IX. Ligaments and Tendons
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Muscle Fatigue and Back Pain

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Sponsor: VA Rehabilitation Research and Development Service

Purpose—As many as 75 million Americans now suffer from severe lower back pain, and each year 7 million more develop this problem. Despite the many millions of dollars spent on innumerable treatments for the back, the majority of patients have chronic, remitting symptoms. Improved methods for assessing back disorders could help to diminish the problem and the financial burden of this disabling condition.

Progress—We have begun to develop and implement a technique to provide the clinician with an objective index with which to measure treatment outcome for lower back musculature. This technique estimates the fatigue rate of contracting muscles by measuring the shift occurring in the frequency spectrum of the surface-detected myoelectric signal. The dynamic interaction of synergetic back muscles during fatiguing contractions can be represented by “fatigue patterns” created by the different frequency shifts occurring in different muscles. Differences in these patterns associated with lower back disorders may represent functional disturbances in back muscles.

Preliminary Results—In preparation for implementing this technique, we designed and constructed a restraining device to reliably stabilize the trunk in selective positions from sitting to standing. The device is equipped with strain-gauge load cells to monitor flexion, extension, or rotation torques of the trunk. A force meter placed in front of the subject provides visual feedback. In addition, preliminary modifications of another device will permit the analysis of multiple channels of myoelectric signals and track the median frequency of the signal.

Data from 6 patients with chronic lower back pain and 16 normal controls are currently being analyzed. Preliminary results indicate substantial differences in the fatigue curves for these two groups. Additional tests to augment the sample size are underway.

Structural and Functional Properties of Normal and Repaired Ligaments

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Purpose—The objective of this research is to evaluate the ligament repair process in a model synovial joint system. A variety of activity conditions will be used in order to determine which set of conditions will maximize the speed and strength of the repair or healing of ligaments. To achieve this objective, it will be necessary to determine the influence of a wide range of physical factors such as rigid immobilization, cage activity, normal activity, intermittent controlled passive motion, and rigorous daily exercise programs on the size and strength of normal and repaired/healing ligaments. The timing of the onset of these forces at the repair line and its magnitude and frequency would need to be optimized in order to achieve the most rapid and complete remodeling of the repaired/healing ligament.

Progress—To date, we have studied medial col-
lateral ligament healing with and without surgical repair using a canine model. The evaluation of the quality of ligament healing and repair has included correlative studies using morphologic, biomechanical, and biochemical techniques. Specifically, we have studied healing ligaments subjected to various regimens of repair and early mobilization over a 6-week time period. We have focused on the biomechanical properties of the ligament repair site and the areas of the ligament proximal and distal to the repair. The structural and mechanical properties obtained were in turn compared to the biochemical results and histological appearance of each of these areas, and very good correlations were found. We are currently performing experiments over a 12-week period to further define proper clinical regimens that may be used to provide better healing of ligament structures. Our goal is essentially twofold: first, to improve the structural integrity of the healing ligament to ameliorate problems of knee joint instability and second, to improve the material properties of the healing ligament substance.

Tensile Properties of the Medial Collateral Ligament as a Function of Age

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Progress—The biomechanical properties of the rabbit medial collateral ligament (MCL) as a function of maturation and age were investigated. Femur-MCL-tibia (F-M-T) preparations were obtained from rabbits of different age groups (open or closed epiphysis). Parallel increases in the animal body weight and ligament cross-sectional area were recorded with age. Cyclic and tensile failure tests were performed to obtain the structural properties of the F-M-T complex and the mechanical properties of the MCL substance. There were significant increases in the load at failure, energy-absorbing capability of the bone-ligament junction, and in the tensile strength of the ligament substance as a result of maturation and subsequent aging. Increases in the area of hysteresis obtained during cyclic loading-unloading were also documented. At the closing of the epiphysis, the mode of failure of the F-M-T structure progressed from tibial avulsion to failure in the midsubstance of the ligament. An asynchronous rate of maturation was observed between the structural properties of the bone-ligament complex and the mechanical properties of the ligament substance.

Effects of Postmortem Storage by Freezing on Ligament Tensile Behavior

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Progress—The purpose of this study was to examine the effect of prolonged postmortem freezing storage (between 1 and 3 months at -20 degrees C) on the structural properties of the medial collateral ligament (MCL)-bone complex as well as the mechanical properties of the MCL substance from the rabbit knee. Tensile testing of the femur-MCL-tibia specimen was performed, and no statistically significant changes were noted between the fresh and stored samples in terms of the cyclic stress relaxation; the load-deformation characteristics; as well as the load, deformation, and energy absorbing capability at failure. The area of hysteresis of the stored samples was significantly reduced in the first few cycles, however. The
mechanical properties of the MCL substance, as represented by the stress-strain curves, tensile strength, and ultimate strain also did not change following storage. We concluded, therefore, that proper and careful storage by freezing has little or no effect on the biomechanical properties of the ligaments.

Structural and Mechanical Behaviors of Tendons and Ligaments

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Progress—This research demonstrated the use of improved technology and experimental methodology to gain more accurate data on the mechanical and structural properties of soft tissues. It is possible to modify the mechanical properties of soft tissues by altering the contents and interactions of its constituents in vivo by increasing or decreasing the levels of stresses and motion.

The data and techniques available today can be used to evaluate the success or failure in the treatment of soft tissue injuries. It has been clearly demonstrated that early mobilization is desirable for management of soft tissue trauma. As a result, the therapeutic values of continuous passive motion or intermittent passive motion have received significant clinical attention. However, complications such as failure of the repair mechanism as well as stretching out of soft tissues, particularly in the case of ligaments, can cause joint laxity if motion is applied too early and too aggressively. Therefore, it is necessary to narrow the range of the spectrum of motion versus immobilization in the management of soft tissue trauma.