

Guest editorial

Knee ligaments and proprioception

Proprioception is usually understood as the conscious and subconscious ability to recognize the location of body parts in space. The ability to detect motions and their direction is called kinesthesia and is usually regarded as a part of the proprioceptive system. The system provides the necessary information for the control of posture and locomotion. The sensory information is conveyed by nerves from skin, muscles and joints. The anatomic basis for the system is mechanoreceptors, load-sensitive encapsulated and unencapsulated nerve endings in muscle and connective tissue. These include muscle spindles, stretch-sensitive receptors in tendons (Golgi tendon organs) and motion-sensitive receptors in ligaments and joint capsules. The muscle spindles provide afferent information about the tension in a muscle. The tension in the muscle spindle is regulated by the efferent γ -motor fibers, as opposed to the α -fibers that activate the ordinary muscle fibers. The muscle spindle system controls muscle tone and thereby joint stability. The role of muscle afferents in proprioception is well accepted, whereas the role of nervous elements in ligaments is debated. In the usual paradigm of a joint, ligaments, tendons, muscles and fasciae are regarded as separate structures with almost independent function. In an interesting thesis, van der Wal (1988) stated that the anatomic separation of different structures was artificial. Instead, he showed by elaborate dissections of the rat elbow that muscles, ligaments, tendons and fasciae are organized in series as one continuous structure and that the sensory nerve organs are found at the interfaces between the different tissues involved. Therefore muscles, ligaments, tendons and fasciae form a single functional unit rather than separate entities and the division between joint and muscle afferents is artificial.

The possible proprioceptive function of knee ligaments, especially the anterior cruciate ligament (ACL), has been the subject of much research over the last 30 years. The cruciate ligaments play a major role in knee stability and are important for transferring muscle force effectively over a stable joint. The often mediocre results of cruciate ligament reconstruction have been ascribed to failure to restore the nerve supply and proprioceptive function. The information gathered so far suggests a neural feedback from ligaments to muscles that is important for con-

trol of motions and muscle force.

In clinical studies, the ability to reproduce certain joint flexion angles or to detect minimal joint motion has been said to be a measure of proprioception (Skinner et al. 1984). However, a lack of proprioceptive ability after anterior cruciate ligament injury (Barrack et al. 1989) as well as a decreased function in failed ACL-reconstructions (Barrett 1991) have not been verified (Klein et al. 1992, Good et al. 1995). The ability to reproduce a certain joint angle or to detect slight motion has been found to deteriorate with age and in arthrosis (Skinner et al. 1984). Poor precision in knee angle identification has been found after patella dislocation in both normal and injured legs (Jerosh and Prymka 1996). Other measures of proprioception, such as latency in hamstring reflex contraction after a sudden anteriorly directed force on the tibia top, have been shown to be increased after ACL injury and to correlate with the feeling of giving way, but not to measured static laxity (Beard et al. 1993). Solomonov et al. (1987) showed in ACL-deficient subjects that quadriceps muscle contraction was momentarily blocked and the hamstrings were slightly activated when a pathologic anterior drawer was provoked by knee extension against resistance. This indicates that tissues other than the ACL were involved in preventing abnormal translation. In other studies, it has been found that during activity some ACL-deficient patients can limit their tibial translation to that of the normal knee (Vergis and Gillquist 1996). O'Connor et al. (1993) showed in a complex experiment on dogs that instability could be compensated for if the sensory input was intact. The dogs developed more severe and earlier arthrosis if the sensory nerves from the knee were cut before the ACL was cut, but if it was cut a long time after the ACL injury there was no difference from controls. The implication is that a sensory feedback makes it possible to compensate for the abnormal instability thus delaying arthrosis. Clinical experiments also seem to show a redundancy in the control system so that the loss of one function can be compensated for by training. Most rehabilitation regimes for knee injuries involve some proprioceptive training. Such training programs have been thought to prevent ACL-injuries in soccer players (Caraffa et al. 1996) and to improve subjective symptoms as well as hamstring reflex latency in

ACL injured patients. Similar programs have been shown to reduce the frequency of ankle injuries in soccer players (Tropp et al. 1984).

Although there have been clinical attempts to interact with the proprioceptive system, most of the physiology of the system remains to be analyzed. The presence of nerve endings and mechanoreceptors in the cruciate ligament is well established both in the human (Schultz et al. 1984, Schutte et al. 1987) and in the cat (Sjölander et al. 1989). Since Gardner (1944) and Skoglund (1956) described the nervous supply of the cat knee, this animal has become the standard laboratory model for experiments on knee proprioception. In elaborate experiments, Johansson (1991) and Johansson et al. (1986, 1988, 1991) have shown that moderate loading of the anterior and posterior cruciate ligaments as well as the joint capsule can modify the signals from the muscle spindle afferents, probably by reflex effects on the γ -motor system in the cat. These reflexes will influence muscle tension and contribute to the functional stability of the joint.

The paper by Gómez-Barrena et al. (pp 545-552), using tracer technique to demonstrate the spinal levels that the ACL reflects on is a continuation of that line of research. Their findings are new and have important implications. Firstly, the finding of large neurons gives precise sensory information from the joint through myelinated nerves and, secondly, the amount of neurons is rather small. The innervation is mainly directed towards the lowest lumbar segment but also to the two next higher levels. This shows that it is anatomically possible for interaction to occur between the sensory feedback and the activity of the quadriceps and hamstrings. The neurophysiology underlying this anatomic demonstration is, of course, an important area for future research. The spatial orientation of the mechanoreceptors in the tissue is of value for the type of information that reaches the proprioceptive system. It seems that the sensory organs are located at interfaces where stress is distributed but, so far, the postulation is only hypothetical (van der Wal 1988). It is necessary to study the receptors and their neurophysiologic function in relation to tissue mechanics in order to explain how different parts of the system react and how training may influence its function. Reprogramming of the system by physiotherapy in order to substitute for a lost function will also be a significant area of research.

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