THE EFFECTS OF AN ECCENTRIC-TYPE EXERCISE VERSUS A CONCENTRIC-TYPE EXERCISE IN THE MANAGEMENT OF CHRONIC PATELLAR TENDONITIS

by

LYNDA JANE CANNELL
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Department of Physical Education

The University of British Columbia
1956 Main Mall
Vancouver, Canada
V6T 1Y3

Date April 27, 1982
The main purpose of this study was to determine which method of tendon rehabilitation - the "eccentric squat" exercise or the universal gym "leg extension/leg curl" exercise produces a more significant result in terms of recovery in the treatment of chronic patellar tendonitis. A second objective was to determine if a relationship existed between patients who presented with patellar tendonitis and certain biomechanical malalignments and/or muscle imbalances that those patients might have possessed.

Nineteen patients with chronic patellar tendonitis were studied. They were selected on the basis that they had a history of athletic participation, wore no orthotics and had had the symptoms of patellar tendonitis greater than four weeks.

Subjects were randomly placed in either of two groups: training using the "eccentric squat" exercise or training using the "leg extension/leg curl" exercise. Subjects were clinically and biomechanically examined by a physician and placed on the twelve week exercise program. They were examined and tested at 0, 6 and 12 weeks. Testing included the following variables: thigh circumference measured 4.4 and 10 centimeters above the medial knee joint line, quadricep and hamstring moment of force as measured on the Cybex at 30 degrees per second and a subjective evaluation of pain rated on a scale from 1 to 10.

There was no significant difference between the groups in either quadricep or hamstring moment of force, however hamstring moment of force significantly increased in both groups. There was a significant difference in pain ratings between the groups averaged over the three testing sessions (p < 0.01). The group training with the "eccentric squat" exercise decreased in pain more than the group performing the "leg extension/leg curl" exercise. Also, the "eccentric squat" group produced twice as many "pain free" subjects at the end of the program than the other group. With the retrospective clinical data on the 129 patellar tendonitis patients seen at the B.C. Sports
Medicine Clinic over a three year period, it appears that the average structural malalignment of the patellar tendonitis patient is no different from the average biomechanical problems any athlete may present with who has any number of difference overuse problems.

It appears indicated to recommend the use of the "eccentric squat" exercise as an approach towards the conservative management of chronic patellar tendonitis.
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Chapter 1

INTRODUCTION

Tendonitis is a painful inflammatory reaction to overuse activities involving tendon. Its course may be acute and self-resolving or it may become chronic in nature resulting in progressive disability and weakening of the tendon (Stanish et al., 1980).

Patellar tendonitis (also known as Jumper's Knee or quadriceps tendonitis) was first described by Sinding-Larson (1921) and Johansson (1922) in adults. Patellar tendonitis is being encountered with increasing frequency as a result of trends aimed at improved athletic performance, namely, year-round participation in a specific activity (jumping, running, kicking or climbing) in which the extensor mechanism of the knee is subjected to excessive strain.

James et al. (1978) examined the incidence of running related injuries in a clinical review of 180 patients. Twenty-nine percent of these 180 runners presented with knee problems, and, of these patients, seven percent were diagnosed as having patellar tendonitis.

More recently, Taunton and Clement (1980) conducted a survey of overuse running injuries incurred over a two year period in patients seen in their clinic. Of the 1650 runners examined, patellar tendonitis was found to be the fifth most common types of overuse running problem (81 patients). They found the most common complaint to be patello-femoral pain caused by a variety of conditions. The second most common was tibial stress syndrome followed by achilles tendonitis, plantar fasciitis, then patellar tendonitis.

While the etiology of patellar tendonitis is still not fully understood, a myriad of treatment regimens have been advocated with both conflicting and less than rewarding results. Once the diagnosis has been made, and the athlete's degree of disability established, a thorough knowledge of the natural history and disease progression of patellar tendonitis is crucial to the rehabilitative procedure. Tendonitis in general (patellar tendonitis being no exception) has long proven to be very resistant to conservative treatment. Rest is no longer an acceptable solution,
and while ice, heat and anti-inflammatory medication decrease the associated pain, the chronic and at times somewhat vicious cycle of tendonitis is not arrested.

It has become evident that the most likely etiology of patellar tendonitis is forces that are generated very rapidly, as during athletic participation, that impose forces that may exceed the maximal tensile strength of the actual tendon, and cause microscopic lesions in the tendon tissue. It is a goal in any therapy program to enhance muscular strength through hypertrophy and thereby strengthen the tendon sufficiently so that imposed athletic stresses do not exceed its tensile capacity.

The fundamental requirement for hypertrophy of any tissue is the maintenance of physiological overload on the structure. Muscle can work in three manners: concentrically (when the muscle shortens while it contracts), isometrically (when the muscle length remains constant while it contracts), and eccentrically (when the muscle lengthens as it contracts). While it is clear that some form of muscle retraining to stimulate hypertrophy is essential in attempting to resolve patellar tendonitis, it is unclear as to which method will optimize the recovery period.

Statement of the Problem

The purpose of this study is to determine which method of tendon rehabilitation - the "eccentric squat" exercise or the universal gym "leg extension/leg curl" exercise - produces a more significant result in terms of recovery in the treatment of chronic patellar tendonitis.

Subproblem

1. To determine if a relationship exists between patients who present with patellar tendonitis, and certain biomechanical malalignments and/or muscle imbalances that those patients may possess.

Hypotheses

In this study it is hypothesized that:

1. The "eccentric squat" exercise provides a more significant result than the "leg extension/leg curl" exercise in terms of ultimate recovery time in the treatment of chronic patellar tendonitis.

2. The "leg extension/leg curl" exercise group is able to produce a significant increase in moment of force as evaluated on the Cybex II isokinetic dynomometer (especially for hamstrings).
3. A relationship exists between those who suffer from patellar tendonitis and those, who upon examination, demonstrate biomechanical malalignments of the leg and foot.

Limitations

The results of this study are limited by:

1. The errors of data collection by the Lummex Cybex II isokinetic dynamometer. Gravitational forces are not taken into account by this machine, as well, errors can occur in the accuracy of reading values off the recording chart.
2. The errors that could occur in taking thigh girth measurements.
3. The method of subjectively evaluating the patient's improvement as one criteria in determining the success of the programs.
4. The subject's own motivation to work at their exercises. All, however, are athletes and it is assumed that their motivational level to improve is exceptionally high.

Delimitations

The study is delimited by:

1. The sample size.
2. The extent to which subjects are afflicted with patellar tendonitis.

Definition of Terms

For the purpose of clarification, the following definitions are considered applicable throughout the study:

1. **Patellar tendonitis** is a painful inflammatory reaction involving the patellar tendon. This reaction is an attempt by the tendon to repair damaged elastin and collagen ultrastructure with scar tissue. The cause of this damage is forces which act upon the tendon and exceed its tensile strength. Clinically, patellar tendonitis will be diagnosed when exquisite pain is elicited upon palpation at either the inferior of superior poles of the patella, or through the patellar tendon to its insertion at the tibial tubercle, in the absence of any other knee disorder (Blazina 1973).

2. **Chronic patellar tendonitis** includes all patients who have had the presenting symptoms of patellar tendonitis greater than four weeks.
3. The "Eccentric Squat" exercise is performed according to that described by Lamb and Stanish (1980) as described in Appendix A. The subject will stand with feet comfortably apart, lower the body to a semi-crouch position (thighs parallel to the floor) at first slowly, then progressing to very rapidly, then returning quickly to upright.

4. The "Leg extension/leg curl" exercise will be performed on the conventional universal gym apparatus initially sitting up and performing leg extensions, then on the stomach performing leg curls (Appendix A).

5. Recovery time involves the following factors which are important in the determination of how successfully the symptoms of patellar tendonitis are controlled by either program: an increase in muscle strength, a decrease in muscle imbalance, and a decrease in pain.

6. Concentric muscle contraction occurs when the involved muscle contracts while shortening.

7. Eccentric muscle contraction occurs when the involved muscle lengthens while contracting.

8. Isometric muscle contraction occurs when the involved muscle contracts while no change in length occurs.

9. Isokinetic exercise as performed on the Cybex II dynomometer during the testing procedure is a dynamic type of resistive exercise with two unique features:

(i) the angular velocity of the Cybex can be specified (in this study at 30° per second).

(ii) when the specified velocity is reached, the device automatically accommodates to give maximal resistance at each point in the range of motion while allowing the specified velocity to be maintained. Therefore, muscular force can be maximal at all points in the range of motion.

Rationale

According to Lamb and Stanish (1980), there are two basic avenues of treatment of patellar tendonitis. One is to remove the stresses which are responsible for the initial lesion, the other is to enhance the strength of the actual tendon so that imposed stresses do not result in injury.

Removing the stresses involves extended periods of rest. To an athlete, this means stopping or greatly decreasing his or her training program. Poor patient compliance and a further decrease in the tensile strength of the tendon ensues.
The most sensible approach would be to increase the tensile strength of the tendon. Tendon is a viable substance that will respond to a training protocol. Lamb and Stanish (1980) believe that tendonitis develops secondary to an eccentrically applied load, as occurs when antagonist muscles contract eccentrically as the movement of a body segment is decelerated and its direction changed. Three methods of enhancing strength are via concentric, eccentric, or isometric contractions. Therefore, this study was designed to examine the difference between the "eccentric squat" exercise which is largely an eccentric type of movement, and the "leg extension/leg curl" exercise which is largely a concentric exercise, in the management of chronic patellar tendonitis.
Chapter 2

REVIEW OF LITERATURE

This chapter presents a general view of the literature. The content of this chapter is divided into six main categories: the structure and function of tendon, pathogenesis of tendonitis, response of the patellar tendon to force, symptoms of patellar tendonitis and treatment.

Structure and Function of Tendon

Tendon is composed of collagen and elastin embedded in a matrix of mucopolysaccharides. Viewed cross-sectionally, tendon represents an organized grouping of regular parallel fibers. The collagen is arranged in a hierarchy of progressively smaller subunits in diameter from the tendon fascicle through fibril or fiber, subfibril, microfibril to the smallest component tropocollagen. In a relaxed or unstretched state, tendon has a wavy appearance. It is not clear whether this wave is an inherent property of the constituent fibrils determined by the amino acid sequences of their component tropocollagen molecules, or the result of the interaction of collagen fibrils with non collagenous components of the tissue. This wavy configuration disappears when the tendon is stretched (due to the elastin content of the tendon), and functions to damp the sudden strain imposed on the tendon when the muscle contracts. When the tissue is stretched, initial extension is associated with a flattening of the wave pattern (Booth 1975, Harkness 1968, Vidiik 1978).

The main function of tendon is the transmission of the tension developed by a muscle, and the mechanical properties of the structure (great tensile strength, flexibility, low extensibility and almost perfect elasticity) reflect these functional demands. Like other connective tissue, tendon is viscoelastic and composed of materials of varying tensile strength. The maximum values for the tensile strength of human tendon is 5-10 kg/mm² and for collagen 15-30 kg/mm² (Harkness 1968). It has been estimated that during a muscle contraction of maximum isometric tension, the tendon is stressed no more than one quarter of its ultimate tensile strength (Vidiik 1969). At these physiological tensions which lie at the bottom of the stress-strain curve, the tendon is relatively easily extensible, and perfectly elastic.
since greater stresses affect the collagen network itself (Booth 1978). Production of muscle tension has been found to be higher in eccentric contraction than concentric contraction, and the difference between the two types of work loads increases with the increase in contraction velocity (Komi 1977).

There is a heterogeneity of fibers in the mechanical and physico-chemical structural stability of tendon (Chvapil 1967). It seems that tendon collagen is stronger than its surrounding matrix. Within the collagen component, smaller bundles are stronger than the larger bundles, which are not ideally arranged along the line of force (Lamb 1980). Harkness (1968) found that as load is applied, weaker fibers should not depend so much on the diameter of their fibers, but more on their location in the tendon (Chvapil 1967). Also, the bone-tendon interface is inherently weaker than the tendon proper, and is therefore usually the site of initial tendon injury (Vidiik 1969).

The heterogeneous nature of tendon is also evident when examining the stress-strain curve for tendons. There is not a linear relationship between applied stress (tension per cross-sectional area) and resultant strain (percent increase in length over resting length). Rather, the curve is characteristically sigmoid in shape indicative of the viscoelastic nature of tendon tissue. Tendons display both elastic and plastic properties. It displays elasticity if it returns to its original geometric shape after the stress is removed, and if it does not return to its original shape, it displays plastic properties. When stressed, the tendon's gradual return to the original shape is termed the elastic after-effect. Vidiik (1967) found that tendons display plastic tendencies when submaximal loads are applied for longer periods of time.

In a region of low strain (0-2 percent greater than original resting length), considerable extension occurs with minimal increases in intratendon tension. Histological studies demonstrated that the wavy structure of the tendon that the collagenous bundles display in a relaxed state are responsible for this phenomenon (Kastelic 1978). Abrahams (1967) showed that the amount of tension in this lower region of the curve is dependent on the rate as well as the magnitude of strain, with rapid straining resulting in considerably higher tensions. Oakes and Bialkower (1977) found that exposure to heat and the enzyme elastase also have detrimental effects on the tendon, destroying this portion of the curve, and decreasing the tensile strength of the tendon.
In the mid portion of the curve in an area of strain equal to 3-5 percent greater than resting length, there is a linear rise in tension with increasing strain. In this portion of the curve, the amount of extension is controlled entirely by the behavior of the collagen fibers which are now fully extended and oriented in the direction of the load (Abraham 1967).

With strain greater than 5-6 percent of the tendon's resting length, there is no further rise in tension, and further strain results in increasing gross disruption. Physical rupture, or complete failure of the tendon, have been demonstrated at strains of 10 percent (Harkness 1968) and 30 percent (Abraham 1967) of the resting length. Damage to the tendon ultra-structure, therefore, can occur at tensions well below those measured as being maximal tensile strength. This damage does not become apparent as a gross rupture. Smaller stresses and strains through the tendon itself during intense exercise can cause the tendon to rupture if there is an alteration of the normal angle between bone and muscle belly that leads to an unequal distribution of stresses at those sites where a rupture would be most likely.

Chvapil (1967) studied the anatomy, physiology and mechanics of bone-tendon muscle groups and showed that the tendon is at its most vulnerable under the following circumstances:

(i) When tension is applied obliquely.
(ii) When tension is applied quickly.
(iii) When the tendon is tense before the trauma.
(iv) When the attached muscle group is stretched in an eccentric manner by external forces such as gravity or the muscular strength of the thigh, for example, in an unexpected manner.
(v) When the tendon is weak in comparison with the muscle.

He demonstrated that, mechanically, even healthy tendons can be ruptured. It has yet to be proven whether the observed changes in the load-elongation (stress-strain) curve after a previous elongation of the tendon are responsible for a weaker tendon that is more susceptible to injury.

Tendon is a viable and metabolically active tissue that is capable of altering its structure in response to external stresses. Significant oxygen consumption, concentration of metabolic enzymes, collagen synthesis and blood flow have been measured. Because of their living and adapting nature, these and other structural characteristics of tendon are influenced by both physical activity and disuse.
In experiments carried out on animals, physical exercise has been shown to increase the tensile strength in tendon (Booth and Gould 1975, Kiiskinen 1977, Vidiik 1967, Tipton 1975). Structural changes that seem to account for this increase of isolated tendon tensile strength seem to be related to the thickness of the tendon tissue and its collagen content. The exercise has been shown to increase collagen synthesis (Heikkinen 1970, Vidiik 1978, Byrd 1973, Kiiskinen 1977), to increase the content of glycosaminoglycan ground substance (Kiiskinen and Heikkinen 1972) and to increase the fiber size and number of cellular nuclei (Booth and Gould 1975). In addition, the oxygen consumption and blood flow in the tendon increases as a result of physical activity (Vailas 1978). Vailas (1978) also demonstrated that the concentration of metabolic enzymes increases as well as the rate of enzyme activity due to the exercise. Increases in nitrogen content have also been recorded (Heikkinen and Vuori 1970).

Physical inactivity causes a reversal on many of the trends associated with physical training. The collagenous network of the tendon is disrupted as a result of a decrease in oxygen consumption and concentration of metabolic enzymes (Vailas 1978), and a decrease in collagen synthesis (Heikkinen and Vuori 1970). Physical disuse also causes a decrease in the capillary volume of the tendons and hence, greater extensibility per unit of load (Booth and Gould 1975).

The constituents of the tendon, therefore, vary in a number of ways with the changes in the level of chronic physical activity. In the rehabilitative phase after an injury, the strength of the tendon is quite sensitive to the quantity of physical activity (Booth and Gould 1975).

Pathogenesis of Tendonitis

The biomechanical aspects of the development of patellar tendonitis rest on the concept that certain activities place enough stress on the knee extensor mechanism to cause microtearing of the attachments of the tendon to bone (Blazina 1973). Tendonitis results in an inflammation of a tendon and of the musculotendinous attachment while tenosynovitis is an inflammation of the tendon in the tendon sheath (most common) (Magee 1980).

The inflammation of the tendon results in a loss of the smooth gliding action of the tendon as dense fibrous adhesions may form, and these adhesions may lead to stenosis of the sheath (Magee 1980). Blazina (1973)
felt that the formation of calcium or scar tissue depended upon which component of the tendon overresponded. Degeneration of the involved tendon would ensue and cause the tendon to become thicker, softer and lose its normal lustre.

Smillie (1978) stated that the exact pathology of tendonitis to his knowledge was unknown, but that there was a possibility that a deficient blood supply at the osseus-tendonous junction could cause circulatory impairment to healing. This has been well described in cases of supraspinatus tendonitis or in tennis elbow. Rathburn and McNabb (1970) have reported the existence of a constant zone of relative avascularity near the insertion of the supraspinatus tendon which corresponds to the most common site of degeneration and rupture of the rotator cuff. These authors suggest that the constant pressure of the head of the humerus on the supraspinatus tendon might wring out the vessels in this area and accentuate the observed avascularity. The patella has been observed to have a somewhat deficient blood supply, particularly at the inferior pole. The blood supply to a tendon is tenuous. Small nutrient arteries enter the paratenon (sheath) of the patellar tendon at the musculotendinous junction and from the periosteum. Branches extend into the deepest fibers to supply blood. It is at the midpoint of the tendon which is at the end of the supply lines that is most likely to suffer the effects of any interference with blood flow. Increases in tension within a tendon has been shown to decrease and to finally stop the blood flow in veins and capillaries (Schatzker 1969). The capillary bed decreases with age and inactivity (Schatzker 1969).

Anatomical pathologic examination of excised tendon tissue performed by Roels (1978), revealed evidence of a local mucoid degeneration and fibrinoid necrosis of the tendon. Also, he observed clefts in the tissue with a cellular border due to microtearing within a tendon. There were also areas of regeneration with proliferation of fibroblasts and thin walled vessels.

Kerlan (Blazina and Kerlan 1973) felt that there was some "factor" of an immunologic or metabolic nature present that dictates why the body responds to injury in such a destructive manner that often accompanies chronic tendonitis.

Stanish and Lamb (1980) stated that the painful inflammatory reaction of the tendonitis is initiated by microscopic disruption of the ten-
don's collagenous elastic ultrastructure, and represents an attempt to repair the damaged tissue with scar. As forces exceed the tensile strenths of the weaker tendon fibers, these fibers rupture and place a greater proportion of the tensile load on the remaining fibers. With such repetitive loading, which is at times unexpected, these fibers then have an increasingly stronger likelihood of rupturing also. Clancy (1976) felt that the ensuing inflammatory response also weakens the tendon ultrastructure causing it to become thicker and softer and further perpetrating the vicious tendonitis cycle.

Subotnick (1978) feels runner's knee problems (being a combination of factors such as chondromalacia, patellar compression/subluxation and/or patellar tendonitis) are related to improper foot function. Torsional and angular malalignments of the lower extremity have a significant influence on knee mechanics. Foot function and its influence upon knee mechanics has in the past been ignored. As the foot abnormally pronates, due in part to a varus leg/foot alignment, the medial longitudinal arch tends to flatten, and an obligatory internal tibial rotation occurs. Hence, excessive and prolonged pronation is a compensatory motion to accommodate a malalignment of the foot or leg and creates increased forces applied not only to the supporting structures of the foot but also the knee (James 1981).

The thigh internally rotates, but the foot, being fixed on the ground, cannot turn in, therefore allowing for an unstable patella (Subotnick 1978). An increased Q angle from lateral placement of the tibial tubercle, or excessive amount of external tibial rotation predisposes the patella to lateral displacement with vigorous quadriceps contraction (James 1981).

The possible relationships between tendon blood supply, blood flow, aging, muscular tension, excessive use and biomechanical malalignments on one hand, and degeneration and rupture on the other, have never been adequately explored.

Response of the Patellar Tendon to Force

The patellar tendon is subjected to both the forces generated by muscular contraction of the quadricep muscle group and to the forces applied externally by the tibia and the femur. A muscle generates force via three mechanisms of contraction: concentric, isometric and eccentric. Whether or
not an injury occurs to the tendon depends upon the magnitude of these forces, the speed of applied tension and the initial strength of the tendon in relation to the muscle (Chavpil 1967).

The tension produced during concentric contractions is inversely related to the velocity of the muscle shortening, with the maximum concentric tension being generated during the isometric condition (Komi 1973). A muscle contraction of maximum isometric force stresses the tendon no more than one quarter of its ultimate tensile strength (Vidiik 1969). The velocity of lengthening influences the amount of tension that can be developed in the muscle during the eccentric contraction. When the muscle is rapidly stretched while contracting, there is a large increase in intratendon tension directly related to the velocity of elongation (Komi 1973). Peak eccentrically generated forces have consistently been shown to exceed those generated by maximal isometric contraction (Harkness 1968, Komi 1973). In contrast, in a resting state, muscle is very extensible and when passively stretched, the tension is almost entirely absorbed by the compliant muscle tissue with no rise in intratendon tension (Cavagna 1977).

Eccentric muscle contraction is an integral part of any skilled or forceful movement. When deceleration of a body part or reversal of direction is necessary, eccentric muscle contraction plays a key role. Cavagna (1977) stated that the amount of force generated is directly related to the mass of the segment involved and the rate deceleration.

Wahrenberg (1978) monitored unskilled subjects during the eccentric phase of kicking a ball. He recorded forces of up to 5200 Newtons in the patellar tendon, a figure which approaches the measured maximum tensile strength of the patellar tendon. The authors concluded that if such forces were to be continued on a repetative basis, such forces could indeed result in patellar tendonitis. Some studies involving running and jumping animals have shown that eccentric forces actually can exceed the established values for tendon tensile strength (Alexander 1974, 1977).

Komi (1973) employed maximal eccentric contraction as the stimulus for muscle hypertrophy, and found that the eccentrically trained subjects suffered from severe muscle soreness during the preliminary period of training. This could possible indicate damage to muscle connective tissue or the tendon-muscle junction. Johnson (1976) reported that subjects exercising eccentrically all found this type of training easier to do rather than the concentric
type, even though they knew they were handling heavier resistances.

More recently, eccentric contraction has been associated with less forceful repetitive activities such as running. Cavagna (1977) demonstrated that the extensor mechanism of the knee and the plantar flexors of the foot contract initially eccentrically upon foot strike and then subsequently concentrically during the toe-off phase. Lamb and Stanish (1980) discuss how mechanical energy may be stored by the stretching of series elastic elements of muscle or tendon during eccentric contraction and be re-utilized by the immediately following concentric contraction. Cavagna (1964, 1977) has shown that the re-utilization of this "stored elastic energy" increases the mechanical efficiency of running by as much as 40-50 percent and may contribute as much as 50 percent of the total energy requirements of running.

Muscles with short fibers and long extensible tendons such as the extensor mechanism of the knee, and the plantar flexors of the foot with their long patellar and achilles tendons, appear to be best adapted for energy storage. It is interesting to note that both these tendons are the site of the chronic tendinitides associated with running and jumping athletes (Taunton and Clement 1980; James 1978).

As far as Lamb and Stanish (1980) are concerned, the most likely etiology for the microscopic lesions characteristic of tendonitis is excessive force generated during repetitive eccentric muscle contractions. Concentric and isometric contractions may exacerbate previously established tendonitis, but those forces do not appear to be sufficient to cause the initial result.

**Symptoms of Patellar Tendonitis**

Clinically, the athlete with patellar tendonitis will present with an aching pain centered over the infrapatellar or suprapatellar region. The pain may be especially localized to the inferior or superior poles of the patella, and may disappear after a period of rest varying from a few hours to several days. Swelling may or may not be present. Deceleration while playing a sport may be impossible without a feeling of giving way (Grossman 1977). Invariably, the athlete has been involved in some type of repetitive activity involving jumping, climbing, kicking or running (Blazina 1973, Roels 1978).

Blazina (1973), in describing the clinical aspects of patellar ten-
donitis conveniently classified the symptoms of patellar tendonitis into three stages. In stage one, the patient will experience pain after activity only, and no undue functional impairment will be evident. When the patient experiences pain during and after activity, he is exhibiting stage two symptoms. This athlete is still usually able to perform at a satisfactory level. The end stage symptoms are classified as such when pain during and after activity is more prolonged, and the athlete has progressively increasing difficulties in performing at a satisfactory level. This athlete, if allowed to continue intense activity, may experience a sudden catastrophic episode, feel a tremendous "giving way" and be functionally impaired and unable to extend the knee. In other words, he may completely rupture the tendon.

Over a seven year period, Blazina (1974) saw 300 basketball players with patellar tendonitis. Of these, 186 were in phase 1, 92 were in phase 2, 18 were in phase 3, 4 were in phase 4. Three of these players ruptured their extensor mechanism while playing.

Patellar tendonitis usually develops over a period of time due to repetitive activity. On rare occasions, the athlete may relate a single episode (a direct blow, a certain landing or take-off) (Blazina 1973).

**Signs of Patellar Tendonitis**

The establishment of the diagnosis of patellar tendonitis on the basis of physical examination depends upon the elicitation by the examiner of definite exquisite tenderness upon palpation of the inferior or superior poles of the patella (Blazina 1973). Generalized effusion of the knee is fairly uncommon, however cystic fluctuations in the area may be palpated (Blazina 1973). Crepitus is not an uncommon phenomenon. Many of the patients exhibit anatomical, biomechanical problems such as genu recurvatum or genu valgum or varum, patellar hypermobility, increased Q-angle, patella alta, muscle imbalances, quadriceps wasting, forefoot and/or rearfoot varum (Blazina 1973, Rubin 1980, Taunton and Clement 1980).

X-ray examination may or may not reveal irregularities of the involved pole of the patella. Fatigue fractures may eventually be detected if follow-up films were taken (Blazina 1973). In adolescents, irregular centers of ossification at the involved poles have been noted and preadolescent and adolescent athletes more often develop tendonitis at the distal insertion of
the patellar tendon. Osgood-Schlatter's disease represents a traction injury at the open apophysis of the tibial tubercle (Rubin 1980). Calcification of the involved tendon especially near the tibial tubercle has been noted especially in patients who had Osgood-Schlatter's disease as a child (Blazina 1973). Another change commonly seen is an elongation of the involved pole (Roels 1978).

Sinding-Larson-Johannson disease is also common among adolescents, and can also represent a type of traction apophysitis as seen with Osgood-Schlatter's disease. It is a form of osteochondritis of the ossification center of the lower pole of the patella.

**Treatment**

The etiology of patellar tendonitis is still not fully understood. There have been, however, a myriad of treatment regimens advocated with both conflicting and less than rewarding results. With Blazina's (1973) classification of symptoms came his outlined approach to treating patellar tendonitis.

Athletes who were stage one in Blazina's criteria were treated with ice or ice massage post activity, and again in the day if indicated. An elastic support wrap was applied to the superior aspect of the knee to ease the pain. If pain increased, anti-inflammatory medication was added for 10 - 14 days.

For those patients who experience pain both during and after activity, treatment was the same as in phase 1, but a form of heat was applied to the involved area prior to activity. Steroid injection into the tendon was the last choice, and avoided if at all possible due to its weakening effect on the tendon ultrastructure.

With prolonged pain in phase three, Blazina felt that rest was the most important. At this stage, surgical intervention was not uncommon. He advised the following approaches:

(1) drilling of the involved pole to increase blood supply to the area to facilitate healing of the tendon.

(ii) excising the degenerated portion of the tendon with resuturing of the defect.

(iii) resection of the involved pole, reattachment of the tendon and removal of the degenerated or calcified portions of the tendon.
Although the authors were fairly successful with the surgical techniques, the conservative treatment protocols were ineffective and inappropriate.

Grossman and Nicholas (1977) advocated that the treatment of patellar tendonitis be preventative in nature. They attempt to find the athlete a sport that will "fulfill he needs for competition" and at the same time avoids the mechanism contributing to the injury (kicking, jumping or running). To limit range of motion of the patella, they place their patients in a two layered, hinged patella restraining brace. They utilize an exercise program to improve leg power consisting of thigh flexion and hip abduction. They emphasize that active resistive quadricep exercises through a range of motion may not be tolerated by the patient and hence be dangerous. Grossman's conservative treatment regimen is relatively the same as Blazina's with the exception that they "practically never inject corticosteroids locally". When conservative measures fail, they may surgically attempt to resect the involved pole of the patella or to remove the degenerated quadricep or patellar tendon with supplemental reefing.

Subotnick's (1978) treatment protocol consists of exercises to build up and strengthen the quadriceps and hamstrings. Straight leg raises and isometric quadricep exercises are indicated. Foot orthotics are also indicated to provide stability at the knee by reducing independent rotation between the leg and the foot which occurs with excessive pronation.

Roels (1978) presented clinical and radiological findings and results of treatment on 36 patients with patellar tendonitis. Similarly to Blazina (1973), phase one of Roel's treatment program included an adequate warm-up with some flexibility exercises, ice massage and local anti-inflammatories with an elastic knee sleeve for support. Phase two followed the initial phase with the addition of some form of heat prior to activity, and possibly a steroid injection. Phase three included a prolonged period of rest that ultimately ended with phase four if the symptoms were not relieved. This necessitated surgery.

Roels concluded, along with Blazina, that patellar tendonitis is not a benign, self-limiting affliction. The long term history and progression of symptoms which are often resistant to conservative measures such as prolonged rest and even immobilization, suggest that patellar tendonitis is not a self-limiting phenomenon.
Krissoff (1979) confirmed jumper's knee as point tenderness over the patellar tendon and outlined his approach to treatment which included ice, aspirin and isometric exercise. He feels that a counter support brace or orthotic may be helpful if there is a static or dynamic malalignment problem. Surgery would only be indicated in chronic cases, and should include arthroscopy prior to actually exploring the tendon.

Rubin (1980) reported that he frequently saw patellar tendonitis in association with chondromalacia patella. Rubin's treatment plan included rest, ice and oral anti-inflammatories. When the pain is severe enough to prevent running, a steroid injection is administered accompanied with appropriate counselling concerning tendon weakness that is associated with corticosteroid injections. If the patients did not respond to these treatments, surgery was indicated to excise the involved area as well as the involved pole of the patella, and to reattach the tendon.

Taunton and Clement (1979) conducted a retrospective study to investigate the etiological factors operative in knee injuries in runners. Preliminary results indicated that in 8 - 12 weeks of daily muscle retraining, most pre-existing muscle imbalances and insufficiencies of the knee flexors and extensors are compensated for when combined with other specific means of treatment (anti-inflammatories and orthotics when indicated). The program enabled their athletes to return to pre-injury training in a minimal period of time. Chronic patellar tendonitis, however, proved more resistant to this conservative treatment. It became apparent to the authors from their retrospective clinical review that further research into the area of the etiology and treatment of patellar tendonitis is warranted.

Lamb and Stanish (1979) proposed as described that lesions to the tendon ultrastructure characteristic of chronic tendonitis occurs primarily during the eccentric phase of movement. They rationalized that since tendon is constantly opposed to large eccentric forces, optimal overload and subsequent hypertrophy of tendon tissue can only be achieved through graded eccentric exercise.

They implemented a program that consisted of the following five steps: (i) warm-up, (ii) flexibility exercises for the hamstrings and quadriceps, (iii) specific eccentric exercises (three sets of ten repetitions), (iv) flexibility post exercise and (v) ice application. This program was performed once daily for a minimum of six weeks. All subjects were instructed to
continue all athletic activities during the six week period unless pain made it impossible. Contrary to all previous treatment programs described, enforced rest is not part of this treatment regimen. The specific eccentric exercise for patellar tendonitis consisted of performing a knee "drop and stop" movement and then return to upright.

Although official results from this program are forthcoming, initial results were subjectively reported as very "gratifying" (Lamb 1980). Of the 17 patients on the patellar tendonitis program, 11 were "better but pain was still occurring", 5 "had no longer any pain or disability", and only 1 became "worse" from the procedure.

Another common location of tendonitis in the runner is in the achilles tendon. The achilles tendon has been examined and treated in much the same manner as the patellar tendon. Leach et al. (1981) treated his patients who were suffering from chronic achilles tendonitis with a modification of their running mileage, a heel elevation in their shoe to take some strain off the tendon complex, oral anti-inflammatory agents and a vigorous stretching routine. With the competitive or dedicated runner with persisting debilitating pain, surgery was indicated. Again, the author had some success with the surgical intervention but the chronic patient that was treated conservatively met with a variety of success rates.

Standard conservative measures of ice, rest and anti-inflammatory medication have predominated as the conservative treatment for patellar tendonitis. Blazina (1974) felt that the necessity for surgical intervention represents our failure to manage the tendonitis problem on a conservative basis. Our inability to arrest the disease progression with conservative methods illustrates our lack of knowledge about the basic mechanics involved, and points out our inability to develop an effective anti-inflammatory medication.

Other longstanding treatment procedures have been examined as to their contribution to the overall treatment plan for tendonitis. The administration of local corticosteroids is well recognized as an important therapeutic measure in the conservative treatment of local inflammatory conditions. Kennedy (1976) has brought to our attention serious complications that follow local steroid injection. Steroids injected into normal tendon weaken it significantly for up to two weeks. This effect may be even more pronounced with repetitive injections. This biomechanical disruption is directly related to
collagen necrosis. Kennedy emphasized that avoidance of vigorous muscular activity for a period of at least two weeks post injection is essential. Although controlling the inflammatory process, there is some evidence that the corticosteroid injection may retard the natural repair process and along with the associated decrease in tensile strength, predispose the involved tendon to further injury.

Long term rest also appears to be of little value in the treatment of chronic tendonitis (Lamb and Stanish 1980). Rest is initially useful in controlling the inflammatory response, but it has been demonstrated repeatedly that rest only further weakens the tendon and predisposes it to further injury upon resumption of activity (Booth and Gould 1975, Tipton 1975). Long term rest is also rarely acceptable to the athlete who is usually intent upon maintaining his or her activity level. Clearly some form of muscle retraining is essential in attempting to resolve patellar tendonitis.
Chapter 3

PROCEDURES

This chapter reviews the testing procedures used in determining the success of the exercises in question.

Subjects

Nineteen patients (13 male, 6 female) with chronic patellar tendinitis were studied. All subjects were patients of one of the three sports medicine physicians at the B.C. Sports Medicine Clinic. Criteria for selection were that the subject must have a history of athletic participation, wear no orthotics and must have had the symptoms of patellar tendinitis for greater than four weeks. The subjects ranged in age from 15 to 50 years.

Treatment Protocol

Subjects were randomly placed in either of two groups: training using the "eccentric squat" exercise, or training using the "leg extension/leg curl" exercise. A detailed step by step instruction of each exercise protocol is found in Appendix A.

Testing Procedures

The subjects were examined by the physician and were evaluated according to the assessment form in Appendix B. The patient was then randomly placed in one of the exercise programs and tested initially as follows:

1. Thigh circumferences were measured at 4.4 and 10 centimeters above the medial knee joint line. All girth variables were measured with a cloth tape. The tape was checked three times for accuracy on each measurement. It was found that the tape had not stretched throughout the course of the testing.

2. The patients subjectively evaluated their estimation of their own pain on a scale of 1 to 10. One denoted being "pain free", progressing to ten which denoted severe pain and disability caused by the patellar tendinitis.
3. Quadricep and hamstring moment of force were evaluated for both legs. All moments of force were measured on the Cybex II isokinetic dynomometer in the J.M. Buchanan Research Centre at the University of British Columbia. Lever length and torque were recorded at a speed of 30 degrees per second. The machine was calibrated before each session for each subject.

Each subject was required to read and sign a consent form outlining the testing and timing requirements. Subjects had a follow-up examination by the physician at six weeks, when clinical changes in their condition were noted, and a full evaluation of girths and moments of force were carried out. This was repeated again at twelve weeks at which time the program terminated with a final examination and evaluation. Subjects were required to keep a daily training log of their exercise programs and progressions and to note any other activities they participated in. The subjects were not told to refrain from activity, however modification of activity was recommended until control of symptoms was achieved.

Analysis of Data

The experimental design was a 2*3*2 analysis of variance with repeated measures on the last two factors with the two groups: "eccentric squat" group, and "leg extension/leg curl" group being the two levels of the independent variable. The dependent variables, the injured leg and the non-injured leg were examined at three different time periods: 0 weeks, 6 weeks and 12 weeks.

With alpha set at 0.05, the hypotheses were tested for significance using four separate analyses of variance to analyze changes in:

1. Quadricep moment of force.
2. Hamstring moment of force.
3. Thigh girth.

This provided information regarding the relative importance of the dependent variable within each level of the independent variable. The analysis was accomplished using BMD: P2V biomedical statistical package available at the computing center of the University of British Columbia (Dixon 1973).
With the retrospective clinical data, frequency distributions and graphic representations were used to evaluate the relationships that exist between the incidence of patellar tendonitis, and the biomechanical malalignments of the leg and foot that these patients present with.
Chapter 4

RESULTS AND DISCUSSION

In this chapter, the group training with the universal gym "leg extension/leg curl" exercise will be referred to as the concentric group, and the group training using the "eccentric squat" exercise will be referred to as the eccentric group. Four separate analyses of variance analyzed changes in (1) quadricep moment of force, (2) hamstring moment of force, (3) thigh girth, and (4) pain. All moments of force are reported in Newtons, having taken the length of the Cybex lever arm into account.

Results

The nineteen subjects whose mean age was 26.3 years (range 15 to 50 years) were examined by one of the three sports physicians at the B.C. Sports Medicine Clinic. The 13 males and 6 females were biomechanically assessed and the results are represented in Table 4.1. All subjects exhibited symptoms of lower pole patellar tendonitis in the absence of any other knee disorders. Nine subjects presented with symptoms confined to the left knee, while seven had symptoms afflicting only the right knee. Three subjects complained of bilateral knee pain, however, in each case, one knee was definitely the most painful (in each case this was the left knee) and this remained constant over the course of the study.

Quadricep Moment of Force

Quadricep variables are summarized in Table 4.2. There was no significant difference in quadricep moment of force over the treatment period of twelve weeks, nor was there any significant difference between the concentric group, training on the universal gym performing leg extensions and leg curls and the eccentric group who performed the eccentric squat exercise. Although there was no significant difference between the group and treatment effects, Figure 4.1 illustrates that the eccentric
Table 4.1 Subject Clinical Evaluation and Biomechanical Assessment

**DESCRIPTIVE**

<table>
<thead>
<tr>
<th>N</th>
<th>19 (13 male, 6 female)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Mean ± SD)</td>
<td>26.3 ± 9.7</td>
</tr>
<tr>
<td>Height (cm) (Mean ± SD)</td>
<td>174.8 ± 10.8</td>
</tr>
<tr>
<td>Weight (kg) (Mean ± SD)</td>
<td>71.9 ± 13.6</td>
</tr>
<tr>
<td>Location of pain</td>
<td></td>
</tr>
<tr>
<td>19 - inferior pole</td>
<td></td>
</tr>
<tr>
<td>0 - superior pole</td>
<td></td>
</tr>
<tr>
<td>3 - Bilateral</td>
<td></td>
</tr>
<tr>
<td>Swelling</td>
<td>7</td>
</tr>
<tr>
<td>Crepitus</td>
<td>3</td>
</tr>
</tbody>
</table>

**BIOMECHANICAL ASSESSMENT**

<table>
<thead>
<tr>
<th>N</th>
<th>% N</th>
<th>DEGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mild -</td>
</tr>
<tr>
<td>Varus leg/foot alignment</td>
<td>17 89%</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate - 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe - 0</td>
</tr>
<tr>
<td>Valgus leg/foot alignment</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td>Genu Varum</td>
<td>11 58%</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate - 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe - 0</td>
</tr>
<tr>
<td>Genu Valgum</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td>Tibial Varum</td>
<td>1 5%</td>
<td></td>
</tr>
<tr>
<td>Leg Length Discrepancy</td>
<td>1 5%</td>
<td>Less than 1 cm.</td>
</tr>
<tr>
<td>Pes Cavus</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td>Pes Planus</td>
<td>2 10%</td>
<td></td>
</tr>
<tr>
<td>Patellar Squint</td>
<td>4 21%</td>
<td></td>
</tr>
<tr>
<td>Increased Q Angle</td>
<td>0 0</td>
<td></td>
</tr>
</tbody>
</table>
group over the 12 week period showed larger gains as compared to the concentric group.

There was a significant difference \( p < 0.0003 \) between the injured and non-injured leg (Figure 4.3 and 4.4). As would be expected, the injured leg was weakest in all cases at the initial Cybex test (0 weeks). At the end of the program (12 weeks), the injured leg was an average of 66.3 N weaker in the concentric group and an average of 57.4 weaker in the eccentric group.

Although there was no statistical evidence that the injured and non-injured legs changed significantly in quadricep moment of force over the 12 week period, a trend showed that at the end of the twelve weeks, the injured leg in the eccentric group was on the average able to exert a larger force by 76.1 N and the concentric group was on the average 30.3 N weaker (Figure 4.2). The non-injured leg was able to exert a larger force by 33.8 N on the Cybex in the eccentric group but was an average of 28.0 N weaker in the concentric group (Figure 4.1).

For the injured leg, seven subjects in the eccentric group recorded larger quadricep moment of force readings at 12 weeks as compared to their initial test at 0 weeks. The mean increase was 114.8 N. One subject remained unchanged while two subjects decreased in quadricep moment of force. The mean decrease was 45.4 N. In contrast, the data from the concentric group had only four subjects recording larger quadricep moment of force readings at the 12 week mark. This mean increase was 45.4 N. The remaining five subjects in the concentric group decreased in moment of force from the initial value. The mean decrease was 97.9 N.

Similarly, looking at the data for the other leg, of the seven subjects in the eccentric group who demonstrated moment of force gains in the injured leg, six of these people recorded moment of force gains over the 12 week period in the non-injured leg. The mean increase was 74.3 N. Four subjects in this group decreased in moment of force an average of 26.7 N. In the concentric group, three subjects increased in moment of force \( (\bar{X} = 71.2 \text{ N}) \), and six subjects actually recorded decreases in moment of force \( (\bar{X} = 81.9 \text{ N}) \). Three of these subjects who recorded moment of force decreases in the non-injured leg were those who presented with bilateral symptoms.
Table 4.2 Mean and Standard Deviations of Quadricep Moment of Force (Newtons) Over the Twelve Week Period

<table>
<thead>
<tr>
<th>TIME</th>
<th>LEG</th>
<th>GROUP</th>
<th>CONCENTRIC</th>
<th>ECCENTRIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Weeks</td>
<td>Injured</td>
<td></td>
<td>620.3 ± 113.9</td>
<td>520.7 ± 156.6</td>
</tr>
<tr>
<td></td>
<td>Non Injured</td>
<td></td>
<td>684.0 ± 179.8</td>
<td>620.3 ± 171.3</td>
</tr>
<tr>
<td>6 Weeks</td>
<td>Injured</td>
<td></td>
<td>590.9 ± 121.5</td>
<td>570.0 ± 162.4</td>
</tr>
<tr>
<td></td>
<td>Non Injured</td>
<td></td>
<td>694.2 ± 113.0</td>
<td>677.7 ± 218.1</td>
</tr>
<tr>
<td>12 Weeks</td>
<td>Injured</td>
<td></td>
<td>590.1 ± 130.8</td>
<td>596.7 ± 160.6</td>
</tr>
<tr>
<td></td>
<td>Non Injured</td>
<td></td>
<td>655.9 ± 125.5</td>
<td>654.2 ± 192.2</td>
</tr>
</tbody>
</table>

Table 4.3 Mean and Standard Deviations of Hamstring Moment of Force (Newtons) Over the Twelve Week Period

<table>
<thead>
<tr>
<th>TIME</th>
<th>LEG</th>
<th>GROUP</th>
<th>CONCENTRIC</th>
<th>ECCENTRIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Weeks</td>
<td>Injured</td>
<td></td>
<td>287.0 ± 98.3</td>
<td>271.0 ± 123.3</td>
</tr>
<tr>
<td></td>
<td>Non Injured</td>
<td></td>
<td>299.9 ± 87.2</td>
<td>282.6 ± 110.8</td>
</tr>
<tr>
<td>6 Weeks</td>
<td>Injured</td>
<td></td>
<td>320.4 ± 92.6</td>
<td>286.1 ± 113.9</td>
</tr>
<tr>
<td></td>
<td>Non Injured</td>
<td></td>
<td>328.0 ± 89.4</td>
<td>292.8 ± 106.8</td>
</tr>
<tr>
<td>12 Weeks</td>
<td>Injured</td>
<td></td>
<td>338.2 ± 90.8</td>
<td>309.3 ± 122.4</td>
</tr>
<tr>
<td></td>
<td>Non Injured</td>
<td></td>
<td>332.4 ± 84.6</td>
<td>312.4 ± 108.1</td>
</tr>
</tbody>
</table>
Figure 4.1 Quadricep Moment of Force (Mean Values and Standard Deviations in Newtons)

Non Injured Leg

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Concentric</th>
<th>Eccentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>684.0 ± 179.8</td>
<td>620.3 ± 171.3</td>
</tr>
<tr>
<td>6</td>
<td>694.2 ± 113.0</td>
<td>655.9 ± 125.5</td>
</tr>
<tr>
<td>12</td>
<td>677.7 ± 218.1</td>
<td>654.2 ± 192.2</td>
</tr>
</tbody>
</table>

Figure 4.2 Quadricep Moment of Force (Mean Values and Standard Deviations in Newtons)

Injured Leg

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Concentric</th>
<th>Eccentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>620.3 ± 113.9</td>
<td>590.1 ± 130.8</td>
</tr>
<tr>
<td>6</td>
<td>590.9 ± 121.5</td>
<td>590.7 ± 160.6</td>
</tr>
<tr>
<td>12</td>
<td>570.0 ± 162.4</td>
<td>520.7 ± 156.6</td>
</tr>
</tbody>
</table>
Figure 4.3 Quadriceps Moment of Force (Mean Value and Standard Deviations in Newtons)

Concentric Group

MOMENT OF FORCE (NEWTONS)

700
700
680
660
640
620
600

620.3 ± 113.9
620.3 ± 113.9
694.2 ± 113.0
655.9 ± 125.5

590.9 ± 121.5
590.1 ± 130.8

0 6 12
WEEKS

Figure 4.4 Quadriceps Moment of Force (Mean Values and Standard Deviations in Newtons)

Eccentric Group

MOMENT OF FORCE (NEWTONS)

750
700
650
600
550
500

620.3 ± 171.3
620.3 ± 171.3
677.7 ± 218.1
654.2 ± 192.2

570.0 ± 162.4
596.7 ± 160.6

520.7 ± 156.6

0 6 12
WEEKS

Non Injured

Injured

Non Injured

Injured
Hamstring Moment of Force

Hamstring variables are summarized in Table 4.3. Over the 12 weeks of training, hamstring moment of force significantly increased (p<0.0001). On the average, this treatment effect showed, for the concentric group, average increases of 50.7 N and 32.5 N in the injured and non-injured legs respectively, and for the eccentric group, increases of 38.3 N and 34.7 N (Figure 4.5 and 4.6). There was no significant group effect.

There was no significant difference between the injured and non-injured legs in hamstring moment of force (Figure 4.7 and 4.8). The injured leg was either of equal moment of force, as measured on the Cybex, as the non-injured leg, or was slightly weaker (on the average 4.5 - 8.9 N). This did not significantly alter over the testing sessions.

Thigh Girths

Thigh girth measurements taken at both 4.4 and 10 centimeters above the medial knee joint line, on the whole did not significantly alter during the study, and there was no difference between the concentric and eccentric groups (Table 4.4). On the average, however, thigh girth as measured in centimeters did increase over the course of the three testing sessions for both the injured and non-injured legs. This was a significant increase for the measurement taken at 4.4 centimeters above the medial knee joint line (p<0.03). For the value taken at 4.4 centimeters, in the concentric group, the injured leg increased an average of 0.2 centimeters, the same for the non-injured leg, and in the eccentric group, the injured leg increased 0.7 centimeters and the non-injured leg by an average of 0.25 centimeters. The remaining measurements did not alter significantly over the treatment period.

There was no significant differences in thigh girth between the injured and non-injured legs. However, on the average, each girth measurement was smaller for the injured side.
Figure 4.5 Hamstring Moment of Force (Mean Values and Standard Deviations in Newtons)

Injured Leg

<table>
<thead>
<tr>
<th>WEEKS</th>
<th>Concentric</th>
<th>Eccentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>287.0 ± 123.3</td>
<td>286.1 ± 113.9</td>
</tr>
<tr>
<td>6</td>
<td>320.4 ± 92.6</td>
<td>309.3 ± 122.4</td>
</tr>
<tr>
<td>12</td>
<td>338.2 ± 90.8</td>
<td>328.0 ± 89.4</td>
</tr>
</tbody>
</table>

Figure 4.6 Hamstring Moment of Force (Mean Values and Standard Deviations in Newtons)

Non Injured Leg

<table>
<thead>
<tr>
<th>WEEKS</th>
<th>Concentric</th>
<th>Eccentric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>282.6 ± 110.8</td>
<td>299.9 ± 87.2</td>
</tr>
<tr>
<td>6</td>
<td>312.4 ± 108.1</td>
<td>292.8 ± 106.8</td>
</tr>
<tr>
<td>12</td>
<td>332.4 ± 84.6</td>
<td>328.0 ± 89.4</td>
</tr>
</tbody>
</table>
Figure 4.7  Hamstring Moment of Force (Mean Values and Standard Deviations in Newtons)

Concentric Group

<table>
<thead>
<tr>
<th>WEEKS</th>
<th>Injured</th>
<th>Non Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>287.0± 98.3</td>
<td>299.9</td>
</tr>
<tr>
<td>6</td>
<td>328.0± 89.4</td>
<td>320.4± 92.6</td>
</tr>
<tr>
<td>12</td>
<td>338.2± 90.8</td>
<td>332.4± 84.6</td>
</tr>
</tbody>
</table>

Figure 4.8  Hamstring Moment of Force (Mean Values and Standard Deviations in Newtons)

Eccentric Group

<table>
<thead>
<tr>
<th>WEEKS</th>
<th>Injured</th>
<th>Non Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>271.0± 123.3</td>
<td>282.6</td>
</tr>
<tr>
<td>6</td>
<td>286.1± 113.9</td>
<td>292.8</td>
</tr>
<tr>
<td>12</td>
<td>312.4± 108.1</td>
<td>309.3± 122.4</td>
</tr>
</tbody>
</table>
Pain

There was a significant difference in pain ratings between the concentric and eccentric group averaged over the three testing sessions ($p < 0.01$). Initially, the concentric "average" pain rating was 6.2 on the continuum scale of 1 (no pain) to 10 (severe pain) and the eccentric group 5.6. By the end of the 12 weeks, the concentric group's pain had diminished on the average by 1.1 scale points, while the eccentric group's pain had diminished by an average of 3 points (Figure 4.8). This change over the three testing sessions was also significant ($p < 0.01$). The interaction between the groups and the three testing sessions was not significant suggesting that the trend of pain to decrease is similar in both the concentric and eccentric groups, however the eccentric group significantly decreases more.

Overall, in the concentric group, two subjects were pain free (one after six weeks, one after twelve weeks), four subjects improved their condition slightly (average of 2.2 scale points), two subjects showed an increase in pain (average of 1.5 scale points), and one subject remained the same. In contrast, in the eccentric group, four subjects were pain free (two after six weeks and two after twelve weeks), five subjects improved their condition (average of 2.8 scale points), while one subject had an increase in pain (by 3 scale points) (Table 4.4 and 4.5).

Clinical Data

Over a three year period, 1978 - 1981, 129 patients presented at the B.C. Sports Medicine Clinic with patellar tendonitis. This accounted for 4.5 per cent of all running induced injuries seen in the clinic during that period. In all, 93 patients were male, and 36 patients were female (72 per cent and 28 per cent respectively). 55 patients were diagnosed as having inferior pole patellar tendonitis, while 14 clinically demonstrated superior pole symptoms. Of these 69 patients, 13 had bilateral involvement.

A summar of the clinical biomechanical evaluation appears in Table 4.7. In general, results show that the patellar tendonitis patient is one who possesses a varus foot/leg relationship, with a degree of genu varum.

Moment of force data for the quadricep and hamstring groups was available only on 26 of the 129 tendonitis patients (19 of whom participated).
### Table 4.4 Mean and Standard Deviations of Thigh Girth (centimeters)
Over the Twelve Week Period

<table>
<thead>
<tr>
<th></th>
<th>Concentric</th>
<th>Eccentric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4.4 Centimeters Above Medial Knee Joint Line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concentric</td>
</tr>
<tr>
<td></td>
<td>0 Weeks</td>
<td>37.7± 1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37.9± 1.2</td>
</tr>
<tr>
<td></td>
<td>6 Weeks</td>
<td>37.8± 1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38.2± 1.3</td>
</tr>
<tr>
<td></td>
<td>12 Weeks</td>
<td>37.9± 1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38.1± 1.4</td>
</tr>
<tr>
<td></td>
<td>10 Centimeters Above Medial Knee Joint Line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 Weeks</td>
<td>44.4± 2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44.5± 2.5</td>
</tr>
<tr>
<td></td>
<td>6 Weeks</td>
<td>45.1± 2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45.0± 2.6</td>
</tr>
<tr>
<td></td>
<td>12 Weeks</td>
<td>44.4± 2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45.2± 3.1</td>
</tr>
</tbody>
</table>
in the study). In examining the quadricep/hamstring ratio, only 7 patients had an acceptable ratio of 50 per cent or better (hamstrings being at least 50 per cent as strong as the quadriceps). Refer to Table 4.6. The remainder of the patients had marked muscle imbalance in both the injured and non-injured legs that were well below the 50 per cent ratio. These ratios were essentially similar for both groups.

Discussion

The results appear to indicate that the "eccentric squat" exercise produces a more superior result in terms of controlling the symptoms of chronic patellar tendonitis than does the conventional universal gym "leg extension/leg curl" exercise. Controlling the symptoms of patellar tendonitis is directly related to controlling the patient's subjective feeling of pain, and not directly dependent on increases in quadricep or hamstring moment of force, or thigh girth. However, it became evident that those patients who became totally pain-free after the twelve week program were those who actually demonstrated an increase in both quadricep and hamstring moment of force, a decrease in muscle imbalance in both the injured and non-injured legs, all secondary to a decrease in their perceived pain.

Although it was not significant (there was a large variance), the quadricep moment of force of those in the eccentric group improved a fair amount (75.7 N in the injured leg and 35.6 N in the non-injured leg). On the average, the quadricep moment of force of those in the concentric group actually decreased (31.1 N in the injured leg and 26.7 N in the non-injured leg). The average decrease in moment of force associated with the concentric group can be largely accounted for by two subjects in particular who dramatically decreased in moment of force as a direct result of the aggravation caused by the particular exercise and training schedule leading to a great increase in pain. Average moment of force decreases for those in the concentric group in the non-injured leg can possibly be explained by the three subjects who presented with bilateral complaints. The course of the exercise appeared to aggravate this leg (the non-injured), in which only minimal signs of patellar tendonitis were initially apparent, and cause an associated moment of force decrease. Exercise compliance and the use of submaximal weights to attempt to induce moment of force gains in a normal leg may also be factors.
Figure 4.9 Pain Ratings (Mean Values)
Figure 4.10 Pain Ratings: Concentric Group

<table>
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<tr>
<th>Subject</th>
<th>Week</th>
<th>Continuum Scale</th>
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<tbody>
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<td></td>
<td>1  2  3  4  5  6  7  8  9  10</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
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</table>

* denotes pain free
Figure 4.11 Pain Ratings: Eccentric Group

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</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
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<td>6</td>
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</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
</tr>
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<td>0</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>12</td>
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</tr>
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<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
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<tr>
<td></td>
<td>12</td>
<td></td>
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<tr>
<td>6</td>
<td>0</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>*</td>
</tr>
<tr>
<td>7</td>
<td>00</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>*</td>
</tr>
<tr>
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<td>12</td>
<td>*</td>
</tr>
<tr>
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<td>0</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
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<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td></td>
<td>6</td>
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</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>*</td>
</tr>
</tbody>
</table>

* denotes pain free
Table 4.5 Patellar Tendonitis Patients (N= 129)* Biomechanical Assessment

<table>
<thead>
<tr>
<th>Condition</th>
<th>N</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varus leg/foot alignment</td>
<td>105</td>
<td>48</td>
<td>51</td>
<td>6</td>
</tr>
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<td>Valgus leg/foot alignment</td>
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<td>0</td>
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<tr>
<td>Genu Varum</td>
<td>64</td>
<td>44</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Genu Valgum</td>
<td>14</td>
<td>12</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Tibial Varum</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Length Discrepancy</td>
<td>11</td>
<td></td>
<td></td>
<td>Less than 1 cm</td>
</tr>
<tr>
<td>Pes Cavus</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pes Planus</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patellar Squint</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Q angle</td>
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<td></td>
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<td>Greater than 15°</td>
</tr>
<tr>
<td>Plantar Flexed 1st Ray</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good Alignment</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral Involvement</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior Pole Involvement</td>
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<td></td>
</tr>
<tr>
<td>Inferior Pole Involvement</td>
<td>55</td>
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<tr>
<td>Surgical Intervention</td>
<td>5</td>
<td></td>
<td></td>
<td>(3.8 per cent of Total N)</td>
</tr>
</tbody>
</table>

*These statistics include the 19 subjects involved in the study
Table 4.6  Quadricep/Hamstring Ratios (%) at Initial Examination

<table>
<thead>
<tr>
<th>Group</th>
<th>Subject</th>
<th>Injured Leg</th>
<th>Non-Injured Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concentric</strong></td>
<td>1</td>
<td>39.0</td>
<td>39.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>38.5</td>
<td>50.0</td>
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<td></td>
<td>3</td>
<td>46.0</td>
<td>45.0</td>
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<td>4</td>
<td>46.5</td>
<td>44.9</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>42.8</td>
<td>42.0</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>63.0</td>
<td>48.8</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>78.2</td>
<td>57.6</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>33.3</td>
<td>34.2</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>41.6</td>
<td>36.7</td>
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<tr>
<td><strong>Eccentric</strong></td>
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<td>45.0</td>
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<td></td>
<td>11</td>
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<td>14</td>
<td>61.7</td>
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<td>15</td>
<td>83.2</td>
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<td></td>
<td>17</td>
<td>56.7</td>
<td>53.9</td>
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<td>23</td>
<td>56.3</td>
<td>61.0</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>35.0</td>
<td>31.0</td>
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<tr>
<td></td>
<td>25</td>
<td>41.0</td>
<td>46.0</td>
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</table>
The eccentric squat program appeared to better control the muscle imbalance between the quadricep and hamstring groups within each leg than did the leg extension/leg curl program. Also important in any rehabilitation procedure is the fact that the injured leg should become as close in moment of force to the non-injured leg as soon as possible. Wyatt and Edwards (1981) suggest ratios between 95 per cent and 98 per cent between the injured and non-injured knees as criteria. At the beginning of the study, this ratio was 90 per cent for the concentric group and 83 per cent for the eccentric group. By the end of the twelve weeks, the injured leg was 89 per cent and 91 per cent as strong as the non-injured leg in the concentric and eccentric groups respectively.

In terms of the initial hypotheses of this study, the leg extension/leg curl group did not increase in moment of force more so than the eccentric squat group. Conversely, as stated, the eccentric group had a larger gain in quadricep moment of force (although not significant).

The hamstrings, on the whole, increased in moment of force ($p < 0.0001$) similarly in both groups. In other words, the eccentric squat exercise appears to provide sufficient stimulation to cause an increase in moment of force for the hamstrings as well as for the quadriceps. This suggests that hamstring strength is of some importance during an eccentric contraction of the quadriceps muscle, and a weakness in this area could certainly be one of the contributing factors in causing the tendonitis. As an athlete, for example, is landing from a jumping situation, or is performing the eccentric squat exercise, the hamstrings must function in assisting initially as a braking force and then again as the athlete initiates action in resuming a standing position. Although hamstring moment of force increments in this study are not large, (average 35.6 N - 53.4 N), the low variability of hamstring strength values contributed to the significance of this gain. As would be expected, there was no difference between the injured and non-injured legs in hamstring moment of force in either group.

Girth measurements have been found to be valuable in estimating relative limb disuse atrophy following an injury. We found an average of a 0.5 to 1 centimeter difference between the injured and non-injured sides. Girth measurements at 4.4 centimeters above the medial knee joint line appear the most imbalanced between the injured and non-injured, possibly due to atrophy in vastus medialis.
These girth measurements do not reflect injury rehabilitation and associated moment of force gains. We did, however, find that on the average, thigh girths taken at both 4.4 and 10 centimeters above the medial knee joint line increased over the twelve week period (not significant). This does not reflect injury rehabilitation, and it would not be practical to correlate this increase in thigh girth to increases in leg moment of force. In essence, thigh girth is an unreliable measure in predicting injury rehabilitation, however, it does give the physician an estimation of injury associated atrophy.

Subjective patient evaluation of pain proved beneficial in this study in the evaluation of the exercises. Each subject evaluated his or her own feeling and estimation of pain on a given scale, and were subsequently asked to compare each rating with the next in order to obtain a general course of progress. The subject's estimation of the pain on the average decreased over the twelve weeks significantly more so for those in the eccentric group \((p<0.01)\). The eccentric group also produced twice as many "pain free" subjects by the end of the program than did the concentric group.

All subjects were required to maintain their activity level as high as possible throughout the program. In other words, as in Lamb and Stanish's protocol, enforced rest was not part of the study. The subjects whose conditions deteriorated (in either group) were all collegiate level athletes and two out of the three in particular, were volleyball players who were in the midst of exceptionally hard training schedules that included stair running, continual jumping exercises and long weekend tournaments that sometimes entailed as many as five matches per day. While it appears that tendonitis patients can attempt to maintain their activity levels, the physician must caution the athlete to limit some activity and restrict themselves from certain detrimental exercises (stair running and jumping drills in particular) until the symptoms have been controlled and the injured leg is gaining strength.

Level and intensity of activity varied greatly with the subjects. For the collegiate athletes, tournament and practice schedules greatly decreased over a holiday period, and this rest from high level activity allowed one subject in particular to become pain free after the first six weeks of his exercise program (Subject 9, Figure 4.10). Upon resumption of high level participation this subject again became symptomatic with an associated increase in his pain rating over the last six weeks. It can be speculated that despite the rest and the rehabilitation program he adhered to, he attempted
to resume intense activity without sufficient time for adaptation after the rest.

Lamb and Stanish (1980) reported that during the first three weeks of the eccentric squat exercise, pain may actually increase. Upon examining the exercise logs each subject was required to keep, specific days associated with pain tended to appear more frequently for the eccentric group during the first few weeks of the program. Muscle tends to become sore in the early stages of eccentric training most probably due to high production of tension, or after fatigue loading with repeated maximal eccentric contraction (Komi 1973).

Exercise compliance is difficult to control for in a study such as this one. Over the twelve week period, it was recommended that the subjects perform their specific exercise routine five times per week, in conjunction with their regular activities. This would entail, over the twelve weeks, sixty exercise bouts. The average number of exercise periods for those in the eccentric group was 46.6 while for the concentric group it was 37.6. Most subjects were able to maintain their activity level throughout the course of the study (three subjects to an excess, while three subjects were very minimally active). Those who were minimally active over the twelve weeks either lacked motivation, or as in most cases, pain was their limiting factor. It was apparent in two cases that after an initial gain in moment of force and a "pain free" rating at the six week mark, motivation to continue working at their exercises decreased, and an attitude that they no longer required exercise therapy developed. They did, however, continue to exercise although not to the same extent as during the first six weeks.

In all, it appeared that exercise compliance was related to the fact that for the eccentric squat exercise, convenience and availability of equipment played a major role. The availability of a universal gym, and the nature of the weight increments make it difficult to be used as a rehabilitative tool. In some cases, patients attempting to slowly increase their resistance will jump from 10 to 15 kg because of convenience rather than purchase and utilize small 1 kg weights in order to increase more slowly. Although this was recommended to those in the concentric group, only three took that advice. In some cases, it can be postulated that overloading an already weakened structure too quickly causes further aggravation.
While it appears that the eccentric exercise is a successful rehabilitative exercise, the exact physiological response of the tendon is unknown. The physiological changes, especially with respect to tendon hypertrophy, associated with eccentric work have yet to be examined. In both concentric and eccentric work, the activation of muscle increases linearly with the increase in force output. Production of muscle tension can be much higher in eccentric contraction, and the difference in tension between maximal eccentric work and concentric work increases with the increase in contraction velocity (Asmussen 1965, Komi 1973). While the two exercises (the eccentric squat and the leg extension/leg curl) were neither uniquely eccentric or concentric respectively, nor were they of maximal stress, the major component of each exercise (the period during which the most loading took place), occurred either during an eccentric phase or a concentric phase.

The speed of muscle contraction is an integral component of the loading phase during the eccentric squat exercise, and it has also been found to be important to rehabilitation in terms of reproducing sport specific speeds (Wyatt 1981). While the leg extension/leg curl exercise must be performed slowly, the eccentric squat exercise must be performed progressively faster. The exercise would then be simulating a jumping/landing situation in terms of the speed of quadricep contraction. It is plausible that in this manner the eccentric squat exercise not only can be useful as a therapeutic exercise but can also have implications in the prevention of such overuse tendinitides. Lamb and Stanish (1980) suggest that strengthening the tendon during the eccentric phase of muscle contraction may lead to less susceptibility to microtearing of the tissue associated with tendonitis. It may also be the case that in performing the exercise at sport specific speeds, the athlete might be better prepared to re-enter high level competition after a minimal period of time.

The signs and symptoms of patellar tendonitis in the 129 patients seen at the B.C. Sports Medicine Clinic over the three year period appear consistent with those described by others (Blazina 1973, Roel 1978, Smillie 1978, Krissoff 1979, Magee 1980). The clinical diagnosis was based upon the recognition of common specific signs elicited during the physical examination, as described by Blazina (1973) and Roel (1978). The usual progression of symptoms was common in nearly all patients. The majority of the patients clinically demonstrated tenderness at the patellar insertion of the patellar tendon.
(lower pole), while only a few exhibited signs at the quadriceps insertion (superior pole).

Our statistics showed that a variety of athletes may experience patellar tendonitis (Table 4.7), and on the average, they possess some degree of varus foot alignment and some genu varum. In terms of etiology, one can first look at the biomechanics of the athlete. While it seems convenient to attempt to correlate biomechanical abnormalities with the injury, it appears that the average structural malalignment of the patellar tendonitis patient is no different from the average biomechanical problems any athlete may present with who has any number of different overuse problems. For example, a runner's predisposition to injury increases with his degree of functional overpronation (Taunton and Clement 1980). The majority of the tendonitis patients did have some degree of varus heel and/or forefoot alignment.

Causes of overuse injuries have been placed in four categories as described by James et al. (1978) and subsequently by Taunton and Clement (1980). Briefly these are: (1) Training errors including persistent high intensity training, and sudden increases in training and/or competition. (2) Anatomical factors including leg length discrepancies, femoral neck anteversion, quadriceps and/or hamstring insufficiency and/or imbalance, genu valgum, varum and recurvatum, Q angle greater than 15°, patella alta. tibial torsion, tibial varum, lower leg-heel and/or heel-forefoot malalignment, pes cavus, and pes planus. (3) Running shoes. (4) Training surfaces.

The most common factors directly implicated in patellar tendonitis (i.e. that occurred in twenty or more patients) were (i) a single severe session of activity that lead to progressive symptoms, and (ii) quadricep insufficiency (poor flexibility and/or muscle dysfunction).

The most prevalent sport the patellar tendonitis patients were involved in were running followed by basketball, volleyball, and soccer (Table 4.7). This could be slightly misleading since by far the majority of patients seen in the clinic are runners. All patients were able to report that the activity that they were most involved in did subject the extensor mechanism to excessive repetitive types of strain.

Of all patellar tendonitis patients seen over this three year period, to date, five have resulted in surgery (3.8 per cent). This is a much lower incidence of surgical treatment than that described by Roel (36 percent) and by Blazina (12 to 20 percent). These higher surgical statistics from a few
years past could reflect the disappointing results these authors had reported with conservative treatment regimens for patellar tendonitis.

Table 4.7 Athletic Involvement of Patellar Tendonitis Patients

<table>
<thead>
<tr>
<th>SPORT</th>
<th>NUMBER (N=129)</th>
<th>% N</th>
<th>NUMBER OF SUBJECTS IN STUDY (N = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td>84</td>
<td>65.0</td>
<td>3</td>
</tr>
<tr>
<td>Basketball</td>
<td>16</td>
<td>12.0</td>
<td>6</td>
</tr>
<tr>
<td>Volleyball</td>
<td>11</td>
<td>8.5</td>
<td>2</td>
</tr>
<tr>
<td>Soccer</td>
<td>4</td>
<td>3.0</td>
<td>3</td>
</tr>
<tr>
<td>Tennis</td>
<td>3</td>
<td>2.0</td>
<td>1</td>
</tr>
<tr>
<td>Rowing</td>
<td>3</td>
<td>2.0</td>
<td>1</td>
</tr>
<tr>
<td>Ballet</td>
<td>2</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Football</td>
<td>1</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>1</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>Hiking</td>
<td>1</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Ice Hockey</td>
<td>1</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Rollerskating</td>
<td>1</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Squash</td>
<td>1</td>
<td>1.0</td>
<td>1</td>
</tr>
</tbody>
</table>
Chapter 5

SUMMARY AND CONCLUSIONS

Summary

The main purpose of this study was to determine which method of exercise rehabilitation - the "eccentric squat" exercise or the universal gym "leg extension/leg curl" exercise - produced a more significant result in terms of recovery in the treatment of chronic patellar tendonitis. A second objective was to determine if a relationship existed between patients who present with patellar tendonitis, and certain biomechanical malalignments and/or muscle imbalances.

Nineteen patients all with chronic patellar tendonitis were placed in one of two groups in which they either performed the "eccentric squat" exercise of the "leg extension/leg curl" exercise. Moment of force evaluations were performed on the Cybex II isokinetic dynomometer for both the quadricep and hamstring muscle groups in each leg, thigh girth measurements both 4.4 and 10 centimeters above the medial knee joint line were taken, and subjective evaluations of pain were collected. This occurred at three testing sessions during the twelve week program: initially at 0 weeks, at 6 weeks and again at 12 weeks.

Results showed that the "eccentric squat" exercise produced a more superior result in terms of controlling the symptoms of patellar tendonitis than did the conventional universal gym "leg extension/leg curl" exercise. Both groups significantly improved their hamstring moment of force over the twelve weeks, but only the "eccentric squat" group averaged larger moment of force readings for the quadriceps. This increase, however, was not found to be significant. There was a significant decrease in pain for those performing the "eccentric squat" exercise, and while the group exercising on the universal gym experienced an average decrease in pain, it was neither significant nor was it of the same extent as experienced by the "eccentric squat" group. Girth measurements did not significantly differ over the twelve weeks.

A relationship appears to exist between patients who present
with patellar tendonitis, and certain biomechanical malalignment problems these people display. This relationship, however, appears similar to the relationship found with any type of athlete who subjects himself to repetitive activity and presents with any number of overuse problems. The most common etiological factors implicated in patellar tendonitis cases were: (i) quadricep insufficiency and/or muscle imbalance, and (ii) a single severe session of activity.

It appears indicated to recommend the use of the "eccentric squat" exercise as an approach toward the conservative management of chronic patellar tendonitis. In addition, attention must be paid to the correction of any biomechanical malalignment problems the patient may possess. While it seems apparent that these athletes can continue to be active while being treated, the type and level of activity should be monitored and modified if warranted.

Conclusions

1. The "eccentric squat" exercise appears to control the painful symptoms of chronic patellar tendonitis better than the "leg extension/leg curl" exercise.

2. Moment of force gains in the associated muscle group do not necessarily correspond to the patient's diminishing pain symptoms. The ability to increase one's moment of force in the affected limb, however, is felt to be important in terms of being essential to a full recovery and to the ability to return to pre-injury activity levels.

3. Girth measurements of limbs do not necessarily reflect strength or moment of force increments. They appear to be of little value as a criteria for determining injury rehabilitation.

4. It seems apparent that an athlete's predisposition to an overuse injury such as patellar tendonitis increases with certain etiological factors and biomechanical malalignment problems, but those who present with patellar tendonitis are generally no different than those who may present with any variety of other commonly seen overuse type injuries.

5. The subjects own evaluation of their pain progressions over the twelve weeks proved valuable in this study.
Recommendations

1. Further research should be conducted using a similar protocol to examine the effects of an "eccentric" type of exercise on other areas commonly associated with chronic tendonitides. An "eccentric" type of exercise could be performed for the achilles tendon and for the wrist extensor tendons associated with tennis elbow.

2. The physiological mechanism of adaptation within a tendon exposed to eccentric forces must be examined and possibly correlated to the clinical management of the tendonitis symptoms.

3. In order to fully evaluate the merits of the "eccentric squat" exercise as a rehabilitative tool in the management of chronic patellar tendonitis, long term follow-up data should be collected on the patients. Ideally, one would like to see a patient continue with full activity with no recurrence of tendonitis symptoms.

4. The role of specialized, graded eccentric type exercise that has been based upon scientific training principals in the prevention of chronic tendonitis should be investigated.
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Appendix A

TREATMENT PROTOCOL
B.C. SPORTS MEDICINE CLINIC

Concentric (Isometric/Isotonic) Rehabilitation

Protocol for Patellar Tendinitis

Phase 1

To achieve the earliest possible control of the symptoms, avoid symptom producing activities where possible and minimize those symptom producing activities that cannot be avoided.

Occasionally, more complete rest with crutches or immobilization is necessary to obtain initial control of the symptoms.

Anti-inflammatory medication and regular ice packs (10 minutes every 2-3 hours) is advisable. A progressive weight program should be started as soon as possible during phase 1.

Phase 2

The progressive isometric/isotonic weight program consists of 3 sets of 10 lifts for each of two exercises. These exercises are to be performed once daily, 5 days per week.

The isometric quadriceps exercise is the start of the program (Table 1). First attempts at this exercise will not produce three sets of ten repetitions. Slowly progress to 10 repetitions as pain diminishes and strength increases.

Figure 1 illustrates the 'Universal weight machine' isometric quadriceps exercise. Insert pin at 10 lbs. (5 kgs.). Grasp the top footpiece normally used for the hamstring exercise and lift the top footpiece until the bottom footpiece is level with the bench top. Then, fully extend the knee, lower the weight on to the foot and hold the leg in the extended position for 5 seconds. Do not attempt to hyper-extend the knee. At the end of 5 seconds, lift the weight off the foot, lower the leg and rest 5 seconds. Repeat to a maximum of 10 repetitions. To correct or prevent the establishment of a dynamic imbalance, it is important that the same weight is used and the same number of repetitions are performed on each leg. Alternate sets of ten lifts between left and right legs, allowing one leg to rest while the other is working.
Figure 2 illustrates the 'Universal weight machine' used to perform the isotonic quadricep exercise after the Start level is mastered. The pin is inserted into the weight stack as per the guidelines of Table 1. Hook the injured side foot underneath the bottom footpiece, then slowly lift the weight (with the injured leg) to full extension. Hold the knee fully extended for two seconds, then slowly lower. Each lift from start to finish should take at least 5 seconds. Repeat this lift up to 10 times (1 set) then rest. Repeat these repetitions twice more. As before, repeat with the other leg.

The Universal weight machine is in graduations of 10 pounds (5 kilograms). It is advisable to purchase four 2 pound fish weights to allow a smaller poundage increase. This also allows a progression between levels in Table 1.

### TABLE 1

Guidelines for Concentric Knee Extensions

<table>
<thead>
<tr>
<th>Body Weight (pounds)</th>
<th>Progression</th>
<th>Stack Weight</th>
<th>Activity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 to 130</td>
<td>Start</td>
<td>10 10 10</td>
<td>Isometric</td>
</tr>
<tr>
<td>130 to 160</td>
<td>Level 1</td>
<td>10 20 25</td>
<td>Isotonic</td>
</tr>
<tr>
<td>160 to 200</td>
<td>Level 2</td>
<td>20 30 40</td>
<td>Isotonic</td>
</tr>
<tr>
<td></td>
<td>Level 3</td>
<td>25 40 55</td>
<td>Isotonic</td>
</tr>
<tr>
<td></td>
<td>Level 4</td>
<td>30 50 70</td>
<td>Isotonic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>modified rest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>jogging-alternate days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>½ speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3/4 speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>full speed daily running</td>
</tr>
</tbody>
</table>
When three sets of 20 drops can be performed easily, progress to the next level as per Table 1. If knee pain occurs during or after a session, immediately apply ice to the area for 10 minutes and do the previous level of intensity the following day. As this is a new activity pattern, there may be some discomfort in your quadriceps and/or knee area, this doesn't indicate damage. Again, ice the area for at least 10 minutes.

Figure 3 illustrates the isotonic hamstring exercise. The pin is inserted into the weight stack at the desired weight. This weight should be approximately ½ the weight used in the quadricep extension (as outlined in Table 1).

To perform the weight-machine isotonic hamstring exercise, lie prone on the weight machine bench and position the back of the lower calf under the top footpiece with the leg extended. Slowly flex the knee to 90 degrees, hold the knee in the flexed position for 2 seconds, and then slowly return the weight to the starting position. Each lift, from start to finish, should take at least 5 seconds. Repeat the exercise. As in the quadricep exercise, attempt to complete 3 sets of 10 repetitions with the same weight on each leg, once daily, 5 days per week.

![Start Lift to 90° Flexion](image)

**FIGURE 3**
Isotonic Leg Flexion Exercise

Athletes who present with minor knee pain may be permitted to follow a modified running program before the symptoms are completely controlled. However, this decision is to be made by the examining doctor- not by the athlete.

**Phase 3**

The graduated running program is not to be started until the symptoms are completely controlled and the isometric lifts can be performed easily at level 1. To start, running is done on alternate days, beginning with 1 km, and increasing by 1 km, every third run. Begin with jogging and gradually progress to full speed running, according to the intensity level in Table 1. Initially, running should be restricted to straight ahead on smooth, flat, even surfaces. Upper body weights, swimming or cycling, if tolerated, should be performed on 'rest' days to maintain fitness. Daily running can commence once Level 4 is reached, providing there are no symptoms.
Phase 4
The maintenance program begins once Level 4 is attained and daily running has been achieved, free of any symptoms.

The maintenance program consists of unrestricted physical activity as tolerated, continuing the level 4 isotonic lifts 2-3 times per week, and a daily program of quadricep, hamstring and lower leg flexibility exercises.

Avoid kneeling on hard surfaces and wear knee pads to protect the knee from direct trauma when the risk presents itself.

Eccentric Rehabilitation Protocol for Patellar Tendinitis

Phase 1
To achieve the earliest possible control of the symptoms, avoid symptom producing activities where possible and minimize those symptom producing activities that cannot be avoided.

Occasionally, more complete rest with crutches or immobilization is necessary to obtain initial control of the symptoms.

Anti-inflammatory medication and regular ice packs (10 minutes every 2-3 hours) is advisable. A progressive weight program should be started as soon as possible during phase 1.

Phase 2
The eccentric weight program consists of three sets of 20 drops performed once daily, 5 days per week.

Figure 1 illustrates the start and finish positions for the eccentric drop. To start, stand erect, place your hands at your sides. Your feel should be flat on the ground, approximately shoulder width apart. Unlock your knees quickly and allow yourself to drop just short of your thighs being parallel to the ground. Then stop your fall with your quadriceps of both legs. Do not let your thighs go beyond the parallel line to the ground! The first time you perform these drops, have someone watch you or watch yourself in a mirror, so as not to go too far on the drop.

a) Start position:
   i) Knees straight
   ii) Feet shoulder width apart

b) Finish position:
   i) Thighs parallel to ground
   ii) Hands to side for balance

FIGURE 1  ECCENTRIC DROP
When three sets of 20 drops can be performed easily, progress to the next level as per Table 1. If knee pain occurs during or after a session, immediately apply ice to the area for 10 minutes and do the previous level of intensity the following day. As this is a new activity pattern, there may be some discomfort in your quadriceps and/or knee area, this doesn't indicate damage. Again, ice the area for at least 10 minutes.

Athletes who present with minor knee pain may be permitted to follow a modified running program before the symptoms are completely controlled. However, this decision is to be made by the examining doctor - not by the athlete.

**TABLE 1**

**Guidelines for Eccentric Drop**

<table>
<thead>
<tr>
<th>Body Weight (pounds)</th>
<th>100</th>
<th>131</th>
<th>161</th>
</tr>
</thead>
<tbody>
<tr>
<td>to</td>
<td>to</td>
<td>to</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>160</td>
<td>200</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Progression</th>
<th>Hand Weights</th>
<th>Activity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>0</td>
<td>modified rest</td>
</tr>
<tr>
<td>Level 1</td>
<td>5</td>
<td>jogging - alternate days</td>
</tr>
<tr>
<td>Level 2</td>
<td>10</td>
<td>½ speed</td>
</tr>
<tr>
<td>Level 3</td>
<td>10</td>
<td>3/4 speed</td>
</tr>
<tr>
<td>Level 4</td>
<td>20</td>
<td>full speed daily running</td>
</tr>
</tbody>
</table>

**Phase 3**

The graduated running program is not to be started until the symptoms are completely controlled and the eccentric drops can be performed easily at level 1. To start, running is done on alternate days, beginning with 1 km. and increasing by 1 km. every third run. Begin with jogging and gradually progress to full speed running, according to the intensity level in Table 1. Initially, running should be restricted to straight ahead on smooth, flat, even surfaces. Upper body weights, swimming or cycling, if tolerated, should be performed on 'rest' days to maintain fitness. Daily running can commence once Level 4 is reached, providing there are no symptoms.

**Phase 4**

The maintenance program begins once Level 4 is attained and daily running has been achieved, free of any symptoms.

The maintenance program consists of unrestricted physical activity as tolerated, continuing the level 4 eccentric drops 2-3 times per week, and a daily program of quadriceps, hamstring and lower leg flexibility exercises.

Avoid kneeling on hard surfaces and wear knee pads to protect the knee from direct trauma when the risk presents itself.
Appendix B

PATIENT ASSESSMENT FORM
B.C. SPORTS MEDICINE CLINIC

Patellar Tendinitis

Patient History:

1. Name: __________________________ Birthdate: __________ Age ______
2. Sex: m f 5. Weight: ______ Height: __________________________
7. Training Program:
   7.1 Sport: __________________________ 7.2 Frequency: __________________________
   7.3 Duration per Activity: __________________________
7.4 Experience: __________________________
7.5 Shoe Design: Brand: __________ Model: __________
   Brand: __________ Model: __________
7.6 Other Comments: __________

Date: __________________________
Birthdate: —
Height: __________________________

Evaluation/comments:
8.1 Patient: __________________________
8.2 Examiner: __________________________
8.3 Cybex: Right Quad Hamstring
   Left Quad Hamstring
8.4 Thigh Circumference: R 4.4 cm. 10 cm
   L 4.4 cm. 10 cm

Biomechanical Considerations:
9.1 genu var val 9.2 tibial var L R val L R
   9.3 subtalar var L R 9.4 forefoot var L R
   val L R
   9.5 leg length discrepancy L R
   9.6 patellar squint
   9.7 Q angle L R
   9.8 swelling

Follow-up (6 weeks):
10.1 Patient: __________________________
10.2 Examiner: __________________________
10.3 Cybex: Right Quad Hamstring
   Left Quad Hamstring
10.4 Thigh Circumference: R 4.4 cm 10 cm
   L 4.4 cm 10 cm

Follow-up (12 weeks)
11.1 Patient: __________________________
11.2 Examiner: __________________________
11.3 Cybex: Right Quad Hamstring
   Left Quad Hamstring
11.4 Thigh Circumference: R 4.4 cm 10 cm
   L 4.4 cm 10 cm