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Lower leg strength in athletes with and without exercise induced leg pain

Eric J. Welker
San Jose State University

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LOWER LEG STRENGTH IN ATHLETES WITH AND WITHOUT EXERCISE INDUCED LEG PAIN

A Thesis
Presented to
The Faculty of the Department of Human Performance
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

By
Eric J. Welker, ATC
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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Robert Kersey

Dr. Robert Kersey

VG Payne

Dr. Greg Payne

Jack Ransone

Dr. Jack Ransone

APPROVED FOR THE UNIVERSITY

Serena W. Stanford

Abstract

LOWER LEG STRENGTH IN ATHLETES WITH AND WITHOUT EXERCISE INDUCED LEG PAIN

by Eric J. Welker

Twenty athletes without (control = 20) and 21 athletes with (test = 21) a history of exercise induced leg pain (EILP), had reciprocal sagittal plane ankle strength isokinetically tested at 60, 90, and 120 deg/s using a Cybex II. Groups were compared on mean torque strength ratios. A repeated measures nested-factorial analysis of variance (alpha = .05) and Fisher's Least Significant Difference (LSD) Multiple-Comparison Test (alpha =.05) were conducted. ANOVA results indicated the main effects of group (ps < .001) and speed (ps <.05) were significant. No significant strength differences were found between subjects, within the two groups. Post hoc analysis indicated significant differences between groups at each of the three speeds of testing. The results suggest lower leg strength differences between athletes with and without a history of (EILP).

Acknowledgments

This study was designed to identify strength deficits or imbalances in athletes with a history of exercise induced leg pain (EILP). The main goals were to provide sports therapists with an isokinetic assessment and rehabilitation foundation for athletes suffering from EILP, and establish a strength baseline of reciprocal muscle groups in the lower leg in a functional test position.

I would like to thank all that contributed to this study: Dr. Robert Kersey, Thesis Committee Chairman, for all his time, patience, and willingness to help; Dr. Jack Ransone, Committee Member; and Dr. Greg Payne Committee Member, for all their time, multiple reviews, and critical thinking that went into developing this project. I would also like to express my gratitude to my colleague Mike Lahaie, whose time, effort, and patience made subject testing much easier to accomplish.

I would also like to extend my thanks to the Athletic and Human Performance Departments of San Jose State University, for allowing me to use their Cybex II dynamometer. The on-campus location dramatically improved recruitment and attendance of the subjects.

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CHAPTER 1

Introduction

Over 40 million people run and walk for sports and recreation in North America (Taunton & McKenzie, 1988). While these individuals benefit by improving cardiovascular fitness and relieving stress, they are increasing susceptibility to overuse injuries of the lower leg. In a 1984 seminar, Brody (as cited by Reber, Perry, & Pink, 1993) stated 70% of runners are at risk of developing an injury severe enough to keep them out of activity for seven to ten days. During running, each leg absorbs an average of three to four times the body's weight with appropriate strides, which average 1,500 per mile (McKeag & Dolan, 1989). Walking applies different levels of musculotendonous stress to the leg. Instead of relying heavily on momentum and upper thigh propulsion (like running), walking and jogging require high levels of intrinsic muscular activity for shock absorption, foot and ankle support, and push-off (Mann, Moran, & Dougherty, 1986).

Because the foot and ankle function as primary shock absorbers during the gait cycle, improper foot and ankle biomechanics can lead to pain or injury development at some point during an athletes participation. If not absorbed properly, overstretch and vibratory stresses are transmitted up the kinetic chain. The lower leg, knee, hip, and low back can all be affected (Clement, Taunton, Smart, & McNicol, 1981). The anterolateral and posteromedial portions of the tibia are particularly susceptible to injury. Anterolateral and posteromedial tibial injuries have been commonly known as shin splints (Lilletvedt, Kreighbaum, & Phillips, 1979; Schon, Baxter, & Clanton, 1992; Viitasalo & Kvist, 1983). Shin splints can be painful, limiting the amount of activity an athlete is able to maintain (James, Bates, & Osternig, 1978; Nesbitt, 1992; Reber et al., 1993; Vogelbach & Combs, 1987).

In 1966, the American Medical Association (AMA) defined shin splints as "pain and discomfort in the lower leg from repetitive running on hard surfaces or from forcible excessive use of the flexors" (Gehlsen & Seger, 1980, p. 479). In 1980, Detmer stated that shin splints had been too narrowly defined by the 1968 AMA Subcommittee Report on Classification of Sports Injuries. The Subcommittee stated that shin splint diagnosis "should be limited to musculotendinous inflammation, excluding fatigue fractures and ischemic disorders. This limitation of the definition is not sensible since in busy clinical practice there are numerous cases in which one cannot localize the tenderness as exclusively musculotendinous in nature" (Detmer, p. 142). Exercise induced leg pain (EILP) is a relatively new term gradually replacing the term shin splints, and encompasses the differential diagnosis of medial tibial stress syndrome, stress fracture, chronic compartment syndrome, muscle strain, muscle herniation, tendonitis, fasciitis, arterial insufficiency, venous pathology, nerve entrapment, and radiculopathy (Clement et al., 1981; Lilletvedt, et al., 1979; McKeag & Dolan, 1989; Melberg & Styf, 1989; O'Toole, 1992; Reber et al., 1993; Rorabeck, 1986; Schon et al., 1992).

Etiology of EILP is a subject of vast debate. Two theories examining EILP were found in the literature. One theory related EILP to soft tissue structures such as muscles, tendons, nerve entrapments, or increased deep intracompartmental pressure (James et al., 1978; McKeag & Dolan, 1989; O'Toole, 1992; Rorabeck, 1986). Another theory implicated lower leg tendon insertion points as the source of pain. The soleus and tibialis posterior tendons apply stress to the bone causing stress fractures of the tibia's outer cortex at the site of tendonous attachments (Clement, 1974; Gehlsen & Seger, 1980).

The unequivocal cause of EILP has not been determined, biomechanical instability, muscle weakness, muscle imbalance, and overuse training error were cited as potential causes (Kendall, McCreary, & Provance 1993; O'Toole, 1992; Sallade & Koch, 1992; Vogelbach & Combs, 1987). Several of these abnormal characteristics have been studied to isolate factors in athletes with EILP. The most prominent biomechanical abnormality found in athletes with EILP was hyperpronation of the midfoot, which was also referred to as excessive subtalar joint mobility (Lilletvedt et al., 1979; Viitasalo & Kvist, 1983). As with EILP, no single cause for hyperpronation was identified. Some researchers indicated that structural abnormalities such as forefoot supination, forefoot pronation, rear foot valgum, rear foot varum, anteversion of the hip, retroversion of the hip, or tibial varum caused hyperpronation (James et al., 1978; Magee, 1992; Nesbitt, 1992). Other researchers felt the problem was frequently lack of lower leg strength and overuse training error, creating an overload of the muscles supporting the ankle and medial longitudinal arch (O'Toole; Reber et al., 1993; Sallade & Koch).

Overload of the lower leg muscles affects the body's ability to adequately control the midfoot and rear foot during the gait cycle. Lack of midfoot and rear foot control contribute to hyperpronation, impairing the body's capacity to absorb shock (Viitasalo & Kvist, 1983). Inability of the body to properly absorb shock, coupled with overuse training error, lead to muscular breakdown, hyperpronation, and the development of EILP (James et al., 1978; Sallade & Koch, 1992).

Biomechanical studies have been conducted to demonstrate how hyperpronation leads to the development of EILP. Brown and Yavorsky (1987) stated hyperpronation was a pathomechanic that placed increased stress on the lower leg, foot, and ankle. "A pathomechanic is the mechanics of any living system in motion resulting in, or leading to dysfunction or injury" (Brown & Yavorsky, p. 7). A brief biomechanical introduction, taken from Brown and Yavorsky, Donatelli (1987), Kravitz (1987), Rodgers (1988), and Vogelbach and Combs (1987), is intended to give a better understanding of the gait cycle, the hyperpronation process, and how the foot, ankle, and lower leg are stressed during the gait cycle.

Rodgers (1988) stated that gait is composed of two phases, stance (when the foot is on the ground) and swing (when the foot is in the air). Stance composes 60% of the total gait cycle and is divided into heel contact (or heel strike), midstance, and push-off (Brown & Yavorsky, 1987). Heel contact is made on the lateral border of the supinated foot. As gait progresses following heel contact, controlled pronation (sole of the foot turns down while lateral border of the foot comes up) occurs preventing the foot from slapping down, thus improving shock absorption (Rodgers; Vogelbach & Combs, 1987). The tibialis anterior, which originates on the lateral border of the tibia and inserts on the medial and plantar surfaces of the medial cuneiform bone, eccentrically contracts to decelerate pronation to the midstance or flat foot stage (Kendall et al., 1993; O'Toole, 1992). The tibialis posterior originates on the posterior lateral surface of the tibia and inserts on the navicular bone, and also works eccentrically to decelerate pronation (Kendall et al.; O'Toole). Both of these muscles act to support the medial longitudinal arch. If pronation forces are excessive and the tibialis anterior and posterior muscles are unable to adequately decelerate the midfoot, the arch becomes overstressed and hyperpronation results (Kravitz, 1987). Hyperpronation occurs during the contact phase of gait, just prior to midstance, and consists of the navicular bone and talus internally rotating and the calcaneus everting, stressing the medial longitudinal arch (Brown & Yavorsky; Donatelli, 1987; Kravitz). In the late stages of midstance, following the flat foot stage, the foot becomes a rigid lever in preparation for push-off (Rodgers; Vogelbach & Combs). The lower leg externally rotates and closed chain supination (sole of the foot turns up) occurs at the subtalar joint (Brown & Yavorsky; Vogelbach & Combs). As the foot supinates, the heel returns from a maximally pronated position to the flat foot position as heel lift off approaches. The propulsive stage or push-off, is from heel lift to toe-off (Brown & Yavorsky). The body weight is shifted from the lateral side of the foot onto the medial side over the great toe (Vogelbach & Combs). Body weight is transferred directly over the great toe and on to the other foot.

The period between heel strike and midstance (flat foot stage) is primarily important when discussing EILP. As already stated, during this period the anterior and posterior lower leg muscle groups eccentrically contract to decelerate the foot and ankle (Kendall et al., 1993; O'Toole, 1992). Overuse may cause muscular fatigue, initiating an inflammatory reaction of the muscles and tendons. Inability of the anterior and tibialis posterior muscles to support the medial longitudinal arch can create several problems: decreased shock absorption, poor midfoot control, talar and navicular hyperpronation, and the development of EILP (Donatelli, 1987; Kravitz, 1987; Vogelbach & Combs, 1987).

Problem Statement

Athletes frequently develop anterolateral or posteromedial tibial pain after extended periods of running (Clement et al., 1981). In many of these cases, structural abnormalities of the lower leg are not apparent (O'Toole, 1992). By examining strength imbalances of the lower leg, this study investigated how to identify athletes susceptible to EILP when obvious structural abnormalities are not present, preventing painful periods of lost participation and allowing development of an aggressive rehabilitation program. The purpose of this study was to determine if significant mean torque strength ratio differences exist between anterior and posterior lower leg muscle groups in athletes with and without a history of EILP.

Null Hypotheses

There will be no differences between isokinetic mean torque strength ratios of subjects with a history of exercise induced leg pain and subjects with no history of exercise induced leg pain.

Limitations

The study was limited in the following ways.

1. The population was composed of San Jose State University athletes, ranging from 18 to 24 years of age, restricting the population age range.

2. Random selection of control group subjects from in and out of season sports resulted in lack of control over conditioning status.

3. Because of random selection, there was no control over the nutritional status of subjects.

4. There was no control on the specific time of day that subjects were tested. Testing times were established by the availability of the subjects and testers.

5. Subjects were encouraged to drive to the test site instead of biking, jogging, or walking which was an uncontrolled warm-up. However, mode of transportation to the test site was not controlled.

6. Cybex dual channel chart recorder print outs were converted into foot-pound measurements by hand.

Delimitations

The study was delimited as follows.

1. Subjects were student athletes from San Jose State University.

2. Test group subjects had a history of exercise induced posteromedial or anterolateral tibial pain.

3. Control group subjects had no history of exercise induced posteromedial or anterolateral tibial pain during their athletic career.

4. Test group subjects were free of any gross structural abnormalities of the lower extremity that may have affected lower leg biomechanics and the development of EILP. Structural abnormalities included: pes cavus, navicular drop, rear foot varum or valgum, forefoot supination or pronation, tibial varum, anteversion, retroversion, or excessive Q-angle.

5. Subjects were asymptomatic of any lower leg conditions or injuries.

6. Subjects completed isokinetic testing without experiencing any pain in the lower leg.

7. Subjects had not suffered severe injuries to the lower extremity during the past year.

8. Subjects did not participate in exercise prior to testing.

9. Subjects did not have experience with isokinetic ankle testing or exercise.

Assumptions

1. Subjects gave maximal effort during strength testing.

2. Subjects responded honestly in regards to medical history and orthopedic screening.

3. Subjects complied with pretest requirements.

Definition of Terms

A definition of terms was included to explain terms unfamiliar to readers. Terms were defined conceptually first and then operationally (when appropriate), to help understand how the terms were used in the study.

1. Anteversion. A position of the hip that occurs when the angle formed by the transverse axis through the femoral neck and through the transverse axis of the femoral condyles, is greater than 12 to 15 degrees (Hartley, 1991, p. 426). For study purposes, anteversion was considered a toed-in gait (pigeon toed) or if the subject was able to passively internally rotate the hip 70 degrees or more.

2. Eccentric muscle contraction. A muscle contraction occurring while the muscular fibers are lengthening, such as when a weight is lowered through a full range of motion (Anderson, 1994, p. 520). For this study, eccentric contraction of the muscles supporting the medial longitudinal

arch, occurred from heel strike to the flat foot stage of gait.

3. <u>Exercise induced leg pain (EILP)</u>. Pain in the posteromedial and or anterolateral portion of the lower leg caused by repetitive stress. Stress can be caused by athletic activity on multiple surface types or repeated contractions of the plantar and dorsiflexor muscle groups, resulting in medial tibial stress syndrome, stress fracture, chronic compartment syndrome, muscle strain, muscle herniation, tendonitis, fasciitis, arterial insufficiency, venous pathology, or nerve entrapment (Schon et al., 1992).

4. <u>Forefoot pronation</u>. Eversion of the forefoot on the hind foot when the subtalar joint is in neutral position (Magee, 1992, p. 452). For the purposes of this study, subjects were standing with the ankle in neutral position for observation. If the lateral aspect of the foot did not come into normal contact with the ground, that subject positively tested for forefoot pronation.

5. <u>Forefoot supination</u>. Inversion of the forefoot on the hind foot when the subtalar joint is in neutral position (Magee, 1992, p. 452). Clinically, a forefoot supination resembles a pes planus foot. For the purposes of this study, any subject exhibiting lack of a medial longitudinal arch was placed into a standing neutral ankle position while bearing as little weight on the affected leg as possible. If the

first toe of the foot did not come into contact with the ground, the subject positively tested for forefoot supination.

6. Halo effect. General effects of a good or bad feeling a tester may have about a subject. The halo effect is a threat to the internal validity of the experiment (Thomas & Nelson, 1990, p. 304).

7. Maximal effort. Exerting maximal ankle plantar and dorsiflexion force through a full range of motion as fast as possible.

8. Mean torque. Average of the second through sixth maximal plantar flexion and dorsiflexion strength measurements taken from the Cybex dual channel strip recorder chart.

9. Navicular drop. An indication utilized by clinicians in identifying patients suffering from excessive pronation of the foot and ankle. For this study, testing for navicular drop was executed using a technique described by Vogelbach and Combs (1987). The ankle was placed in a neutral nonweight-bearing position and the navicular tubercle marked. With the patient in a partial weight-bearing stance, the distance from the floor to the navicular tubercle was measured. The patient then assumed full weight on to the same foot and again the distance from the floor to the navicular tubercle was measured. The difference between the

two points was calculated. According to a clinical symposia by Brody (as cited in Vogelbach & Combs, 1987) normal values for this test were 3/8 inch. Greater than 5/8 inch was abnormal.

10. Pes cavus. A deformity of the foot characterized by an excessively high arch with hyperextension of the toes at the metatarsophalangeal joints, flexion at the interphalangeal joints, and shortening of the Achilles tendon (Anderson, 1994, p. 1201). For the purposes of this study, pes cavus was considered an excessively high medial longitudinal arch that did not decrease when a full weight bearing position was assumed.

11. Pes planus. An abnormal but relatively common condition characterized by flattening of the arch of the foot (Anderson, 1994, p. 1201). For this study, a medial longitudinal arch that was completely flat on the floor while the subject was full weight bearing was considered a pes planus foot.

12. Q-angle. The Q-angle is produced when lines are drawn from the middle of the patella to the anterior superior spine of the ilium and from the tubercle of the tibia through the center of the patella (Arnheim, 1993, p. 551). In this study, measurements were taken when the knee was fully extended and flexed 30 degrees. Normal Q-angles were

considered to be 10 degrees for males and 15 degrees for females.

13. Rear foot valgum. Eversion of the calcaneus when the subtalar joint is in neutral position (Magee, 1992, p. 452). For measurement purposes, from a posterior view of the Achilles tendon during full weight-bearing, any measured Achilles tendon valgus angulation greater than three degrees was considered excessive rear foot valgum.

14. Rear foot varum. Inversion of the calcaneus when the subtalar joint is in neutral position (Magee, 1992, p. 452). For measurement purposes, from a posterior view of the Achilles tendon while full weight-bearing, any measured Achilles tendon varus angulation greater than three degrees was considered excessive rear foot varum.

15. Retroversion. A position of the hip that occurs when the angle between the femoral neck and the transcondylar axis is decreased to less than 15 degrees (Hartley, 1991, p. 427). For study purposes, subjects observed with an extremely toed-out gait or externally rotated femurs were considered retroverted.

16. Severe injury. Any injury that required surgical repair, immobilization, created neurological dysfunction, or resulted in athletic participation disqualification.

17. Submaximal effort. Below maximal effort through a full range of motion, allowing familiarity with speed and resistance settings of the Cybex II isokinetic unit.

18. Tibial varum. With a tibial varum deformity, the distal tibia is closer to the midline than the proximal portion. The normal position is approximately 0 to 10 degrees from the perpendicular (Hartley, 1991, p. 613). For study measurement, excessive tibial varum was considered greater than 10 degrees deviation from the perpendicular axis in the distal one-third of the tibia.

19. Torque. The ability of a force to rotate a body about some axis (Serway & Faughn, 1992, p. 212).

CHAPTER 2

Review of Literature

To more fully understand the development of EILP, a thorough review of the literature was completed. The review of literature demonstrated the relationship between hyperpronation and the development of EILP, how muscles supporting the midfoot become over stressed, possible causes of hyperpronation, and how muscular imbalance was related to injury. A second portion of the literature review examined research establishing functional positioning for testing, reliability of isokinetic testing, and the effects of different testing positions.

Hyperpronation and the Development of EILP

Prentice (1990) defined shin splints as a musculotendonous overuse condition. "Three basic causes of shin splints are abnormal biomechanical function, poor conditioning, and improper training methods" (Prentice, p. 324). Further defining the problem, Prentice added that anterior tibial pain was caused by weakness of the anterior muscle group. In developing posterior shin splints, excessive subtalar joint pronation placed stress on the tibialis posterior, flexor digitorum longus, and flexor hallucis longus, leading to an inflammatory response of the muscles.

Brown and Yavorsky (1987), described two types of compensation for biomechanical abnormalities of the lower leg: normal and abnormal. Normal compensation was the body's reaction to irregular surfaces and caused no pathology. Abnormal compensation was compensation for abnormal structure and function of the body. Continued abnormal compensation may lead to injury. Hyperpronation is a biomechanical abnormality forcing abnormal lower leg compensation. Researchers agree that hyperpronation caused by muscular failure or structural abnormality, in conjunction with training error, will lead to EILP (O'Toole, 1992; Sallade & Koch, 1992).

Overstress of the Midfoot During Running

To demonstrate how the body becomes over stressed, Burdett (1982) conducted biomechanical analysis using cadaver models to predict ankle joint forces during activity. Burdett used indirect methods to calculate forces from an anatomically and biomechanically correct model of the ankle joint. Burdett's goal was to determine muscle forces at the ankle joint during the stance phase of gait.

To obtain anatomical data, lower leg dissection of five cadavers was completed. Photographs of the cadavers were taken in all planes while the foot was plantar and dorsiflexed. Measurements of the calcaneus and Achilles tendon with the long axis of the tibia, were made throughout the full range of plantar and dorsiflexion. A biomechanical force model was developed indicating force generation from the origin to insertion points of the lower leg muscles.

This model was used to estimate the ankle joint forces during the stance phase of gait.

To compare with and corroborate cadaver findings, gait analysis of three adult male subjects running a six minute mile pace was completed. The runners were filmed from three angles using two 16 mm cameras operating at 100 frames per second. Results indicated accurate prediction of forces that occurred in the posteromedial muscles which support the medial longitudinal arch. Forces stressing the medial longitudinal arch were estimated to be from 4 to 5.3 times body weight in different subjects. Results also showed the dorsiflexors (primarily the tibialis anterior) of the ankle were most active at a moderate running pace when rear foot heel strike was emphasized (primarily in jogging). Relative magnitudes of the forces predicted in the three runners were consistent with those predicted with the cadaver ankle joint model.

McKeag and Dolan (1989) also explained that breakdown of musculature controlling the lower leg while running, was in effort to support the medial longitudinal arch. One of the primary medial longitudinal arch supporters, the tibialis anterior, works as a decelerator of the foot in running gait, preventing excessive repeated lower leg trauma. The tibialis posterior, commonly injured by hyperpronation, also decelerates the foot. Hyperpronation in the support phase of gait, results in strain of the tibialis anterior and posterior muscles. Strain of the muscles causes inflammation and pain, decreasing muscle function. Inability of the muscles to support the medial longitudinal arch and subsequently to absorb impact forces, can lead to musculotendonous or periosteal injury.

O'Toole (1992) reported similar findings citing anatomic variation such as leg length discrepancy or flat feet as rare causes of injury. Instead, imbalance of the muscles around a joint and poor flexibility were frequently to blame. O'Toole agreed with McKeag and Dolan (1989) citing a much higher probability for development of tendon strain and tendonitis in eccentrically contracting midfoot decelerator muscles.

In agreement with O'Toole (1992) and Brown and Yavorsky (1987), Sallade and Koch (1992) found that training on uneven surfaces placed abnormal stress on lower leg musculature. Inflexibility, muscle weakness, biomechanical instability, and too much training too soon were also listed as primary lower leg injury causes. Sallade and Koch stated that correction of training error with eccentric strengthening of midfoot decelerator muscle groups, primarily the tibialis anterior, could alleviate overstrain and reduce excessive pronation.

Electromyography of the Lower Leg Muscles

Electromyographical (EMG) studies by Cornwall and McPoil (1994), Mann et al. (1986), and Reber et al. (1993) were conducted to isolate muscles placed under high amounts of stress, determine the amount of muscular activity in the leg during the gait cycle, and support lower extremity biomechanical analysis. Of primary concern was the amount of force the tibialis anterior and posterior muscles exerted during different gait cycle speeds.

The EMG study conducted by Reber et al. (1993) showed that the tibialis posterior muscle was most active during the midstance phase of the gait cycle, with intensity of contraction between 70% and 80% manual muscle testing (manual muscle testing was not further defined in the study). EMG results also showed the tibialis anterior muscle contracted at greater than 20% manual muscle testing for more than 85% of the gait cycle at training pace. Previous research by Monad in 1985 indicated that muscles contracting at a level greater than 20% of their maximal contraction may be susceptible to fatigue overload.

Mann et al. (1986) proposed to demonstrate differences in EMG data between jogging, running, and sprinting. Fifteen San Francisco State University track athletes were tested. Each specialized in 100 to 800 meter races. The runners were filmed at high speed using two 16 mm cameras at 200 frames per second. EMG data were collected through the use of skin surface electrodes throughout the body. Ankle analysis during gait showed there were greater levels of dorsiflexion at heel strike as gait speed decreased and heel strike was emphasized. Results indicated a higher muscle stress level on the tibialis anterior during jogging and running versus sprinting. EMG analysis showed the tibialis anterior muscle was active throughout all gait cycles except during the late forward swing period of sprinting gate.

As gait speed increased the total gait cycle time decreased. The support phase time decreased from 260 ms while jogging, to 210 ms for running, and 140 ms for sprinting. Mann et al. (1986) concluded such a dramatic reduction in support phase time increased joint ranges of motion and injury risk because of greater force and energy expenditure by the body. The researchers did not consider that prolonged stance phase time dramatically increased stress lower leg muscles were required to absorb. However, Burdett (1982) indicated muscle stress increased in fast walking and jogging gait cycles where heel strike was emphasized.

Cornwall and McPoil (1994) utilized EMG techniques in a more discriminating method than Mann et al. (1986). Isolated tibialis anterior muscle function was studied and how it affected rear foot motion in walking. Changing rear foot motion is synonymous with increasing or decreasing rear foot valgus or varus motion. These terms are the same as pronation and supination of the foot respectively. Therefore, increasing valgus positioning of the calcaneus (rear foot) is the same as increasing pronation.

Cornwall and McPoil (1994) tested 16 subjects with an average age of 27 years (SD ± 5.24 years). Videotape and EMG were used to record rear foot motion while walking. The study was conducted to specifically demonstrate the plausibility of developing exercise protocols to correct control problems of the foot.

EMG results indicated the tibialis anterior muscle was active from just prior to heel contact to the flat foot stage (flat foot stage is just prior to midstance). During this period, the tibialis anterior indirectly controlled rear foot motion of the calcaneus by limiting navicular bone pronation and supporting the medial longitudinal arch. Therefore, if tibialis anterior muscle weakness impaired control of pronation, stress would be transmitted to other structures supporting the medial longitudinal arch.

Possible Causes of Hyperpronation

To reemphasize, a primary biomechanical abnormality associated with EILP is hyperpronation. Hyperpronation is secondary to excessive subtalar joint mobility. The following research examined excessive subtalar joint mobility and how it affected hyperpronation and development of EILP.

Prentice (1990), explained that excessive subtalar joint mobility had a direct relationship to the amount of stress placed on the posterior soft tissue structures supporting the midfoot. "In developing posterior shin splints, excessive subtalar joint movement into pronation places stress on the tibialis posterior, flexor digitorum longus, and flexor hallucis longus. These posterior muscles contract eccentrically to combat hypermobility. This condition may lead to an inflammatory response of the involved muscles" (p. 325). Prentice did not explain the cause of excessive subtalar joint mobility or the role weak anterior muscles played in increasing stress on the posterior muscle group.

Lilletvedt et al. (1979) studied 32 female athletes from Montana State University and surrounding high schools. Subject age ranged from 14 to 26 years. Subjects were interviewed and placed into one of five groups based on evaluation by the Montana State University athletic trainer. Grouping was based on injury status. Subjects with no shin splints were in group one. Subjects with various shin splint injury levels filled groups two through four. Subjects currently suffering from shin splints were placed in group five. A manual biometer was used to make 15 anatomical measurements: subtalar joint inversion and eversion, dorsiflexion at the ankle joint with the knee flexed and extended, and positioning of the calcaneus. Analysis of variance was used to determine significant differences between groups without shin splints and groups with previous or current shin splint problems.

Results indicated 6 of 15 recorded measurements could be used to predict the development of shin splints. Included in the list of diagnostic measurements was increased subtalar joint mobility. As previously established in the biomechanical review, subtalar joint hypermobility increased the probability of hyperpronation.

Viitasalo and Kvist (1983) also found subtalar joint mobility increased the incidence of injury. Athletes were divided into two groups, bad (n = 13) and slight (n = 22) shin splint cases. Comparisons of the test groups passive and active ankle movements were made to a control group (n = 13). The position of the subtalar joint was determined by the vertical axis of the calcaneus with the lower leg. Goniometer measurements were recorded in three standing positions. The degree of functional mobility was measured while subjects ran barefoot on a treadmill and high speed posterior lower leg view films were taken.

Results indicated that subjects suffering from shin splints, regardless of severity, had a higher degree of passive subtalar joint mobility. Achilles tendon valgus angles indicated the shin splint groups had increased passive subtalar joint eversion. Achilles tendon valgus angles were reported: shin splint groups 10.5 degrees, SD ± 4.3 degrees versus 8.3 degrees, SD ± 3.2 degrees in the control group. The results also indicated that there were no significant differences between groups Achilles tendon angles, during full support, while treadmill running.

In 1981, Clement et al. reviewed the clinical records of two sportsmedicine physicians and identified 1,650 running patients who had 1,819 injuries over a two-year period. A thorough history was taken to identify previous injuries, training errors, specific symptoms, and activities that increased or decreased pain. Patients were excluded from the study if they had previous surgery or direct trauma causing injury. Observation of leg alignment was completed to note tibial torsion, tibial varum, and several other hyperpronation causing factors. Athletes were then classified on the extent of their functional hyperpronation. Results showed that 27.2% of men and 28.8% of women in the study had lower leg pain. Several causes for injury were outlined. Most significantly, these researchers found that a runner's predisposition to injury increased with the degree of functional pronation.

James et al. (1978) reported similar findings to Clement et al. (1981). Using high speed filming, measurements of the horizontal axis in relation to the vertical axis of the tibia in weight-bearing, nonweight-bearing, and running on a treadmill, were recorded. Results indicated 58% of the 180 subjects were over pronating. Inability of the ankle joint to maintain a neutral position was said to be caused by any of four anatomic conditions: (1) tibial varum, (2) functional equinas with a tight triceps surae, (3) subtalar varus, or (4) forefoot supination. All of these anatomic conditions cause hyperpronation or increase the stress placed on the muscles supporting the medial longitudinal arch or midfoot.

De Lacerda's 1980 study assessed 81 female students for body weight, height, navicular bone position, and footprint angle. Subjects then exercised in a controlled environment over an extended period. Subjects with an excessive navicular drop measurement (indication of hyperpronation and stress on the medial longitudinal arch) were found to have a significant correlation with subjects complaining of shin splints.

A possible cause of navicular drop, not examined by De Lacerda's 1980 study, was weakness of the tibialis anterior muscle which inserts on the medial and plantar surfaces of the medial cuneiform bone (Kendall et al., 1993). Because the tibialis anterior muscle directly supports the medial cuneiform bone and indirectly supports the navicular bone, strength testing of the tibialis anterior may have indicated a correlation between athletes with muscular weakness and excessive navicular drop or hyperpronation.

Clarke, Frederick, and Hamill (1983) conducted a study examining the ability of various running shoes to control the rear foot (calcaneus) while running. Ten runners whose training ranged from 50-130 kilometers per week were chosen for the study. Subjects were all rear foot strikers with no injuries and were asymptomatic at the time of data collection. The subjects were filmed using a photosonic camera at 200 frames per second, while running at a seven minute per mile pace. The runners wore 36 different kinds of shoes. Each runner had reference markers placed on the rear of the shoe in line with the axis of the lower leg to just below the belly of the gastrocnemius muscle. These marks were used to measure change of the rear foot angle while running, wearing the various shoes. Results showed that maximal pronation and total rear foot movement were decreased using shoes with greater support of the midfoot and medial calcaneus. This indicated decreased hyperpronation of the foot when adequate support was given to the midfoot.

The previous studies repeatedly demonstrated the amount of functional pronation an athlete had, was directly related to the amount of support given to the midfoot. None of the reviewed studies conducted strength testing to specifically identify weakness or imbalance of the muscle groups supporting the midfoot and medial longitudinal arch.

Muscular Imbalance and Injury Development

Kendall et al. (1993) defined muscle balance as "a state of equilibrium that exists when there is a balance of strength of opposing muscles acting on a joint, providing ideal alignment and optimal stabilization" (p. 416). Kendall et al. also stated that muscular imbalance is directly related to biomechanical irregularities. "A state of muscle imbalance exists when a muscle is weak and its antagonist is strong. The stronger of the two opponents tends to shorten, and the weaker one tends to elongate. Either weakness or shortness can cause faulty alignment. Weakness permits a position of deformity..." (Kendall et al., p. 184). Positions of deformity can occur with only the stresses of body weight and gravity. For example, a position of pronation results when the inverters of the foot are weak and body weight distorts body alignment. Muscular imbalances contributing to the development of injuries have been identified throughout the body. One of the best documented muscular imbalances is between the quadriceps and hamstring muscle groups (Arnheim, 1993; Prentice, 1990; Sutton, 1984). The following studies were reviewed to demonstrate the role muscular imbalance plays in injury development.

Prentice (1990) stated the imbalance theory (upper-leg, anterior to posterior muscle groups) called for 60% to 70% hamstring to quadriceps strength ratio to reduce injury risk. Two other possibilities of hamstring injury listed were muscular fatigue and imbalance between medial and lateral hamstring muscles.

Sutton (1984) suggested excessive antagonist force placed on an eccentrically contracting hamstring muscle is another mechanism of hamstring injury. An additional injury factor is fatigue. According to Rhea (personal communication as cited by Sutton, 1984) muscles are far more susceptible to overload in a fatigued condition.

Lower leg muscles withstand stress similar to that of the thigh. As weak anterior lower leg muscles fatigue at training speeds, control of the midfoot and medial longitudinal arch may be lost. As a result the foot increases functional pronation placing greater stress forces on the anterior and posterior medial muscle groups. These muscle groups react with maximal eccentric contraction causing an overuse inflammatory condition.

In 1991, Knapik, Bauman, Jones, Harris, and Vaughan performed extensive preseason screening for strength and flexibility in 138 female college athletes to identify musculoskeletal imbalances associated with athletic injuries. Knee and hip, flexion and extension were isokinetically measured. Over a three year period all injuries to the 138 subjects were recorded. Results showed "more injuries occurred if knee flexion torque was 75% or less of the knee extension torque" (Knapik et al., p. 79). Athletes producing 15% or more knee flexion torque than the opposite leg were 2.6 times more likely to suffer an injury. Knapik et al. explained that if a force was generated by the stronger leg operating at a high contractile velocity, injury may occur when the weaker leg "...was unable to absorb or properly transfer that force" (Knapik et al., p. 79). The researchers did not indicate that strength imbalance of the hip affected injury rate, but indicated hip flexibility did.

No significant strength to injury relationships were found measuring isokinetic strength at 30 deg/s. Knapik et al. (1991) stated the knee is capable of a maximal velocity of about 700 deg/s and believed the high velocity of the 180 deg/s testing may be closer to those experienced during athletic events. Perrin (1993) refuted that isokinetic dynamometer testing could simulate the angular velocities experienced during athletic participation.

Berg, Blanke, and Miller (1985) attempted to profile muscular fitness of female basketball players. Primary concerns were peak torque, peak torque ratios, and local muscle endurance of the shoulder, elbow, knee, and ankle. A Cybex II isokinetic measurement device was used for all measurements. Each subject was ordered to warm-up progressively with the Cybex dynamometer set at 60 deg/s, applying greater levels of force over several repetitions. The ankle was tested at speeds of 30, 60, 90, 120, and 150 deg/s. The authors did not specify if ankle strength tests were conducted with the knee extended or flexed, but indicated the Cybex test protocol was used. Cybex has only two ankle plantar and dorsiflexion protocols. One with the knee at zero degrees flexion and the other with the knee flexed 90 degrees ("Isolated-joint testing," 1982). Maximal exertion measurements were taken for three repetitions at each angular velocity. A two minute rest period was allowed following each test speed. Mean peak torque was calculated for the three repetitions. The authors found the ankle torque ratios to be uniquely small due to the far greater torque levels of the plantar flexors than the dorsiflexors. Dorsiflexion to plantar flexion peak torque ratios were reported as follows: nondominant leg = (ND) and dominant leg = (D); at 30 deg/s ND =.37, D =.39; 60 deg/s ND =.43, D =.44; 90 deg/s ND =.46, D =.49; 120 deg/s ND =.54, D =.54; 150 deg/s ND =.59, D =.60. An important finding by Berg et al. was inverse torque production as angular velocities increased. More simply, the greatest torque production was produced at the lowest test velocity.

In 1974 Clement presented an "etiological theory based in cyclic training stress inducing a local muscle fatigue in the lower leg. This causes a loss of shock absorbing function and structural stress to bone creating a painful periostitis reaction. Resultant disuse muscular atrophy furthers the loss of shock absorption and the cycle is reinforced" (p. 81). Data were collected over a 10 year period by a family practice physician with a special interest in sportsmedicine. Twenty athletes, 12 males and 8 females (mean age 18 years ± 5 years), participating in heavy year round training were examined. Symptoms included severe medial tibial pain, which increased with stress and decreased with rest. Bilateral measurements indicated decreased muscle girth in the affected limb of 1.46 cm on average. One legged hopping ability was also decreased on the affected side due to pain and weakness.

Clement (1974) found that tibial stress fractures treated with four to six weeks of rest were prone to reinjury, and suggested regaining muscular strength was of equal importance. Twelve of the injured athletes began a progressive resistance program with alternative nonweight-bearing cardiovascular training. With a gradual reintroduction into their sport, the athletes treated with a combination of rest, lower leg strengthening, and alternative cardiovascular training returned to full participation in an average of 4.83 weeks after initial treatment. Clement did not indicate if any of the athletes treated had a reoccurrence of injury.

Gehlsen and Seger (1980) conducted a study to isolate possible causes of shin splints. The purpose of the study was to determine if angular displacement between the calcaneus and the midline of the lower leg while running was related to shin splints. A secondary purpose was to compare the strength and flexibility of ankle joint plantar flexion, dorsiflexion, inversion, and eversion in nonshin splint and shin splint injured subjects.

Two groups of conditioned female athletes were randomly selected and tested to measure strength of the ankle joint in all planes. One group had a previous history of chronic shin splints and the other group had no history of injury. Subjects were filmed at high speeds while running 3 m/s and 5 m/s over 10 meters. A posterior lower leg view was filmed, focusing on the Achilles tendon angle. Each subject was filmed twice, once with and once without shoes. "Cable tension procedures were used to measure the strength of ankle-joint plantar flexion, dorsiflexion, inversion, and eversion. The position of the ankle joint for all strength measurements was 90 degrees of flexion" (Gehlsen & Seger, p. 480). A goniometer was used to measure ankle range of motion in all planes.

Analysis utilizing a two-way ANOVA revealed significant differences in Achilles tendon angular displacement between the two groups (shin splint and nonshin splint) while running. The results indicated a higher rate of subtalar joint mobility in the shin splint group, and that the shin splint subject's gait differed from the nonshin splint subjects. Gehlsen and Seger (1980) found that the nonshin splint runners contacted the ground in an inverted position and moved into neutral position for takeoff. The shin splint subjects moved the foot from inversion to eversion (hyperpronation) and back to inversion for takeoff.

Strength tests indicated the shin splint group had a higher mean value for plantar flexion strength than the nonshin splint group. According to the researchers, the increased posterior muscle group strength produced a forward bowing effect of the tibia, creating a stress fracture. There were no other significant strength differences found and no significant differences in flexibility.

Gehlsen and Seger (1980) did not mention a specific knee position used while strength testing. For reproducibility purposes, the specific knee joint angle used for testing should have been included.

Knee Positioning for Isokinetic Testing

According to Cawthorn, Cummings, Walker, and Donatelli (1991), there is limited clinical agreement on standard testing protocols for each of the extremities. Cawthorn et al. stated that many of the isokinetic protocols used are based on tradition, rather than anatomical or kinesiological considerations. In effort to reproduce a functional position of the leg during the contact to midstance phase of the jogging gait cycle (the period when hyperpronation occurs), the following studies were examined.

Brown and Yavorsky (1987) found in analysis of running, the contact phase of gait (heel strike) was the period when the dorsiflexors and inverters of the ankle contract to actively decelerate the foot and absorb shock. "A normal foot does not pronate past the contact period, and reaches its maximally pronated position at the end of contact, just prior to midstance" (Brown & Yavorsky, p. 5).

Biomechanical analysis of running was conducted by Pink, Perry, Houghlan, and Devine (1994). The researchers analyzed 14 volunteer recreational runners while running on a treadmill and over ground. Subjects ran at self-selected paces: warm-up (slow) and training (fast) paces. Motions of the hip, knee, and ankle as well as vertical displacements of the body were measured using a Vicon motion analysis system.

Results indicated no significant differences between the ankle or knee flexion-extension range of motion measurements when comparing the treadmill with over ground running at either a slow or a fast pace. At heel strike, the knee was flexed 15 degrees and knee flexion increased as the leg loaded. "Maximum flexion (38 degrees) was seen just before midstance, and the knee began to move in the direction of extension" (Pink et al., p. 543).

Mann, Baxter, and Lutter (1981) stated that at the time of contact with the ground, there is an increased amount of flexion at the hip and rapidly increasing flexion of the knee joint. Specific knee and hip joint angles were not mentioned. Tables listing measurement results of sagittal plane knee motion during jogging, showed knee flexion to be approximately 34 degrees at heel strike.

According to Magee (1992), while running, the knee is straight or slightly flexed at heel strike and at midstance the knee is flexed. A specific knee joint angle corresponding with the period during pronation of the foot was not mentioned. Magee did state that during the loading response of walking gait, the knee is flexed 15 degrees.

Hoppenfeld (1976) gave less detail stating the knee is normally extended at heel strike and during midstance is normally flexed. Despite not having an exact degree of knee flexion, the literature supported that the knee is flexed during the contact phase of gait just prior to midstance.

The previous analyses have indicated that the knee joint is flexed during the contact to midstance phase of the jogging gait cycle. This information is vital when attempting to reproduce a functional position for strength testing. Commonly, experts believe the posterior lower leg muscle group is much stronger with the knee joint in full extension versus slight to moderate flexion ("Isolated-joint testing," 1982). Increased ankle plantar flexion strength with full knee extension is attributed to recruitment of the large gastrocnemius muscle. More recent research by Mann et al. (1986) showed the gastrocnemius plays only a small role in providing strength for various gait cycles, primarily because full knee extension is not a functional position. Therefore, to test the lower leg muscles stabilizing the ankle joint when midfoot pronation occurs, the knee joint should be flexed approximately 40 degrees.

Reliability of Isokinetic Testing

Isokinetic testing protocols have been developed for various parts of the body. No one test protocol has been determined as the most reliable for the lower leg. Studies have been conducted to determine the reliability of isokinetic testing of the knee and ankle. Factors directly related to reliability of measures are warm-up procedures, rest allowed during testing, and using mean torque measures versus peak torque measures.

Stratford, Bruulsema, Maxwell, Black, and Harding (1990) studied the effect of intertrial rest interval on the assessment of isokinetic thigh muscle torque. Their purpose was to determine the impact a 30 second rest period had on knee flexion and extension torque at an angular velocity of 60 deg/s. A second purpose was to determine the effect averaging peak torque repetitions had on reliability of the study.

Isokinetic testing was conducted on 16 subjects using a Cybex II isokinetic dynamometer with dual channel recorder. Two measurement protocols were used: 1) no rest between trials, and 2) a 30 second rest between trials. A warm-up of easy pedaling on a bike for five minutes was followed by five minutes of rest. Subjects then performed four warm-up trials at 60 deg/s, progressing from half effort to full effort. A two minute rest followed, prior to testing. Subjects were verbally prompted to initiate maximal movement but were not offered verbal encouragement during testing.

Experiment results showed a higher reliability in the test protocol allowing the 30 second rest interval. Higher reliability was also shown for the mean of five trials as opposed testing based on a single trial (Stratford et al., 1990).

Perrin (1993) stated the most effective testing method for reliability of data was to have the subject practice each test velocity for 5-10 repetitions at submaximal levels, prior to recorded testing. Testing should also be executed at lower velocities first to "facilitate motor learning at a slow velocity prior to testing at faster velocities (Griffin, 1987, p. 1207)". "Maximum torque is typically evaluated from the first 2 to 6 contractions" (Baltzopoulos & Brodie, 1989, p. 110).

Karnofel, Wilkinson, and Lentell (1989) conducted isokinetic testing of the ankle in all planes of motion. Their purpose was to determine the intra-rater and inter-rater reliability of peak torque values obtained using well defined protocols for measurement at the ankle joint. Subjects were tested using a Cybex II isokinetic dynamometer and dual channel strip recorder. For dorsiflexion/plantar flexion testing, subjects were stabilized in supine position on the Cybex Upper-Body Exercise Table (U.B.X.T), with the knee flexed 45 degrees. Forty-five degrees of knee flexion was selected because the authors felt it represented a functional position during the gait cycle. Subjects were tested at angular velocities of 60 and 120 deg/s. Low speed angular velocity was tested before high speed. Subjects were allowed a warm-up of three submaximal and three maximal trials before each data collection. A 30 second rest period was allowed between each warm-up and test period. Prior to testing, subjects were instructed to push and pull as hard and fast as possible. The subjects' arms remained folded across the chest during testing. No verbal encouragement was offered to the subjects during testing.

"The actual testing at both speeds consisted of six successive maximal reciprocal movements" (Karnofel et al., p. 152). Averaging the last five of six repetitions, the mean peak torque curves were calculated directly from the strip charts, recorded by the dual channel recorder.

The Pearson Product Moment Correlation was used following data collection to determine inter-rater and intra-rater reliability. A one-way ANOVA with repeated measures was used to determine if there had been a learning effect across test sessions. The results showed that torque values at 60 deg/s were higher than those at 120 deg/s. Mean peak torque for dorsiflexion at 60 deg/s was 15.1 (SD ± 5.2) and at 120 deg/s 8.3 (SD ± 3.4). Plantar flexion mean peak torque at 60 deg/s was 51.1 (SD ± 18) and 120 deg/s 31.4 (SD ± 12.9). Intra-rater and inter-rater reliability coefficients for all motions except eversion were above .80. Despite an inappropriate statistic being used (Pearson Correlation Coefficient) to determine reliability, this study provided valuable baseline ankle mean peak torque strength values.

Isokinetic testing protocols have not been concretely established. Studies indicated that a short, moderate to maximal warm-up on the isokinetic dynamometer, testing low speeds before high, offering no visual or verbal feedback during testing, and averaging measurements produced the most reliable results.

Summary

Previous literature indicated that several possible causes of EILP exist. The development of EILP can be both musculotendonous and osseous. Hyperpronation is the most commonly cited biomechanical factor contributing to the development of EILP. Causes of hyperpronation are structural or related to muscular overload and overuse training error (O'Toole, 1992; Sallade & Koch, 1993; Vogelbach & Combs, 1987). Hyperpronation results in decreased ability of the body to absorb shock. This leads to an attempt by muscles and tendons to compensate for and correct "pathomechanics" (Brown & Yavorsky, 1987, p. 7). Poor shock absorption caused by muscular imbalance and overuse may lead to the development of EILP.

Biomechanical literature indicated that during the contact phase of the gait cycle, the foot is fully pronated just prior to midstance and the knee is flexed from 34 to 38 degrees (Brown & Yavorsky, 1987; Magee, 1992; Mann, Baxter, et al., 1981; Pink et al., 1994). Because of these biomechanical considerations, ankle strength should be tested with the knee flexed approximate to the angle occurring during the contact phase of the gait cycle (Karnofel et al., 1989).

Isokinetic studies indicated that a short, moderate to maximal warm-up on the isokinetic dynamometer, testing low speeds before high, offering no visual or verbal feedback during testing, and averaging measurements produced the most reliable results (Karnofel et al., 1989; Perrin, 1993; Stratford et al., 1990).

CHAPTER 3

Methods

This chapter provides a detailed description of the subjects, apparatus, procedures, experimental design, and statistical analysis used to measure mean torque strength ratios between anterior and posterior lower leg muscle groups. The purpose of this study was to determine if significant mean torque strength ratio differences exist between anterior and posterior lower leg muscle groups in athletes with and without a history of EILP.

Subjects

Forty-one subjects were selected from current San Jose State University athletic team rosters (excluding swimming and diving). A twenty-one subject test group was composed from all athletes who received treatment or reported a history of EILP during their athletic participation at San Jose State. Names entered into the test group selection process were gathered by examining injury history forms (completed at the beginning of each academic year for physicals), athletic training room treatment records, and team inquiries (announcements). The remainder of San Jose State University athletes never receiving treatment for EILP composed the control group population. Twenty control group subjects were selected using stratified random sampling. Stratified random sampling was used because control group population eligibility was contingent upon subjects being current student athletes at San Jose State University with no history of EILP. Names of athletes with no documented history or admission of EILP during team inquiries were placed in a bag and randomly drawn. Any athlete selected as a control group subject reporting a history of untreated or undocumented EILP during their San Jose State University athletic career was placed into the test group and another control group subject randomly selected. Placement of subjects into test or control groups was based on injury history. Selected student athletes were contacted in person or by telephone for recruitment into the study. Injury history and current injury status were determined during recruitment. If for any reason a subject chose or was unable to participate, another subject was selected by methods previously described for the appropriate group and recruited. All subjects read and signed the Agreement to Participate in Research form approved by the Human Subjects Institutional Review Board of San Jose State University (see Appendix A).

Following selection, each subject was independently screened by two athletic trainers who were certified by the National Athletic Trainers' Association, to determine existence of any gross lower extremity structural abnormalities. Structural abnormalities such as pes cavus, navicular drop, rear foot varum or valgum, forefoot supination or pronation, tibial varum, excessive Q-angle, or severe hip anteversion or retroversion eliminated test group subjects from further study. Since subject grouping was based on injury history, control group subjects exhibiting lower extremity structural abnormality, but with no history of EILP, remained in the control group. If following the lower extremity examination, discrepancy concerning structural abnormality existed between Certified Athletic Trainers, objective anatomical measurement of the malalignment in question was taken (see Appendix B for measurement procedures and exclusion parameters). Structural norms for Q-angle, subtalar range of motion, navicular drop, forefoot supination, forefoot pronation, and tibial varum were taken from literature (Hartley, 1991; Magee, 1992; Prentice, 1990; Vogelbach & Combs, 1987). If a subject was eliminated from the study because of structural abnormality contributing to the development of EILP, testing error, or refusal to participate, another subject was selected for the appropriate group using methods previously described.

Apparatus

All subjects were tested using a calibrated Cybex II Isokinetic dynamometer and U.B.X.T. (Cybex Division of Lumex Inc., Ronkonkoma, NY 11799). This apparatus was designed to provide anatomically correct positioning, positive stabilization, and specialized input accessories for testing the ankle in plantar flexion and dorsiflexion motions. The Cybex II unit used was located on the campus of San Jose State University. As already discussed in the literature review, the Cybex II isokinetic dynamometer produced high reliability coefficients when consistent test protocols were used. Literature examining isokinetic test reliability indicated a short, moderate to maximal warm-up on the isokinetic dynamometer, testing low speeds before high, offering no visual or verbal feedback during testing, and averaging four to six repetitions excluding the first and last, produced the most reliable results (Karnofel et al., 1989; Perrin, 1993; Stratford et al., 1990). Strength measurements were recorded using a Cybex dual channel strip recorder.

Procedures

All subjects wore a tennis-type shoe with a flat heel for proper stabilization on the apparatus foot plate and clothing which allowed unrestricted movement of the lower leg. Subjects were encouraged to drive to the test site to prevent an uncontrolled warm-up effect from walking, running, or riding a bike.

Upon arrival, the Agreement to Participate in Research form was read and signed (see Appendix A). To reduce the halo effect and protect the subject's right to privacy, all data was coded. Test group subjects randomly drew cards numbered from 1-30. Control group subjects randomly drew cards numbered from 31-60. After a code number had been selected, it was recorded on all data collected for that subject. The selected code number was discarded to insure that no other subject would have data recorded under that code number. Leg dominance was established by asking subjects which leg they preferred when attempting to kick a ball with maximal power and accuracy.

To insure optimal stability and reliability of measurement, the following Protocol for Isokinetic Assessment (Appendix C) was utilized for each subject. Height and weight were measured and recorded. Orthopedic evaluation for lower extremity structural abnormalities was independently executed by two Certified Athletic Trainers, using an Orthopedic Checklist (Appendix D). Prior to isokinetic testing, bilateral contract/relax self stretching exercises for the anterior and posterior lower leg muscle groups were executed. Stretching was described (Appendix E) and demonstrated by a Certified Athletic Trainer for the triceps surae group (composed of the gastrocnemius and soleus muscles), tibialis anterior, and flexor hallucis longus muscles. Muscle groups were statically stretched for 10 seconds, then isometrically contracted for five seconds. This procedure was repeated three times for each leg, with alternation of legs after three repetitions (Olaf & Hamberg, 1989). Stretching time was monitored by a Certified Athletic Trainer.

Following flexibility exercises, subjects were positioned on the Cybex U.B.X.T. according to the Cybex Isolated-Joint Testing and Exercise Handbook (Appendix F), with one exception; the knee of the extremity being tested was flexed 45 degrees to replicate the lower extremity position during the contact phase of the gait cycle (Brown & Yavorsky, 1987; Magee, 1992; Mann, Baxter, et al., 1984). All subjects had their dominant leg tested first. Proper positioning was checked by measuring knee joint flexion with a goniometer; the stationary arm aligned with greater trochanter of the hip, the goniometer axis over the axis of the knee, and the movable goniometer arm aligned with the lateral malleolus. Following positioning on the Cybex unit (U.B.X.T), verbal introduction to the isokinetic device, and explanation of the test was read from an Introduction to Testing used for all subjects (Appendix G). Subjects then executed three submaximal and three maximal warm-up repetitions preceding each speed of testing, followed by a 30 second rest. Following measured testing at each speed, there was one minute of rest allowed before the next test speed warm-up. Maximal measurements were conducted at and in the order of 60, 90, and 120 deg/s. Lower speeds were tested first to facilitate motor learning and to improve reliability of measures (Perrin, 1993). At each speed, subjects were instructed to execute seven plantar flexion and dorsiflexion maximal effort repetitions. Testing of the contralateral extremity followed completion of the 120 deg/s test. Verbal encouragement was not offered during measured maximal testing. Subjects were given instructions before each series of repetitions to produce maximum effort. No form of visual feedback was given to the subjects during testing.

Design

Two groups of athletes participated in this study. A test group ($\underline{n}$ = 21) was composed of athletes with a history of EILP. A control group ($\underline{n}$ = 20) was randomly selected from athletes with no history of EILP. At the time of testing, all subjects were asymptomatic of any injuries affecting lower extremity strength. Both groups were isokinetically tested on the dependent variable isokinetic ankle dorsiflexion/ plantar flexion mean torque strength. The independent variables were history of exercise induced leg pain, subjects, and isokinetic testing speed (60 deg/s, 90 deg/s, or 120 deg/s). Testing was conducted to determine if lower extremity strength differences were present in athletes with a history of EILP. For all 41 subjects, anterior and posterior muscle groups isokinetic torque measurements (repetitions two through six) were averaged and converted into individual motion mean torque and mean torque strength ratios. Mean torque strength ratios were used with the independent variables (history of EILP, no history of EILP), subjects, and isokinetic testing speed (60 deg/s, 90 deg/s, and 120 deg/s) in a repeated measures nested-factorial analysis of variance (ANOVA) to determine if any statistical difference between subject groups existed. Post hoc analysis was calculated using a Fisher's Least Significant

Difference Multiple-Comparison Test. A .05 alpha level was used for all analyses in this research.

Analysis of Data

For statistical analysis, only the mean torque strength generated by the dominant leg was analyzed. Following strength testing, Cybex dual channel recorder charts were analyzed using the Cybex Chart Data Card (Appendix H). Torque measurements were determined, and the second through sixth measurements averaged. Mean torque was used to determine an anterior to posterior muscle mean torque strength ratio. Ratios were calculated by dividing dorsiflexion mean torque by plantar flexion mean torque.

Statistical analyses on the raw data included: means, standard deviations, ranges, and mean strength ratios of anterior to posterior muscle groups. The independent variables, injury history, subjects, and isokinetic testing speeds of 60 deg/s, 90 deg/s, and 120 deg/s, and the dependent variable, mean torque strength ratios, were used to calculate a repeated measures nested-factorial ANOVA. Calculations were conducted using the Number Cruncher Statistical Systems (Hintze, 1995). A repeated measures ANOVA was used because the dependent variable strength, was tested more than once on the same subject (Thomas & Nelson, 1990). The design was nested since subjects were restricted to only one of the two main groups (Winer, 1971). Post hoc analysis was done using a Fisher's LSD Multiple-Comparison

Test. A .05 alpha level was used for all analyses in this research.

Summary

This chapter described the subject selection procedures, screening protocol, testing protocol, apparatus used, and the statistical analysis used in this study. The subjects were all San Jose State University athletes between 18 and 24 years old. There were 41 subjects, 24 female and 17 males. Control group subjects were all athletes with no history of EILP and were selected by stratified random sampling. Test group subjects were all athletes with a history of EILP. The subjects were orthopedically screened prior to testing according to the criteria in Appendix D. A Cybex II isokinetic dynamometer was used in this study. The testing procedures consisted of stretching exercises, introduction to the testing procedures, warm-up on the Cybex II, and ankle dorsiflexion/plantar flexion muscle testing. Through these procedures dorsiflexor and plantar flexor mean torque strength was studied. All necessary data were recorded and analyzed using descriptive and inferential statistics.

CHAPTER 4

Results

The first portion of this chapter describes the demographic information of the control and test groups. Descriptive and inferential statistics are then presented. The results describe the differences in strength between subject groups with and without a history of EILP.

The purpose of this study was to determine if significant mean torque strength ratio differences exist between anterior and posterior lower leg muscle groups in athletes with and without a history of EILP. Isokinetic ankle dorsiflexion and plantar flexion tests were conducted using seven maximal repetitions at three speeds (60 deg/s, 90 deg/s, and 120 deg/s). From the measured maximal repetitions, individual mean torque strength was determined for the ankle dorsiflexors and plantar flexors. The dorsiflexion mean torque was divided by the plantar flexion mean torque and a mean torque strength ratio was derived.

Description of Sample

Both lower extremities of 21 subjects with a history of exercise induced leg pain and 20 subjects with no history of exercise induced leg pain, were tested at three speeds using a Cybex II isokinetic dynamometer. All test group subjects had a history of chronic bilateral anterolateral or posteromedial EILP. All control group subjects had no history of EILP. Demographic information for both groups is presented in Table 1.

Table 1

Mean Age and Lower Extremity Dominance Distribution for Subjects

	control	test
Subject number (n)	20	21
Males (n)	9	8
Females (n)	11	13
Mean Age (years)	20.3(SD ± 1.6)	19.9(SD ± 1.2)
Right Leg Dominant (n)	18	20
Left Leg Dominant (n)	2	1

The mean age for the control group was 20.3 years (SD ± 1.60) and for the test group was 19.9 years (SD ± 1.20). The age ranges for the control and test groups were five and three years respectively. The control group was composed of 9 males and 11 females. The test group was composed of 8 males and 13 females. Eighteen control group members were right leg dominant and two were left leg dominant. Twenty test group members were right leg dominant and one was left leg dominant. Subject distribution across athletic teams is listed in Table 2.

Table 2

Subject Distribution Across Athletic Teams

	control	test
Football	4	5
Baseball	3	2
Softball	2	3
Women's Gymnastics	0	6
Men's Gymnastics	1	1
Women's Soccer	4	1
Men's Soccer	1	0
Women's Volleyball	1	1
Women's Tennis	3	0
Women's Basketball	1	2
Total (*n*)	20	21

Descriptive Statistical Analysis

Bilateral mean torque strength averages, standard deviations, and range values were calculated for ankle dorsiflexion/plantar flexion muscle tests at 60 deg/s, 90 deg/s, and 120 deg/s. These values are presented in Table 3. Dominant leg control and test group mean torque strength ratio averages, standard deviations, and strength ratio average percentage differences are presented in Table 4. Prior to testing, six subjects were dropped from the test group because of lower extremity structural malalignments which could have contributed to the development of EILP. A seventh subject's data was not included in analysis because his foot lifted away from the foot plate, affecting strength measurement accuracy.

The dominant leg of the control group produced greater mean torque strength ratio values than the test group at all three testing speeds. The control group mean torque strength ratios were 21% greater than the test group at the 60 deg/s testing speed. As the speed of testing increased from 60 deg/s to 90 deg/s to 120 deg/s, the percentage differences between mean torque strength ratios also increased from 21% to 25% at 90 deg/s and 29% at 120 deg/s. The mean torque strength ratios slightly decreased in both the control and test groups as the speed of testing increased.

Table 3

Bilateral Ankle Mean Torque Strength Descriptive Analysis

Test Speed	Group	Leg	Mean Torque ± Standard Deviation	Range
60 deg/sec	Control	Right	37.40 ± 9.14	40.00
60 deg/sec	Test	Right	29.70 ± 9.80	44.60
60 deg/sec	Control	Left	36.02 ± 9.50	30.47
60 deg/sec	Test	Left	32.30 ± 8.10	25.60
90 deg/sec	Control	Right	36.16 ± 10.11	37.10
90 deg/sec	Test	Right	26.90 ± 6.20	23.63
90 deg/sec	Control	Left	36.92 ± 13.40	49.73
90 deg/sec	Test	Left	32.20 ± 8.42	29.83
120 deg/sec	Control	Right	35.70 ± 11.20	41.64
120 deg/sec	Test	Right	25.20 ± 6.60	25.80
120 deg/sec	Control	Left	36.62 ± 15.50	60.30
120 deg/sec	Test	Left	32.03 ± 9.12	28.40

Table 4

Dominant Leg Mean Torque Strength Ratio Average Descriptive Analysis Results

Test Speed	Group	Mean Torque Ratio Avg.	±	Standard Deviation	Percentage Difference
60 deg/sec	Control	37.40	±	9.12	
60 deg/sec	Test	29.65	±	9.80	21% test<control
90 deg/sec	Control	35.90	±	10.50	
90 deg/sec	Test	26.92	±	6.14	25% test<control
120 deg/sec	Control	35.46	±	11.30	
120 deg/sec	Test	25.26	±	6.53	29% test<control
Totals	Control	36.25	±	10.20	
	Test	27.28	±	7.80	25% test<control

In addition, higher dorsiflexion mean torque strength values were produced at 60 deg/s, 90 deg/s, and 120 deg/s testing speeds by The dominant leg of the control group (M = 14.74, 10.70, and 8.01) versus the test group (M = 12.04, 8.46, and 6.03). As speed of testing increased from 60 deg/s through 120 deg/s, the percentage of dorsiflexion strength differences also increased. At 60 deg/s the test group produced a dorsiflexion mean torque average 18% less than the control group. At 90 deg/s and 120 deg/s, the control group dorsiflexion mean torque average increased to 21% and 25% greater than the test group mean torque averages.

The plantar flexion mean torque strength values were almost equal between groups at 60 deg/s, 90 deg/s, and 120 deg/s testing speeds (control M = 40.40, 31.24, and 24.20 vs. test M = 42.44, 32.3, and 24.61) with the highest difference (4.8% test group greater than control group) occurring at the 60 deg/s testing speed. At testing speeds of 90 deg/s and 120 deg/s, the plantar flexion percentage differences decreased to 3.3% and 1.7% respectively.

Inferential Statistical Analysis

This study was conducted to determine if significant differences exist in dorsiflexion/plantar flexion mean torque strength ratios, between groups of athletes with and without a history of EILP, across three speeds of isokinetic testing. A repeated measures nested-factorial analysis of variance was conducted using the NCSS (1995 version). The research design was a three (60 deg/s, 90 deg/s, and 120 deg/s test speeds) by two (history of EILP and no history of EILP) factorial design. The independent variables were injury history, subjects, and speed of testing. The dependent variable was strength. An alpha level of .05 was selected for all analyses. Table 5 presents the results of the ANOVA. Two of the three main effects, history of EILP (group), and speed of testing were significant; subjects was not. The ANOVA results indicated the effect of group was statistically significant, Fs(1,38) = 13.08, ps < .001, power = .52. The effect of speed was also significant, Fs(2,76) = 3.57, ps < .05, power = .45. There were no significant strength differences found between subjects within the two groups; F (38,3) = 3.81, p = .14, MSE = 189.33. There were no significant interactions between group and speed (p = .60). This may be due to having very low power to test those interactions (power = .10), as a result of small sample size.

Post hoc analysis was done using Fisher's LSD Multiple-Comparison Test to determine significant differences between levels, among groups. The results (see Table 6) indicated that there were significant mean torque strength differences between the test and control groups at each of the three speeds of testing.

Table 5

Analysis of Variance for Mean Torque Strength

Source of Variance	*df*	*F*	MS used as denominator for *p* calculation
Between Groups (A)	1	13.08*	B(A)
Subjects Within Groups B(A)	38	3.81	S
Speed (C)	2	3.57**	BC(A)
Groups x Speed (AC)	2	0.51	BC(A)
Subjects x Speed BC(A)	76	0.60	S
Error (S)	3	49.72	
Total Adjusted	122		
Total	123		

*Term significant at an alpha level = .001

**Term significant at an alpha level = .05

Table 6

Fisher's LSD Results ($p < .05$)

Group	Speed	Mean ± SD	Significant($p < .05$)
1	60	37.40	
2	60	29.65	*
1	90	35.90	
2	90	26.92	*
1	120	35.46	
2	120	25.26	*

1 = control group

2 = test group

* Term significant at an alpha level = .05

Summary

The first portion of this chapter described the demographic information of the control and test groups. Descriptive and inferential statistics were then presented. The purpose of this study was to determine if significant mean torque strength ratio differences exist between anterior and posterior lower leg muscle groups in athletes with and without a history of EILP. Both lower extremities of 21 subjects with a history of EILP, and 20 subjects with no history of EILP, were tested using a Cybex II isokinetic dynamometer. Bilateral mean torque strength averages, standard deviations, and range values were calculated for ankle dorsiflexion/plantar flexion muscle tests at 60 deg/s, 90 deg/s, and 120 deg/s. The control group produced greater mean torque strength ratio values at all three testing speeds. The dominant leg of the control group had higher dorsiflexion mean torque strength values at all three speeds of testing. The plantar flexion mean torque strength values were almost equal at all speeds of testing between groups. A repeated measures nested-factorial analysis of variance was used to determine if mean torque strength ratios varied significantly between subject groups, across three speeds of testing. The independent variables were injury history classification, subjects, and speed of testing. The dependent variable was strength. A repeated measures nested-factorial ANOVA (alpha = .05) and Fisher's LSD Multiple-Comparison Test (alpha =.05) were conducted using NCSS (1995 version). ANOVA results indicated the effect of group was significant ($\underline{p}$s < .001). The effect of speed was also significant ($\underline{p}$s <.05). There were no significant strength differences found between subjects within the two groups. Fisher's LSD indicated that there were significant mean torque strength differences between the test and control groups at each of the three speeds of testing.

CHAPTER 5

Summary, Discussion, Conclusions, and Recommendations

The first portion of this chapter summarizes the testing procedures used and results of the study. The second section discusses the results of the study compared to similar previous studies. The conclusions section lists pertinent findings. The recommendations section provides suggestions on practical use of the results and suggestions for future research.

The purpose of this study was to determine if significant mean torque strength ratio differences exist between anterior and posterior lower leg muscle groups in athletes with and without a history of EILP. The following test procedures were used.

1. Maximal isokinetic strength values for the plantar and dorsiflexors of the ankle were measured with the knee flexed 45 degrees. Mean torque plantar flexion and dorsiflexion strength was calculated from the second through sixth maximal repetitions. Mean torque strength ratios were calculated by dividing dorsiflexion mean torque by plantar flexion mean torque measurements taken at 60 deg/s, 90 deg/s, and 120 deg/s. Control and test group means, standard deviations, and ranges were calculated for all three testing speeds.

2. The significance of strength difference was calculated between the control and test groups at all three

testing speeds using the group's isokinetic mean torque ratio averages from the dominant leg.

Summary

Forty-one subjects participated in this study. Twenty subjects with no history of exercise induced leg pain (EILP) were randomly selected and composed a control group. Twenty-one subjects with a history of EILP, composed a test group. The subjects were screened to determine if any injury affecting the measurement of ankle strength occurred within the past year. All subjects were orthopedically screened for structural malalignments causing predisposition to EILP. Test group subjects were disqualified from further study if lower leg structural malalignments existed: control subjects were not. All subjects completed controlled stretching exercises for the anterior and posterior lower leg muscle groups. Maximal dorsiflexion and plantar flexion mean torque strength was isokinetically tested for seven repetitions at 60 deg/s, 90 deg/s, and 120 deg/s with the knee flexed 45 degrees. A Cybex II isokinetic dynamometer with dual channel chart recorder was the testing device used in this study.

Maximal isokinetic mean torque strength was measured and analyzed through descriptive and inferential statistics. The means, standard deviations, and ranges were presented for the control and test groups. For all three testing speeds, the control and test group's mean torque strength measurements were used to calculate dorsiflexion/plantar flexion mean torque strength ratios. ANOVA results indicated the effect of group was significant (ps < .001). The effect of speed was also significant (p <.05). There were no significant strength differences found between subjects within the two groups. Fisher's LSD Multiple-Comparison Test indicated that there were significant mean torque strength differences between the test and control groups at each of the three speeds of testing.

The control group produced greater mean torque strength ratio values at all three testing speeds. Descriptive analysis indicated the control group mean torque strength ratio averages were at least 21% greater than the test group at the three testing speeds. As the speed of testing progressed from 60 deg/s through 120 deg/s, the percentage difference between group's mean torque strength ratios increased and mean torque strength ratios slightly decreased. This drop in torque values as speed of testing increased was consistent with other studies (Berg et al., 1989; Karnofel et al., 1989). The dominant extremity of the control group had higher dorsiflexion mean torque strength values at all three speeds of testing. The plantar flexion mean torque strength values were almost equal between groups.

Discussion

Similar Cybex isokinetic strength research was previously conducted by Karnofel et al. (1989) of ankle plantar and dorsiflexors, with the knee flexed 45 degrees, at

60 deg/s and 120 deg/s. Results showed that torque values (found by averaging the last five of six repetitions) at 60 deg/s were consistently higher than those at 120 deg/s. Mean peak torque for dorsiflexion at 60 deg/s was 15.1 (SD ± 5.2) and at 120 deg/s 8.3 (SD ± 3.4). Plantar flexion mean peak torque at 60 deg/s was 51.1 (SD ± 18) and 120 deg/s 31.4 (SD ± 12.9). Karnofel et al. reported at 60 deg/s the anterior muscle group produced 30% of posterior muscle group strength. This is lower than the 37% ratio found in the control group utilized for this study. A possible reason for the difference in data could be that Karnofel et al. tested a population (N = 41) with an age range of 20-75 years as opposed to the present study age range of 18-24 years.

Other studies examined the same strength measurements but used different testing procedures. Berg et al. (1985) attempted to profile fitness levels of female basketball players. Cybex testing was conducted for several joints including the ankle at 30, 60, 90, 120, and 150 deg/s. Mean peak torque was calculated from three maximal repetitions at each speed. Dorsiflexion to plantar flexion peak torque ratios across subjects were reported. The dominant leg had a mean peak torque ratio higher than the non-dominant leg at all speeds except 150 deg/s. At 60 deg/s, the anterior muscle group produced 43% and 44% of the posterior muscle group in the non-dominant and the dominant legs respectively.

Mean torque strength ratios increased as the speed of testing increased.

The mean torque ratios found by Berg et al. (1985) were higher than those found by Karnofel et al. (1989). Ankle strength measured by Karnofel et al., with the knee flexed 45 degrees, showed a downward trend in mean torque strength ratios as testing speed increased. Berg et al. reported a mean torque strength ratio increase as testing speed increased. There are several possible reasons for mean torque strength ratio increases: position of testing, averaging the three highest torque measurements versus averaging the same five measurements, decreased plantar flexion output, speed of testing, and subject learning effect.

Position of testing has the greatest potential for dramatically affecting results. As stated previously, Cybex has only two testing protocols for the ankle: with the knee fully extended and with the knee flexed 90 degrees. When the knee is fully extended the plantar flexors have their greatest potential for torque production due to optimal recruitment and output from the gastrocnemius muscle ("Isolated-joint testing," 1980). High plantar flexion output with low dorsiflexion output decreases mean torque strength ratios. Testing the ankle with the knee flexed to 90 degrees puts the plantar flexor muscles at a disadvantage and the dorsiflexors in their optimal testing position

("Isolated-joint testing"). High dorsiflexion output with low plantar flexion output increases mean torque strength ratios. These were primary concerns when determining the position of testing used in the current study. By testing the ankle with the knee flexed 45 degrees, neither the plantar flexors or dorsiflexors were at an advantage. Forty-five degrees knee flexion is also approximate to angles produced during the contact phase of the running gait cycle (Brown & Yavorsky, 1987; Magee, 1992; Mann, Baxter, et al., 1984; Pink et al., 1994).

Conclusions

The means, standard deviations, and ranges calculated in this study, will be useful to clinicians who utilize Cybex isokinetic testing devices for identification of lower leg muscular imbalance in athletes ranging from 18-24 years of age, at 60 deg/s, 90 deg/s, and 120 deg/s. The mean torque strength values indicated that as the speed of testing increased, the torque output decreased. The test group produced slightly higher plantar flexion values than the control group. At 60 deg/s test group plantar flexion values were 4.8% higher than the control group. At testing speeds of 90 deg/s and 120 deg/s, the plantar flexion percentage differences decreased to 3.3% and 1.7%, respectively.

Results also indicated that the control group was able to produce higher dorsiflexion mean torque than the test group at all three testing speeds. As speed of testing increased from 60 deg/s to 120 deg/s, the percentage of dorsiflexion strength differences also increased. At 60 deg/s the test group produced a dorsiflexion mean torque average 18% less than the control group. At 90 deg/s and 120 deg/s, the control group dorsiflexion mean torque average increased to 21% and 25% greater than the test group mean torque averages.

Since test group dorsiflexion output was consistently lower than the control group, the conclusion can be drawn that asymptomatic athletes with a history of EILP will have lower dorsiflexion/plantar flexion mean torque strength ratios than athletes with no history of EILP. Plantar flexion mean torque output should not deviate significantly between groups of athletes.

The significant differences found between groups and between groups at each of the three testing speeds, suggests testing athletes at the defined speeds should produce significant differences between mean torque strength. For example, a clinician isokinetically tests an athlete with a history of EILP and no significant lower extremity structural abnormalities. If test results demonstrate no difference between control group scores found in the current study, the clinician may rule out muscular imbalance as a contributory cause of the EILP. Conversely, if the results indicated a strength deficiency, the clinician could design a rehabilitation program targeting the specific muscle group and speed of training.

Recommendations

The means, standard deviations, and ranges of maximal ankle dorsiflexion/plantar flexion isokinetic mean torque values were presented in order to provide clinicians with a diagnostic guideline when isokinetically evaluating athletes with EILP. This investigation has allowed the researcher to make the following recommendations.

1. Further testing of subjects as described in this study, to improve statistical power to reject the null hypothesis.
2. A study to determine the isokinetic ankle strength levels of recreational athletes with and without a history of EILP may improve the ability to generalize results.
3. Further testing of ankle dorsiflexion/plantar flexion needs to be conducted to establish normative standards of isokinetic ankle strength with the knee flexed 45 degrees.
4. Isokinetic screening of athletes with a history of EILP could provide evidence for preventive rehabilitation prior to participation.
5. Isokinetic testing following injury could identify muscular imbalances and provide clinicians with

specific muscle groups and speeds in need of rehabilitation.

References

Anderson, K. N. (Ed.). (1994). Mosby's Medical Dictionary (4th ed.). St. Louis, MO: Mosby-Year Book, Inc.

Arnheim, D. D. (1993). Modern Principles of Athletic Training (8th ed.). St. Louis, MO: Times Mirror/Mosby College Publishing.

Baltzapoulos, V., & Brodie, D. A. (1989). Isokinetic dynamometry: applications and limitations. The Journal of Orthopaedic and Sports Physical Therapy, 11, 232-235.

Berg, K., Blanke, D., & Miller, M. (1985). Muscular fitness profile of female college basketball players. The Journal of Orthopaedic and Sports Physical Therapy, 7, 59-64.

Brown, L. P., & Yavorsky, P. (1987). Locomotor biomechanics and pathomechanics: a review. The Journal of Orthopaedic and Sports Physical Therapy, 9, 3-10.

Burdett, R. G. (1982). Forces predicted at the ankle during running. Medicine and Science in Sports and Exercise, 14, 308-316.

Cawthorn, M., Cummings, G., Walker, R. J., & Donatelli, R. (1991). Isokinetic measurement of foot invertor and evertor force in three positions of plantar flexion and dorsiflexion. The Journal of Orthopedic and Sports Physical Therapy, 14, 75-81.

Clarke, T. E., Frederick, E. C., & Hamill, C. L. (1983). The effects of shoe design parameters on rear foot control in running. Medicine and Science in Sports and Exercise, 15, 376-381.

Clement, D. B. (1974). Tibial stress syndrome in athletes. Journal of Sports Medicine, 2, 81-85.

Clement, D. B., Taunton, J. E., Smart, G. W., & McNicol, K. L. (1981). A survey of overuse running injuries. The Physician and Sportsmedicine, 9, 47-58.

Cornwall, M. W., & McPoil, T. G. (1994). The influence of the tibialis anterior muscle activity on rear foot motion during walking. Foot and Ankle, 15(2), 75-79.

De Lacerda, F. G. (1980). A study of anatomical factors involved in shin splints. The Journal of Orthopaedic and Sports Physical Therapy, 2, 55-59.

Detmer, D. (1980). Chronic leg pain. American Journal of Sports Medicine, 8, 141-144.

Donatelli, R. (1987). Abnormal biomechanics of the foot and ankle. The Journal of Orthopaedic and Sports Physical Therapy, 9, 11-16.

Gehlsen, G. M., & Seger, A. (1980). Selected measures of angular displacement, strength, and flexibility in subjects with and without shin splints. Research Quarterly for Exercise and Sport, 51, 478-485.

Griffin, G. W. (1987). Differences in elbow flexion torque measured concentrically, eccentrically, and isometrically. Physical Therapy, 67, 1205-1209.

Hartley, A. (1991). Practical Joint Assessment: A Sports Medicine Manual. St. Louis, MO: Mosby Year Book, Inc.

Hintze, J. L. (1995). User's Guide. Kaysville, UT: Number Cruncher Statistical Systems.

Hoppenfeld, S. (1976). Physical Examination of the Spine and Extremities. Norwalk, CT: Appleton & Lange.

Isolated-joint testing and exercise...A handbook for using CYBEX II and the U.B.X.T. (1980). Bay Shore, NY: Lumex Inc.

James, S. L., Bates, B. T., & Osternig, L. R. (1978). Injuries to Runners. The American Journal of Sports Medicine, 6, 40-49.

Karnofel, H., Wilkinson, K., & Lentell, G. (1989). Reliability of isokinetic muscle testing at the ankle. The Journal of Orthopaedic and Sports Physical Therapy, 11, 150-154.

Kendall, F. P., McCreary, E. K., & Provance, P. G. (1993). Muscles Testing and Function (4th ed.). Baltimore: Williams & Wilkins.

Knapik, J. J., Bauman, C. L., Jones, B. H., Harris, J. M., & Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female college athletes. The American Journal of Sports Medicine, 19, 76-81.

Kravitz, S. R. (1987). Basic concepts of biomechanics: relating the foot and ankle to overuse injuries. The Journal of Physical Education Recreation and Dance, 58(5), 31-33.

Lilletvedt, J., Kreighbaum, E., & Phillips, R. L. (1979). Analysis of selected alignment of the lower extremity related to the shin splint syndrome. Podiatric Sports Medicine, 69, 211-217.

Magee, D. J. (1992). Orthopedic Physical Assessment (2nd ed.). Philadelphia: W. B. Saunders Company.

Mann, R. A., Baxter, D. E., & Lutter, L. D. (1981). Running symposium. Foot and Ankle, 1, 190-224.

Mann, R., Moran, G. T., & Dougherty, S. E. (1986). Comparative electromyography of the lower extremity in jogging, running, and sprinting. The American Journal of Sports Medicine, 14, 501-510.

McKeag, D. B., & Dolan, C. (1989). Overuse syndromes of the lower extremity. The Physician and Sportsmedicine, 17(7), 108-123.

Melberg, P., & Styf, J. (1989) Posteromedial pain in the lower leg. The American Journal of Sports Medicine, 17, 747-750.

Monad, H. (1985). Contractility of the muscle during prolonged static and repetitive dynamic activity. Ergonomics, 28, 81-89.

Nesbitt, L. (1992). A practical guide to prescribing orthoses. The Physician and Sportsmedicine, 20(5), 76-87.

Olaf, E., & Hamberg, J. (1989). Autostretching. Milan: New Interlitho Spa.

O'Toole, M. L. (1992). Prevention and treatment of injuries to runners. Medicine and Science in Sports and Exercise, 24, S360-S363.

Perrin, D. H. (1993). Isokinetic Exercise and Assessment. Champaign, IL: Human Kinetics Publishers.

Pink, M., Perry, J. Houglum, P. A., & Devine, D. J. (1994). Lower extremity range of motion in the recreational sport runner. The American Journal of Sports Medicine, 22, 541-549.

Prentice, W. E. (1990). Rehabilitation Techniques in Sports Medicine. St. Louis, MO: Times Mirror/Mosby College Publishing.

Reber, L., Perry, J., & Pink, M. (1993). Muscular control of the ankle in running. The American Journal of Sports Medicine, 21, 805-810.

Rodgers, M. M. (1988). Dynamic biomechanics of the normal foot and ankle during walking and running. Physical Therapy, 68, 1822 - 1830.

Rorabeck, C. H. (1986). Exertional tibialis posterior compartment syndrome. Clinical Orthopaedics and Related Research, 208(6), 61-64.

Sallade, J. R., & Koch, S. (1992). Training Errors in Long Distance Running. Journal of Athletic Training, 27, 50-53.

Schon, L. C., Baxter, D. E., & Clanton, T. O. (1992). Chronic exercise-induced leg pain in active people. The Physician and Sportsmedicine, 20(1), 100-114.

Serway, R. A., & Faughn, J. S. (1992). College Physics (3rd ed.). Orlando, FL: Saunders College Publishing.

Stratford, P. W., Bruulsema, A., Maxwell, B., Black, T., & Harding, B. (1990). The effect of inter-trial rest interval on the assessment of isokinetic thigh muscle torque. The Journal of Orthopaedic and Sports Physical Therapy, 11, 362-366.

Sutton, G. (1984). Hamstrung by hamstring strains: a review of the literature. The Journal of Orthopaedic and Sports Physical Therapy, 5, 184-195.

Taunton, J. E., & McKenzie, D. C. (1988). The role of biomechanics in the epidemiology of injury. Sports Medicine, 16, 107-120.

Thomas, J. R., & Nelson, J. K. (1990). Research methods in Physical Activity (2nd ed.). Champaign, IL: Human Kinetics Publishers.

Viitasalo, J. T., & Kvist, M. (1983). Some biomechanical aspects of the foot and ankle in athletes with and without shin splints. The American Journal of Sports Medicine, 11, 125-130.

Vogelbach, W. D., & Combs, L. C. (1987). A biomechanical approach to the management of chronic lower extremity pathologies as they relate to excessive pronation. Athletic Training, 22, 6-16.

Winer, B. J. (1971). Statistical Principles in Experimental Design (2nd ed.). New York: McGraw-Hill Book Company.

Appendix A

Agreement to Participate in Research

Responsible Investigator: Eric J. Welker, ATC

Title of Protocol: Mean Torque Strength Differences of the Lower Leg in Athletes With and Without a History of Exercise Induced Leg Pain.

1. I have been asked to participate in a research study investigating strength relationships of the lower leg.
2. I will be asked to report to San Jose State University's Human Performance Department at a scheduled time where both lower legs will be isokinetically strength tested using a Cybex II isokinetic dynamometer.
3. No risks or injuries are anticipated during the testing procedure.
4. There are no discernible benefits or compensation offered for participation in this study.
5. The results of the study may be published but no information that could identify any subject will be included.
6. Questions about the research may be addressed to the responsible investigator (listed above) at (408)924-1294. Complaints about the research may be presented to Dr. James Bryant, SJSU Human Performance Department Chair (408)924-3010. Questions or complaints about research, subject's rights, or research-related injury may be presented to

Serena Stanford, Ph.D., Associate Academic Vice President for Graduate Studies and Research, at (408)924-2480.

7. No service of any kind, to which a subject is otherwise entitled, will be lost or jeopardized if they chose not to participate in the study.

8. Consent is given voluntarily. A subject may refuse to participate in the study or any part of the study. If a subject decides to participate in the study, he or she is free to withdraw at any time without prejudice to the subject's relations with San Jose State University.

9. At the subject's request, they will receive a signed and dated copy of the consent form.

The signature of a subject on this document indicates agreement to participate in the study.

The signature of a researcher on this document indicates agreement to include the named subject in the research and attestation that the subjects has been fully informed of his or her rights.

______________________	______________________	______
Subject's Signature	Investigator's Signature	Date

Appendix B

Anatomical Limitations for Exclusion From Testing

Anteversion. Subjects exhibiting an excessively toed-in gait (pigeon toed), squinting patellae, or able to passively internally rotate the hip more than 70 degrees.

Forefoot pronation. While standing in a nonweight bearing neutral ankle position, the lateral aspect of the foot did not come into contact with the ground.

Forefoot supination. Standing in a nonweight bearing neutral ankle position, the first toe did not come into contact with the ground.

Navicular drop. Measurement differences of the distance between the navicular tubercle (of the midfoot) and the floor, while weight bearing and nonweight bearing were not greater than 5/8 of an inch.

Pes cavus. Pes cavus was any excessively high arch that did not decrease when full weight bearing.

Pes planus. When the medial longitudinal arch was completely flat on the floor.

Q angle. Q-angles greater than 10 degrees for men and 15 degrees for women, were considered abnormal.

Rear foot valgum. Indicated by valgus angulation from a posterior view of the Achilles tendon during full weight bearing.

Rear foot varum. Indicated by varus angulation from a posterior view of the Achilles tendon during full weight bearing.

Retroversion. Extremely toed-out gait or extreme genu varum.

Tibial varum. Excessive tibial varum was considered greater than 10 degrees deviation from the perpendicular in the distal 1/3 of the tibia.

Appendix C

Protocol for Isokinetic Assessment

1. Consent and Subject Information forms
2. Height and weight measurement
3. Musculoskeletal screening
4. General body stretching and warm-up
5. Subject set-up and stabilization
6. Alignment of joint and dynamometer axes of rotation
7. Verbal introduction to isokinetic testing
8. Warm-up at 60 deg/sec. (three submaximal, three maximal repetitions)
9. Rest (30 seconds)
10. Maximal testing at 60 deg/sec. (seven repetitions)
11. Rest (one minute)
12. Warm-up at 90 deg/sec. (three submaximal, three maximal repetitions)
13. Rest (30 seconds)
14. Maximal testing at 90 deg/sec. (seven repetitions)
15. Rest (one minute)
16. Warm-up at 120 deg/sec. (three submaximal, three maximal repetitions)
17. Rest (30 seconds)
18. Maximal testing at 120 deg/sec. (seven repetitions)
19. Testing of contralateral extremity
20. Recording of test details to insure replication on retest
21. Explanation of results to the subject

Appendix D

Orthopedic checklist

Subject code number______________

Examiner____________________

1. Anteversion - internally rotated hips, genu valgum, squinting patellae + / -

2. Retroversion - genu varum, bow legs + / -

3. Excessive Q-angle + / -

4. Tibial varum - bowing of the lower leg greater than 10 degrees from the vertical. + / -

5. Pes planus - Extremely flat medial longitudinal arch. + / -

6. Pes cavus - Abnormally high medial longitudinal arch that does not decrease when full weight bearing. + / -

7. Forefoot supination - First toe does not contact ground while standing with ankle in neutral position. + / -

8. Forefoot pronation - Lateral aspect of foot does not come into contact with the ground while standing with the ankle in neutral position. + / -

9. Rear foot varum - posterior view, varus Achilles tendon angulation while full weight bearing. + / -

10. Rear foot valgum - posterior view, valgus angulation of the Achilles tendon while full weight bearing. + / -

Appendix E

Stretching Techniques

Anterior Muscle group

Starting position:

With the left foot on the floor, place the right knee, shin, and upper side of the foot on the cushion so that the heel points straight up. Support the body with the arms folded on the left knee.

Stretching:

1. Straighten the right ankle by sitting back and pressing the buttock down on the heel so that a stretch is felt in the shin. Hold the stretch position for 10 seconds.
2. Relax and sit forward. Now press the top of the right foot down on the cushion and hold that position for 5 seconds.
3. Relax; repeat steps one and two, two more times.

Posterior muscle group

Starting position:

Stand facing the wall. Place your hands shoulder height on the wall for support, bend the left knee and hip. Keep the right knee and hip straight and move the right leg backward, in line with the trunk, until the right heel cannot be pressed against the floor.

Stretching:

1. Bend the left knee and hip and push with the arms to press the right heel down on the floor, so that a stretch is

felt in the calf and back of the knee. Hold the stretch position for 10 seconds.

2. Press downward lightly with the ball of the right foot and hold this position for five seconds.

3. Relax; repeat steps one and two, two more times.

Appendix F

Cybex Isokinetic Testing Set-up Procedures

ANKLE *Plantar/Dorsiflexion (with 90° Knee Flexion)*

ANKLE ***Plantar/Dorsiflexion (with 90° Knee Flexion)***

Fig. 1

- U.B.X.T. backrest down flat
- U.B.X.T. seat to highest position (for long leg lengths, middle position may allow thigh stabilization pad to be placed closer to knee)
- Thigh stabilization pad w/wide Velcro strap (DD) in receiving tube #5
- Pelvic and torso stabilization straps

Fig. 3

The ankle plantar/dorsiflexion footplate has two straps which are positioned on patients foot approximately as shown. These straps must be as tight as comfortably tolerable. It is particularly important to keep heel down and back against heel stop. Positioning the foot on the footplate with about 16° "toe-out" relative to the dynamometer is recommended to match oblique upper-ankle (talocrural) joint axis. To accomplish this, have patient internally rotate tibia 16° and position heel at rear corner of footplate closest to dynamometer.

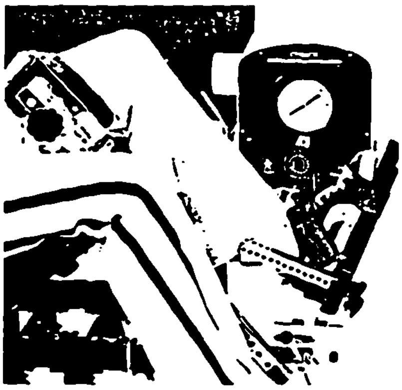


Fig. 2

- Short input adapter (U)
- Plantar/dorsiflexion footplate (BB)
- Start test in full dorsiflexion.

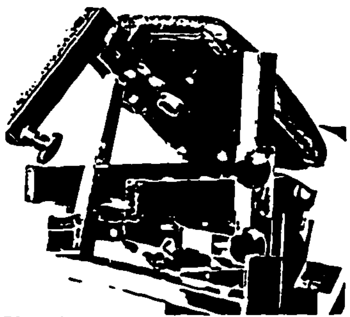


Fig. 4

- Footrest (B) in universal adapter (J) may be installed in receiving tube #4 to support contralateral limb if desired.

ANKLE *Plantar/Dorsiflexion (with 90° Knee Flexion)*

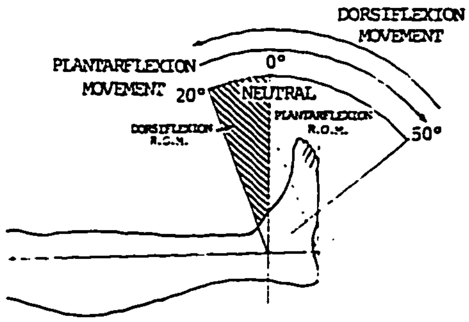


Fig. 5

- Axis of rotation passes obliquely (approx. average 16° anteromedially) through the tip of the fibula (lateral malleolus) and the trochlea of the talus exiting just distal to the tip of the tibia (medial malleolus). This is compensated by appropriately positioning foot on footplate (see Fig. 3).

- Ankle dorsiflexion range may be less and plantarflexion torque may be greater with knee extended than with knee flexed because of greater stretch (tightness) of gastrocnemius.

- Stabilization of foot on footplate eliminates movement of longitudinal arch which might otherwise falsely add to range of motion measurement.

- Dotted lines represent only foot angles, not axis of rotation or actual foot position.

ANKLE PLANTAR/DORSIFLEXION (With 90° Knee Flexion)
Position dynamometer & U.B.X.T. and attach accessories as indicated in Fig's. 1 & 2. See also Fig. 4.
Position and stabilize patient: check rotational axes alignment through R.O.M. according to *significant error indications* on pg. 11. Use of plantar/dorsiflexion footplate is explained in Fig. 3. Position patient so that knee is flexed 90° and ankle is neither inverted (adducted) nor everted (abducted) when foot is flat on footplate. Hip angle can vary widely without affecting measurement. Thigh stabilization pad should be as close to knee as possible with strap tight. If axes of rotation are aligned correctly, upper leg will not move significantly during testing or exercise. Engage U.B.X.T. floor-lock mechanism.
Select *30, 180,* or *360* ft. lbs. scale and check zero torque baseline on *TORQUE CHANNEL.*
Select *150°* scale and check *ZERO TEST* on *POSITION ANGLE CHANNEL.*
Position and lock patient at anatomical zero (Fig. 5) by turning speed selector to 0°/sec. (not *OFF*).
Set *INPUT DIRECTION CW* for left limb - *CCW* for right limb.
Set 0° baseline at fifth major division (midline) of *POSITION ANGLE CHANNEL* by turning goniometer gear dial.
Standardize instructions to patient. Allow 5-10 warm-up/familiarization repetitions at each test speed. Check tightness of locking knobs.
Start test in full dorsiflexion. Set *CHART SPEED* as required for test protocol.

Tinted area applies to Dual-Channel Systems only.
Letters after listed accessories refer to "Illustrated Parts List" on pg. 1.
Illustration showing numbers for U.B.X.T. receiving tubes is on pg. 8.

Appendix G

Introduction to Testing

The Cybex II unit is designed to provide maximal stability during isokinetic testing and is widely used in the field of research. This experiment is composed of three maximal exertion tests for the ankle. Each test will be preceded by a warm-up, and is followed by a rest period.

You will be asked to execute three submaximal and three maximal repetitions for warm-up, followed by a 30 second rest. Following the rest, maximal exertion testing for seven repetitions will begin at the same test velocity as the warm-up and will be followed by a one minute rest period. This procedure will be followed for all three testing speeds. If at any time you feel uncomfortable, experience pain, or wish to discontinue the test, notify the examiners immediately. Testing of the opposite leg will follow the completion of three measured maximal sets on this leg.

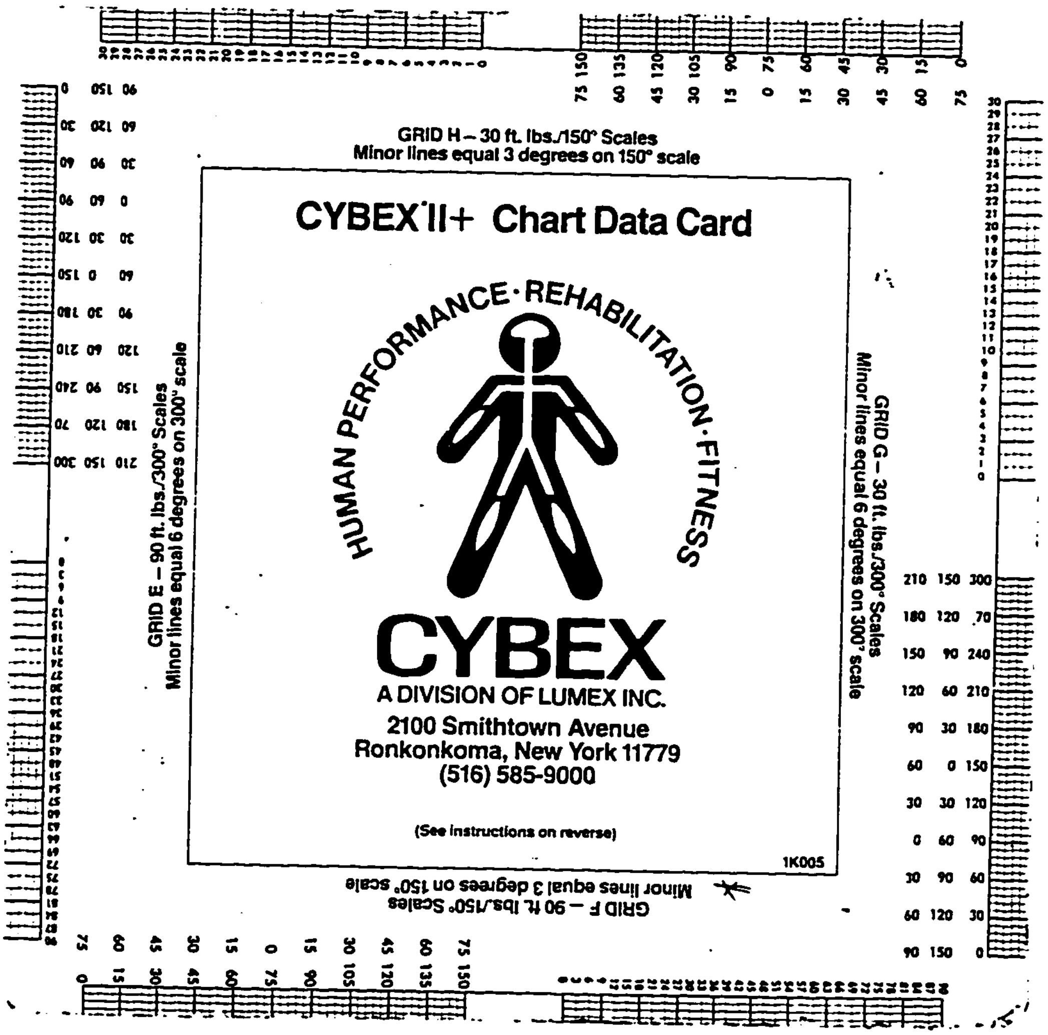
Some important points to keep in mind during the testing:

- Verbal encouragement will not be offered during testing.
- Hold on to the table tightly.
- Remember to push down and pull up as hard and as fast as you can through a full range of motion.
- Avoid any extra effort using the knee or hip that may affect the measurement accuracy of ankle strength.

Do you have any questions about this procedure?

Appendix H

Cybex Chart Data Card



GRID H – 30 ft. lbs./150° Scales
Minor lines equal 3 degrees on 150° scale

CYBEX II+ Chart Data Card

HUMAN PERFORMANCE·REHABILITATION·FITNESS

CYBEX
A DIVISION OF LUMEX INC.
2100 Smithtown Avenue
Ronkonkoma, New York 11779
(516) 585-9000

(See instructions on reverse)

1K005

GRID G – 30 ft. lbs./300° Scales
Minor lines equal 6 degrees on 300° scale

GRID F – 90 ft. lbs./150° Scales
Minor lines equal 3 degrees on 150° scale

GRID E – 90 ft. lbs./300° Scales
Minor lines equal 6 degrees on 300° scale

CYBEX®

June 5, 1996

Eric Welker, ATC
999 W. Hamilton Ave. #51
Campbell, CA 10022

Dear Mr. Welker:

In response to your correspondence dated June 3, 1996, please accept this letter as authorization to reproduce pages 77 and 78 of the Isolated Joint Testing and Exercise Handbook...A Handbook for using CYBEX II and the U.B.X.T. (1980).

It is understood that the pages will only be included in your thesis and will not be submitted for publication.

Sincerely,

Sean P. O'Neill

Sean P. O'Neill
Manager, Corporate Communications

2100 Smithtown Avenue • Ronkonkoma, LI, New York 11779 • 516.585.9000

Division of Lumex, In

Eric Welker, ATC
999 W. Hamilton Ave. #51
Campbell, CA 95008

Sean O'Neill
Marketing Manager
Cybex Corporation

July 15, 1996

Dear Mr. O'Neill

I am a graduate student at San Jose State University, and have recently completed my masters thesis using a Cybex II unit. To simplify methodology explanation and comply with university policy, I am requesting permission to reproduced the Cybex II Data Chart Card (1980 version).

The chart card wording was not changed in any way. The reproduction will only be included in the thesis and will not be submitted for publication.

I would greatly appreciate an expeditious response because time is a factor. Thank you in advance for your time and effort.

Regards,

Eric Welker

OK approved for usage/
reproduction as
specified above.

Sean P O'Neill

7/24/96