Restoring neuromuscular control is an important goal of rehabilitation following musculoskeletal injury, especially in physically active individuals. Unlike other treatment goals such as restoring range of motion, neuromuscular control is abstract and multifaceted. Proprioception is one aspect of neuromuscular control, and in order to fully integrate proprioception retraining into a rehabilitation program, athletic trainers and therapists must understand the hierarchical nature of restoring neuromuscular control.

The purpose of this article is to describe a rehabilitation paradigm that includes three levels of neuromuscular control: volitional muscle contractions, reflex responses, and pattern-generated movements (see Figure 1).

**Neuromuscular Control Paradigm**

Movements usually result from volitional muscle contractions that are initiated by conscious effort. The individual voluntarily wills to move joints in a certain way to accomplish a goal. But pain, swelling, and altered mechanoreceptor activity can impair one’s ability to contract muscles at will. The most obvious example of this is the impaired function of the quadriceps muscle group following knee injury.

The body has many reflexes. Most are protective in nature. Sensory input travels to the spinal cord and brain, and triggers predictable, involuntary efferent responses. These efferent responses are often manifested as involuntary muscle contractions causing joint movement.

Altered mechanoreceptor activity can impede the execution of reflex responses. A loss of reflex control is commonly seen following lateral ankle sprain as injured individuals typically demonstrate slowed peroneal muscle response to sudden ankle inversion (Lofvenberg et al., 1995).

The final component of neuromuscular control involves pattern-generated movements. In sport and work activities, high-speed coordinated muscle action is required to execute complex tasks. Repetition of a complex motor task results in the establishment of a motor pattern. One cannot consciously act to control each muscle while executing a complex motor task such as a golf swing. Thus the motor pattern must be established through practice and instruction before one can master an efficient and consistent swing.
CONTROL OF VOLITIONAL MUSCLE CONTRACTIONS

RESTORATION OF REFLEX RESPONSES TO PERTURBATIONS

RESTORATION OF NORMAL PATTERN GENERATED MOVEMENTS

FIGURE 1  Rehabilitation paradigm for restoring muscular control.

When pain, swelling, and injury affect one’s ability to consciously control muscle contraction and reflex responses, the ability to execute pattern-generated movements is also affected. Although the notion of functional rehabilitation is not new, it is rarely appreciated for what it is: repeated rehearsal of pattern-generated movements that have been inhibited as the result of injury.

Effects of Injury on Neuromuscular Control

Musculoskeletal injury can result in pain, swelling, joint instability, and limited range of motion. These all adversely affect proprioception and neuromuscular control.

Although the precise mechanism has not been fully described, pain certainly inhibits normal neuromuscular control. Pain appears to inhibit alpha efferent pathways while facilitating gamma efferent pathways. The athlete in pain is unable to volitionally contract some muscles fully and also experiences involuntary spasm and hypersensitivity to joint movement and muscle stretching.

It is difficult to isolate the effects of pain on neuromuscular control because pain is nearly always accompanied by inflammation and/or instability.

The impact of swelling on neuromuscular control is more clearly demonstrated. The impact of knee injuries on neuromuscular control of the quadriceps is widely recognized. Even without injury, effusion within the knee results in decreased motor activity of the quadriceps.

Spencer et al. (1984) found that electromyographic (EMG) activity of the vastus medialis muscle during volitional contraction was diminished by infusion of 30 cc of saline into the human knee. Infusion of 200 cc resulted in marked inhibition throughout the quadriceps muscles. Swelling within a joint capsule alters mechanoreceptor activity, which may explain why swelling has such a profound impact on neuromuscular control.

Injury to ligaments and joint capsules also alters input from mechanoreceptors. In addition to the pain and swelling that result from these injuries, disruption of the ligaments alters the afferent feedback received by the central nervous system.

Warner et al. (1996) found impaired joint position sense in individuals with glenohumeral joint instability. Changes in EMG activity during the throwing motion have also been demonstrated in experienced pitchers with glenohumeral instability (Glousman et al., 1988). These changes are manifested by altered reflex responses, changes in joint position sense, and altered pattern-generated muscle activity.

Hierarchy of Rehabilitation Goals

Pain and swelling must be managed before a rehabilitation program can progress beyond the restoration of volitional muscle control. In addition, improvements in joint position sense and the quality of pattern-generated movements cannot be restored until the integrity of the joint is restored (see Figure 2).

Strategies to control pain and minimize and reduce swelling are the primary goals early in the management of musculoskeletal injuries. Protection of the injured tissues, cryotherapy, compression, and elevation—along with medications and modalities such as transcutaneous electrical nerve stimulation—are used in various combinations to achieve these goals.

Once pain and swelling are controlled, efforts to restore range of motion may be initiated, provided that the healing tissues are not compromised by the exercises.

The next goal of rehabilitation should be the restoration of

September 1998 The Professional Journal for Athletic Trainers and Therapists