is early intervention, prevention, and health promotion.

Primary Prevention

Primary prevention focuses on preventive measures before the event occurs and focuses on eliminating or reducing risk through protective actions (Rogers, 2003). These actions can include activities such as pre-placement physicals, worker education, hazard identification, ergonomic evaluations, and stretch/warm-up programs. The OEHN must be able to understand that multiple issues affect MSDs and be able to identify hazards and trends in the workplace to create specifically tailored MSD prevention programs.

Pre-placement physicals allow for minimum standards to be met prior to hiring workers for specific tasks. The pre-placement physical, which includes performing the essential job functions, can uncover previously unknown medical conditions while reducing the company's risk of paying for pre-existing conditions (Moshe et al., 2008). The time spent with the potential worker during the physical is an opportunity to teach proper body mechanics and basic ergonomics. Furthermore, the efforts spent on the pre-placement physical and teaching will underscore the company's commitment to a healthy workforce and safe work practices while complying with the Americans with Disability Act.

Education on a variety of health topics can provide valuable information to workers. Education that focuses on MSDs would include ergonomic and MSD risk factors, stretching/warm-up, smoking cessation, and benefits of exercise. The OEHN is a resource for the workforce and can present information individually to the employee during a consult, to larger groups in presentation form, or during a health fair setting. Educating the worker on healthy habits, such as encouraging exercise, weight control, and disease management, will influence both personal and work fulfillment. The OEHN can also provide regular health messages on area bulletin boards while visiting the work areas and through mass communication methods such as email. Topics can include cardiac health, staying fit during the winter months, nutrition tips, as well as sponsoring and supporting programs such as the Great American Smokeout Challenge, Weight Watchers meetings, or the 10,000 Steps Program.

Hazard identification and safety walkthroughs are formalized processes that look for and intervene in health and safety issues in the work areas. The OEHN, along with other members of the multidisciplinary ergonomics team, management, and area workers must first complete a job hazard analysis to understand the exposures in the environment. Hazards can range from food in the work area to respiratory hazards, but hazards specific to MSDs would include work area or tool design issues. After identifying the hazard(s), planning begins to reduce or remove the exposure. Some interventions are relatively simple such as speaking with the person practicing an unsafe behavior. Other interventions require more analysis, effort, and planning, such as identifying work areas that need to be redesigned. For MSDs this can include engineering controls (elimination, automation), work area layout modifications, and hand tool and machinery modifications, administrative controls (job rotation), and workplace stretch/warm-up programs. All of the planned changes must be evaluated for use with the entire workforce to ensure that new problems are not substituted for old ones. Identifying hazards before they can affect the workers is important to keep workers safe, reduce costs, and consistently practice a preventive approach to safety.

Ergonomic evaluations analyze how the worker physically interacts with the work environment (International Ergonomics Association, 2000). The intent is to identify the capabilities and limitations of the musculoskeletal system, ensure that items in the work environment are being utilized appropriately, and identify processes, workstations, and tools that need re-designed or modified to further reduce the hazard. The evaluation attempts to measure or model "the 'internal' mechanical responses of body tissues to the 'external' physical demands of a work activity" (Keyserling, 2000, p. 40). Ergonomic evaluations are ideal for focusing on a specific worker's activity and creating ideal situations for one-on-one training and education. Optimally, these evaluations should be performed whenever the worker is new to the area (newly hired or transferred), on an annual basis after the initial evaluation, and after any issues of discomfort or injury occurrence are reported.

Utilizing a warm-up program can change a reactive safety program to proactive status, with the OEHN as the primary driver to analyze, plan, implement, and evaluate the program. The OEHN is instrumental in implementing such a program and can present data outlining injury and workers' compensation cost trends, data illustrating current health insurance costs, and how such a program can impact both. For instance, the US BLS (2008) data reveal that the shoulder and back are the most frequently occurring MSDs; therefore, incorporating a general trunk calisthenics as a base for warm-up for most programs would be beneficial.

Once the warm-up program is developed, the OEHN must educate the pre-selected employees who will be the leaders of the warm-up program. After training the warm-up leaders, the work group is then trained. The OEHN must be present initially to ensure that the concepts are understood and the warm-up is conducted correctly and safely. Whether tailored specifically to the workers in the area or company-wide, the OEHN can encourage activity to improve wellness both at work and home. Area programs can include a specialized warm-up to prepare the workers for their tasks for the day. Company-wide programs focus on basic activities such as a 10,000 steps a day campaign, encouraging workers to get up and move around intermittently throughout the day, and encouraging healthy behaviors through contests in the workplace.

Secondary Prevention

Secondary preventive measures occur after a disease process has already begun and focus on early detection of MSDs to reduce the impact of the event once it has occurred (Rogers, 2003). Examples of preventive measures include implementing an efficient early reporting system for injuries, instituting work area re-design, initiating focused or personal ergonomic evaluations, and fine tuning preventive programs. Creation of a robust communication process to all stakeholders for new injuries and trends can further reduce the impact.

To help the injured employee and reduce the possibility of injury to others in the work area, there must be a system to report and collect the data. The OEHN must ensure that a consequence-free reporting structure is in place to both treat the injury and intervene in the problem. The workforce, along with management, must have a program with a clear pathway to report issues that range from acute injuries to mild discomforts to the OEHN. The OEHN is the primary point of contact for management, the injured employee, workers' compensation insurer, and treating health provider. The reporting program also collects the data on who was involved, how and where the injury occurred, and what processes were involved. Data collection systems are only as good as the data received, so all employees need to be aware of and follow the reporting process.

After notification of the injury, the OEHN works with the injured employee, area managers, supervisors, engineers, and other safety personnel to evaluate and correct identified hazards. The root cause of the injury (or injury trend) must be understood prior to taking this step, so careful analysis is warranted. Resolving issues after minor injuries occur and before any significant injuries will begin the transition to a preventive focused environment.

Secondary prevention also occurs when the OEHN conducts a post-injury ergonomic evaluation. Each step of the job is reviewed, especially the tasks related to the root cause analysis, to determine how the worker performs day-to-day tasks. The evaluation would provide education on ergonomics, identified problems, and real-time solutions for work activities. Furthermore, the ergonomic evaluation can provide data on understanding poor tool or area design, support initiatives to alter the work area, as well as provide feedback on potential hazards. Area or company-wide training can be altered based on the findings of the evaluation to minimize future injuries.

Tertiary Prevention

Tertiary preventive measures focus on reducing the impact and severity of existing injuries and help workers achieve their maximum level of functioning (Rogers, 2003). This can be accomplished by implementing and utilizing return to work, work hardening, and injury review and prevention programs, as well as high levels of communication between the injured worker, the OEHN, treatment providers, and work group. The OEHN must assess both occupational and non-occupational factors, including psychosocial factors that can cause or exacerbate MSDs.

Once an injured worker is on disability, returning the employee to work as quickly and safely as possible is key and benefits both the worker and the employer. Workers who return to work faster are likely to recover more quickly and more fully than those who stay at home (IWIF, 2001). The OEHN can act as the case manager and make appropriate referrals, disseminate (translating and censoring) the appropriate information to all stakeholders when necessary, identify work accommodation opportunities, educate the affected individuals, and return the employee to the workplace with the health care provider's approval. The OEHN interprets, clarifies and explains the restrictions, ensures that the restrictions can be accommodated, identifies additional accommodation duties, and confirms that the affected worker is compliant.

Another program that can assist the injured employee with return to work after a MSD is work hardening. Work hardening is a specialized rehabilitation program that simulates workplace tasks in a monitored environment (Lepping, 1990). Typically the program is instituted after a moderate amount of time on disability, and it assists injured workers to return to work and begin transitioning back into their work tasks and schedule. The structured program consists of bringing the worker back to perform a portion of their tasks or work on a progressively graded schedule. If the employee is unable to return to a regular work schedule, he/she can return on a graduated schedule where the essential duties of the job are performed 4 hours the first week, 6 hours the next, etc. until able to return to full duty. The OEHN can facilitate this process by being the contact person for all parties and working with the employee, the health provider, and the employer to understand the demands of the workplace and the concerns of the health provider. The graduated return "hardens" the employee's musculoskeletal system to be able to cope with and thrive back in the work environment.

One of the core jobs of the OEHN is to be a communication hub for many different parties both internally and externally. Interpreting the information, making decisions, and communicating to stakeholders is a valuable method of reducing risks, injuries, and overall impact to the employee and employer. As the only employee qualified to view certain medical documents, understand terminology, and be accountable to an outside entity through licensure, the OEHN is in a unique position to affect change.

As the OEHN is the core of the various programs and services, the safety and wellbeing of the workforce can be dramatically affected by his/her efforts. The OEHN plays a critical role in identifying, intervening, treating, and monitoring MSDs in the workplace.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

A search of several academic and public databases for studies relating to MSDs resulted in an abundance of data. There were multiple studies published in 2008, indicating a continued interest in the area of muscle injury, injury prevention, and stretching. After reviewing the studies relating the effects of stretching to flexibility and performance, the data had mixed results concerning static stretching. When reviewing the databases for muscle injury in relation to stretching and warm-up activities, the results were conflicting, but somewhat clearer. Of the study and literature reviews, two associated positive results from warming up and stretching related to injury outcomes were documented (Emery et al., 2007; Woods et al., 2007).

The research shows that although MSDs continue to decline, the risk is still present and the severity of injuries, when occurring, remains constant. Understanding the contributing factors that cause MSDs and how OEHNs can identify and reduce them is just as important as preparing the employee for work.

The widely accepted practice of stretching to prevent muscle soreness and injury requires review, as the positive and negative effects of stretching on the muscle remains unclear. Stretching needs to be implemented under certain circumstances, and a warm-up program should begin to gain acceptance as the primary pre-activity preparation. As research on stretching activities continues, the correlation to the average worker needs to be understood. An athlete utilizing his/her musculoskeletal system for maximum effect over a short duration is much different than an employee working 40 hours a week. Shrier (2004) found that while it appears that pre-exercise stretching negatively affects performance, regular stretching, when not associated with pre-exercise activity, was beneficial in terms of injury and DOMS. As future studies provide more data on the cause and effect of musculoskeletal injuries, the relationship of stretch and warm-up activities, and the varying degrees of stretch shortening cycles (highly "explosive" movements to low impact), changes in pre-exercise activity will occur.

After reviewing the available research on stretch and the effects on muscle injury, the evidence indicates both negative and inconclusive results from stretching. The negative aspects of stretching resulted in a range of performance issues including decreased sprinting power and vertical jump performance (Fletcher et al., 2007; Power et al., 2004; Robbins & Scheuermann, 2008). Two studies hypothesized that stretching inhibited the positive effects of active warm-up (Behm et al., 2004; Power et al., 2004). Many studies showed neither positive nor negative results from stretching prior to activity (Bazett-Jones et al., 2008; LaRoche et al., 2008; Torres et al., 2008), while others did not use a large enough sample size to draw any meaningful outcomes (Guissard et al., 2004; Power et al., 2004; Torres et al., 2008). Although the data reviewed in this paper show non-positive findings on stretching activities, removing stretch from the workplace is unwarranted. The benefits of stretch prior to work can be positive in terms of injury prevention and the activity focuses the workgroup at the start of the day. However, warm-up appears to be the safest and soundest approach of pre-work activities.

Gaps in the current areas of study include, first and foremost, a clear understanding of muscle on the microscopic level. How the sarcomere operates is the key to understanding the macro function of muscle, and the research is unclear as to the actions of stretching, if it injures the muscle tissue, or if the tissue insult is really just a means of muscle strengthening.

The use of homogenized study groups (college students, Army recruits, track athletes) paired with high impact or explosive muscular actions sheds light on these specific groups. To benefit the workforce, studies must include a cross section of individuals with varying degrees of health risks. Future research should focus on stretching versus warm-up in the workplace, specifically on activities that are repetitive and both low impact (computer work) and high stress (lifting) activities. Furthermore, studies should be independently conducted, rather than employer sponsored, to prevent bias in research outcomes.

Final Thoughts

The world has begun to notice how important activity is on health outcomes, regardless of age, gender, or ethnicity. Obesity is continuing to increase in the United States. A recent American Heart Association (AHA, 2008) report stated that the percentage of children in the 95th percentile for obesity rose from 4% in 1971-1974 to 17% in 2003-2006. The ramifications for inactivity can be far greater than the impact from MSDs, and can terminally influence heart and lung disease, stroke, and diabetes health outcomes.

As an example, video game makers have begun to change focus from a 'sit and stare' style of play to a 'get up and interact' activity (e.g., Ninetndo's Wii Fit, Konami's Dance Dance Revolution). Activity encouraging games are being implemented everywhere, from after school programs to senior citizen centers, to get people up and moving about. For the adolescents, the games are both engaging to play and incorporate a peer accepted format that encourages activity. For the senior citizens, these games support activity without having to travel to the various venues to partake and they can participate in the activity either alone, or in a group to have fun and stay active. For both groups, the games are a social activity that not only enhances the game, but encourages participation.

Calisthenics, as a preventive injury program, is a both a social and physical activity designed to focus the mind and body on the day. It can be implemented in a group format and while performing the movements, work area business can be conducted (safety meeting, area priorities, etc.).

The focus of this paper has been on the effects of stretch on MSDs and the findings have recommended a single solution - increased activity, primarily through warm-up exercises. While many companies search for options to decrease costs associated with doing business, this simple, low cost recommendation could reduce injuries, workers' compensation costs, lost efficiency, and the largest expense, health care costs.

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APPENDIX

COMMON OCCUPATIONAL MSD DEFINITIONS

Strain – A strained muscle, ligament or tendon has been pushed or pulled to its extreme by forcing he joint beyond its normal range o motion. It commonly results from lifting a heavy weight or bearing an unexpected external force, usually traction force. By definition, the symptoms of strain should resolve within a few days to a week.

Sprain – A sprain is an injury in which a ligament has been stretched beyond its limit, causing tears or disruption in some fibers within the substance of the ligament. Reactive inflammation with associated edema and local venous congestion develops over hours to days. A complete tear of the ligament is sometimes called a third-degree sprain.

Tendonitis – Tendinitis is inflammation of a tendon. It may be the result of a primary inflammatory disease, such as rheumatoid arthritis, or it may be secondary to a mechanical injury.

Tenosynovitis – Tenosynovitis is inflammation of a tendon sheath.

Bursitis – Inflammation of a bursa is known as bursitis. An example is olecranon bursitis casued by inflammation in the thin tissue planes between the skin and olecranon.

Myositis – Myositis is inflammation of muscle. The inflammation may be primary, as in polymyositis, or secondary to mechanical injury, as when a muscle has been overstretched.

Arthritis – Arthritis indicates an abnormal joint caused by injury, disease, or congenital abnormality. Examples include posttraumatic arthritis, osteoarthritis, and congenital hip dysplasia.

Repetitive strain injuries – Repetitive strain injuries are related to cumulative trauma (primarily end range, repetitive movements which involve a forceful or a vibratory component). These cumulative traumas may lead to pain and acute or chronic inflammation of the tendon, the muscle, the capsule, or the nerve. Eventual scarring and stenosis can entrap tendons, nerves, and vascular tissues. Cumulative trauma may involve the extremity (commonly the hand, wrist , elbow, or shoulder) or the trunk (low back strain).

Source: LaDou, 2004.