THE UNIVERSITY OF ALBERTA

A STUDY OF THE ANATOMICAL ALIGNMENT AND PHYSICAL CHARACTERISTICS OF COMPETITIVE FEMALE FIGURE SKATERS

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A THESIS

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Dedication

To my husband Glenn, whose loving support and encouragement helped rekindle the inspiration to continue the project to completion.

Abstract

In this study, comparisons were made between female subjects who had remained free of overuse injuries during their skating careers, (group I), and subjects who had a history of overuse injuries (group II). The measurements of selected physical characteristics, as well as information pertaining to the subjects training habits, skating ability, and history of injuries, were compared between the two groups. Within group II, another comparison was made of selected physical characteristics between subjects who had experienced similar overuse injuries. The purpose of these comparisons was to attempt to determine any physical characteristics or training habits that may predispose an individual to overuse injury.

There were 100 subjects in total, 50 that have been free of overuse injuries during their skating careers, and 50 who had experienced one or more overuse problems. Each of the subjects filled out a questionnaire and had several physical measurements taken by the examiner, using a goniometer and a tape measure. A computer analysis of the results was performed to yield frequency data for all variables. In most cases, the measurement means were used for comparison.

The results revealed a genu varum alignment in 72% of group I and 82% of group II. A genu recurvatum alignment was also present in 80% of the subjects in both groups. While standing, all subjects had a valgus heel alignment and the means between the groups were similar. The mean values for medial hip rotation were greater than those for lateral hip rotation in both groups. No significant difference was found between the two groups for the means of Q angle, patellar position (standing, sitting and supine), longitudinal arch, and ankle dorsiflexion. The comparison within group II of physical characteristics, revealed no significant differences due to the low number of

subjects representing each injury. The training variables examined between groups I and II also showed no significant differences in the means.

Information provided in this study suggests that there may not be any variables that could be used consistently to predict the development of overuse injuries.

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I. INTRODUCTION

In the sport of figure skating, many strenuous hours of physical training are required to be successful in competition. The emphasis on free skating ability has been increasing dramatically over the past several years, and will ultimately be the only element of competition judged in single skating. It is recognized that at early levels of competition, the performance of difficult .double and triple jumps leads to success. Unfortunately for some, the athletic discipline required is accompanied by chronic, overuse injuries that often limit training and performance. However, there are many competitors who are able to maintain an injury-free status year round.

This study is concerned with the anatomical alignment, physical characteristics, and training habits of competitive figure skaters.

A. Statement of the Problem

The Purpose of this study is threefold:

(1) To compare structural alignment and physical characteristics of the lower limbs of skaters who have been limited by overuse injuries to those who have not.

(2) To compare structural alignment and physical characteristic of lower limbs of skaters who have experienced similar overuse problems.

(3) To examine other variables which may contribute to the predisposition of some skaters to overuse injuries.

B. Justification for the Study

It is the author's experience that competitive figure skaters suffer from chronic overuse injuries more often than has been indicated by previous studies. Because of this injury rate, it is important to determine the nature of any relationships that may exist between the type of overuse injuries and other significant variables such as congenital or acquired anatomical malalignment, joint and muscle flexibility, training habits, physical maturation and level of expertise. Truly, the most important epidemiological information to be derived may be the differences present before injury that distinguish the skaters who become injured from those who do not (Caine, 1985).

C. Limitations of the Study

The limitations of the present study include:

1. The overuse injury - prone population may not have been truly represented, since recruitment involvd the reporting of injuries from memory.
2. The questionnaire approach for obtaining information.
3. The subjectivity involved in the physical examination measurements using the goniometer and the tape measure.
4. The validity of the physical measurements.
5. The reliability of the examiner in diagnosing injuries based on description and location of physical symptoms.
6. The reliability of the examiner in differentiating between overuse and acute type injuires from the subjects' description.

D. Delimitation of the Study

The present study was delimited by the following factors:

1. The sample size.
2. The subjects were 11 years of age or older.
3. The subjects were chosen based on availability.
4. The results were reported based on the percentages obtained in the data collection. No statistical analysis was performed.

E. Definition of Terms

Free Skating - The component of figure skating that requires the balance, strength and agility to perform jumps, spins and intricate footwork in harmony with music.

Overuse Injury - An activity-related injury caused by a repetitive manoeuvre rather than by a single or multiple traumatic blow. A gradual breakdown or tissue reaction not specifically related to one temporal event. The injury must be severe enough to require medical attention and at least one week off the ice with or without physical therapy (Reid, 1987, Williams, 1986).

Injury-Free - Having no injuries specifically related to skating of the overuse nature requiring medical attention and/or physical therapy.

Alignment - The anatomical structure of a body without consideration of attitudes related to posture.

Juvenile "A" - The competitive level where the skater has passed the second figure test, and the junior bronze free skating test, and is 12 years of age or younger as of the preceding July 1st.

II. REVIEW OF RELATED LITERATURE

A. Figure Skaters' Injuries

The material published pertaining specifically to figure skaters' injuries is not extensive, most studies being retrospective in nature. Davis and Litman (1979), reported on the types of injures to the foot and ankle in 45 competitive skaters. They felt that the problems experienced were associated with the stiffness and the fit of the skating boot.

A study by Smith and Micheli (1982), involved a physical examination and a questionnaire given to each of the 19 skaters studied. They found most injuries to be from overuse, with low back pain, ankle bursitis and anterior knee pain being the most common complaints. However, due to the small sample size, it was difficult to draw any conclusions with respect to the anatomical findings and the injuries experienced. Brock and Striowski (1986), used a questionnaire approach to examine injuries of nationally ranked Canadian figure skaters. They found that close to 50 percent of the 60 respondents had had a significant injury during the year. They also found nearly an equal distribution of overuse and acute injuries, although, the overuse injuries resulted in significantly longer periods of inactivity.

In a questionnaire-study of 70 competitive skaters, Garrick (1988), also reported an equal distribution of overuse and acute injuries, with significantly greater training time lost with overuse injuries. The two most common overuse problems found in this study were patellofemoral dysfunction and Achilles tendinitis. Ankle bursistis and other "boot-related" symptoms were also common. Garrick (1988), has also collected data over a seven year period from skaters seeking treatment at a sports medicine facility. During this period, 107 skaters were seen with 242 injuries being reported. A predominance of overuse injuries was shown, with the knee and ankle being the two most common injury locations.

Hickey (1980), commented on the effects of compensatory pronation on the competitive skater. He was most concerned with poor-fitting boots and the lack of orthotics for those skaters who need them. He noted that skaters symptoms are similar to those of runners, with knee pain, plantar fasciitis, and shin splints topping the list.

The most recent published study, conducted by Brown and McKeag (1987), was concerned with injuries to pair skaters. They found a difference between males and females in the types of injuries experienced, but no attempt was made to distinguish between the overuse and acute variety.

B. Overuse Injuries

Definition

Chronic overuse injuries plague athletes of all ages in many different sports. They occur when repetition of a manoeuvre, rather than a single or multiple traumatic blow results in a gradual breakdown or tissue reaction (Reid, 1987, Williams, 1987).

Risk Factors Related to Overuse Injuries

There are several factors that may predispose an individual to developing an overuse injury. Many of these are related to the age of the athlete.

Caine (1984, 1985) has argued that because the normal growth pattern is nonlinear, a child's body proportions are not equivalent to those of an adult. For example, a child's legs account for considerably less than half of their height, while closer to half of an adult's height is in leg length. Caine (1984) has therefore, argued, although without documentation of a full biomechanical analysis, that under a given physical loading, a child's locomotor apparatus is exposed to greater stress - hence to a high risk of overuse injury.

The ratio of muscle and tendon strength to bone length has been considered a risk factor by some authors (Caine, 1983, Kozer and Lord, 1983, Lopez and Pruett, 1982, O'Neill, Daniel and Micheli, 1988). This ratio may be lower in children because their bones increase in length prior to maximum strength development. If this is true, the torques developed by the longer bones may exceed the capabilities of their muscles, increasing the risk of overuse injuries (Caine, 1984). The child therefore may be at greatest risk during the growth spurt when the peak of height-growth velocity occurs prior to the peak of muscle-growth velocity. Injury-rate statistics have not actually reflected this concern (Reid, 1987).

Another factor closely related to this is Micheli's (1983), hypothesis - that the growth spurt causes increased muscle-tendon tightness around the joints with accompanying loss of flexibility. He refers to this as the "overgrowth phenomenon", and claims that it may contribute to conditions favorable to overuse injuries.

During pubescence, repetitive stress of the growth plate cartilage, the growth cartilage at the joint surfaces, and the apophyseal insertions may increase the risk of overuse injury (Caine, 1985). However, according to Reid (1987), the incidence of epiphisitis during this growth period is higher, but most overuse injuries occur after the growth plate is closed and seems to parallel increasing activity.

As well as these unique physical characteristics, prepubescent and pubescent athletes, like athletes of all ages, may have congenital or acquired anatomical malalignments which can increase their risk of chronic overuse injuries (Bates, 1985, Newell and Bramwell, 1984, Lysens et al, 1984, Stanish, 1984, Subotnick, 1981, O'Neill, Daniel and Micheli, 1988).

The final and possibly the most important factor to be considered as a risk factor for overuse injuries is training, (O'Neill, Daniel and Micheli, 1988, Reid, 1987). There can be a multitude of errors made in training, such as poor equipment, lack of warm-up, inappropriate progression of skills, too rapid changes in exercise patterns, insufficient rest, poor technique, etc.

Types of Overuse Injuries

This study is concerned with several types of overuse injuries to the lower limbs. In particular, extensor mechanism injuries to the knee and injuries to the lower leg, ankle and foot, many of which involve the plantar flexion mechanism of the ankle.

In the following paragraphs, selected injuries will be described and the current literature concerning any anatomical variations that may predispose an individual to such problems will be reviewed.

1. Plantar Fasciitis

The plantar fascia is a multilayered aponeurosis that runs forward from the calcaneal tuberosity and fans out to insert on the metatarsal heads (Tanner and Harvey, 1988). As a tension band, it supports the medial, longitudinal arch, particularly when the ankle is plantar flexed. Since this is the toe-off position for running and jumping, the plantar fascia aids in push-off power (Marshall, 1988, Hamilton, 1988, Tanner and Harvey, 1988). Marshall (1988), and Hamilton (1988), both consider "toe-heel" landings in running and jumping to also put considerable stress on the plantar fascia. Repeated traction on the fascia can cause the insidious onset of pain along its medial aspect, or at its insertion on the calcaneus (Frey and Shereff, 1988).

Excessive foot pronation at the subtalar joint is the most common structural, predisposing factor reported in the literature (Marshall, 1988, Jesse, 1980, Kwong et al, 1988, Tanner and Harvey 1988, Frey and Shereff, 1988, Hickey, 1980). According to Kwong et al (1988), Frey and Shereff, (1988), and Tanner and Harvey (1988), another important factor is the tightness of the Achilles tendon which limits the range of ankle dorsiflexion. Also, a cavus foot has been thought to be a predisposing factor, owing to a lack of shock absorption, and increased tension on the fascia (Kwong et al, 1988, Marshall, 1988, Tanner and Harvey 1988).

2. Achilles Tendinitis

The Achilles tendon, which is the largest tendon in the body, is the common attachment for the gastrocnemius and the soleus muscles. In approximately the lower one-third of the leg, the Achilles tendon attaches these calf muscle to the calcaneus (Booher and Thibodeau, 1985). Contraction of the gastrocnemius-soleus complex produces plantar flexion of the ankle joint and inversion of the heel. Repeated, forcible contractions, such as those involved in running and jumping activities, can lead to Achilles tendinitis. Problems usually occur in the area of the musculotendinous junction, along the tendon itself, or at the insertion of the Achilles tendon into the calcaneus (Harvey, 1983, Krissoff and Ferris, 1982). The inflammatory condition usually develops gradually and is especially likely to occur if there has been a recent increase or change in training (Shields, 1982). The condition progresses by repeated microtrauma and tearing of the tendon fibres leading to edema and inflammation that may become chronic (Shields, 1982).

With respect to predisposing factors for Achilles tendinitis, there have been several postulated. The most common factor in the literature is over pronation (Hamilton, 1988, Clement et al, 1984, Jesse, 1980, Subotnick, 1980, Hickey, 1980). Clement et al (1984), having studied Achilles tendinitis in runners, attempted to described how functional over-pronation of the foot may affect the Achilles tendon. (The toe-off phase of running closely resembles that of a jumping action): In midstance, with the body weight over the foot, and the knee slightly flexed, there is an internal rotation on the tibia. In preparation for take-off, the foot begins to supinate and the knee extends, both imparting external rotary forces on the tibia. Ideally, supination and knee extension begin simultaneously, but in the case of an over pronated foot, pronation is still occuring after knee extension. As a result, the external tibial rotation generated by knee extension conflicts with the internal rotation produced by prolonged pronation. These authors have speculated that this opposition of forces imparted to the tibia may blanch or wring out vessels in the tendon and peritendinous tissue. If this is true, degenerative changes in the Achilles tendon could be due to vascular impairment (Clement et al, 1984). During the role from excessive pronation to supination, Clement et al (1984) also observed a whipping action of the Achilles tendon. The tendon is pulled medially during pronation and internal tibial rotation and then laterally during supination and external tibial rotation at take-off. This whipping may contribute to microtears in the tendon, particularly its medial aspect.

There are other symptoms which have been mentioned in the literature as possible predisposing factors for Achilles tendinitis. Frey and Shereff (1988), Hamilton (1988), and Subotnick (1980), have suggested cavus foot due to excess traction on the plantar flexors. Tightness in the heel cord itself with limited ankle dorsiflexion particularly with the knee extended, has been described by Santopietro (1988), Hamilton (1988), and Frey and Shereff (1988). Frey and Shereff (1988), Subotnick (1980) and Clement et al (1984), have blamed a varus alignment of the tibia, heel, and/or forefoot which may place added strain on the tendon similar to the whipping effect described above. Hamilton (1988), suggested that individuals with congenitally small or thin Achilles tendons, which is not always related to body size, may be more prone to strains and overloads leading to tendinitis. The condition may also be secondary to irritation from foot wear or extreme muscular effort (Frey and Shereff, 1988).

3. Peroneal Tendinitis

The peroneal muscles, brevis and longus, are located in the lateral compartment of the lower leg. They both have long tendons that wrap around the lateral malleolus before inserting into the foot. These muscles are strong evertors of the foot and they also provide primary lateral dynamic stability in the ankle joint (Frey and Shereff, 1988, and Santopietro, 1988).

According to Frey and Shereff (1988), tendinitis in these tendons is related to the pulley action of the lateral malleolus. Santopietro (1988), says the most frequent foot type associated with peroneal tendinitis is the flat foot with a plantar-flexed first metatarsal. An everted, or valgus heel alignment is often present as well (Santopietro, 1988). Hickey (1980), in his study of figure skaters, admitted that excessive foot pronation and instability could lead to peroneal muscle strain and fatigue, due to the sheer forces involved in the lift-off and landing phases of the skating jumps. In Garrick's study of figure skaters injuries, he found this tendinitis to be most often associated with pressure from incorrectly placed padding inside the boot (Garrick, 1988).

4. Shin Pain

There are several causes of shin pain, such as tibial stress fractures, compartment syndromes causing vascular impairment, and muscular strains leading to symptoms of tendinitis. This study is particularly concerned with muscular strain placed on the anterior and posterior tibialis muscles.

> The American Medical Association has defined the term "shin splints" as follows: Pain and discomfort in the leg from repetitive running on hard surfaces or forcible, excessive use of the foot flexors; diagnosis should be limited to musculotendinous inflammations excluding fracture and ischemic disorders. (cited in Viitasalo and Kvist, 1983).

Shin splint pain is described most often as diffuse linear pain along the anterior or medial edge of the midshaft or distal one-third of the tibia (Harvey, 1983). The pain can vary from dull, aching discomfort occurring after activity, to an intense, persistent pain that increases with activity (Mubarek et al, 1982). Athletes returning to training after a period of rest, or those who have altered their training regimes are especially susceptible (Harvey, 1983).

In the literature, two commonly proposed explanations for medial shin pain are: (1) tendinitis of the tibialis posterior muscle, and (2) increase in the pressure of the deep posterior muscle compartment of the leg (Bates, 1985, Davey et al, 1984, Eriksson, 1987, Puranen, 1974). The posterior tibialis muscle originates on the intermuscular septum of the calf. It passes behind the medial malleolus and inserts on the tarsal bones. Because of its location, it is considered a plantar flexor as well as an invertor of the foot. It also serves to maintain the height of the longitudinal arch (Frey and Shereff, 1988).

The anterior tibialis muscle originates on the tibia and inserts on the tarsal bones. Although it is a dorsiflexor of the foot, it is also the primary invertor, and aids in the maintenance of the longitudinal arch (Snell, 1973).

Biomechanically, the most often reported common denominator in the physical structure of those troubled with shin pain is excessive pronation of the feet. Because both the anterior and posterior tibialis muscles are involved in inversion of the foot and support of the longitudinal arch, these muscles can be susceptible to strain when excessive pronation is present (Bates, 1985, Hickey, 1980). This strain can lead to elevated compartment pressures, periostitis (inflammation of the periosteum of a bone due to excess traction of a tendon on its attachment site), tendinitis, or myositis (Bates, 1985).

Myburgh (1988) studied shin soreness in 25 exercisers involved in various activities (running, aerobics, racquetball, field hockey, basketball, and ballet). He found a greater range of subtalar and talar joint motion in those with reported pain. This range implies a greater degree of pronation in the foot. Santopietro (1988), has reported that individuals with tendinitis of either of the tibialis muscles usually have excessively pronated or flat feet. Jesse (1980), reported an increased susceptibility to shin pain in individuals with excessively pronated feet. Viitasalo and Kvist (1983), compared subjects with shin pain problems to those without on the basis of the following: (1) the leg-heel alignment (Achilles tendon angle) while standing, (2) the leg-heel alignment while running barefoot on a treadmill, and (3) the passive range of motion at the subtalar joint. They found a significant difference between the groups for all three of these parameters, indicating that excessive pronation was present in the symptomatic subjects.

Another predisposing factor reported in the literature for both anterior and posterior tibialis tendinitis was stress from attrition or pressure from footwear on the tendons (Garrick, 1988, Frey and Shereff, 1988, Davis and Litman, 1979).

5. Stress Fractures - Metatarsal

The mechanical development of a stress fracture must be thought of as a dynamic process or reaction (Oosterhuis, et al, 1984). Bone is a living material that requires stress in order to maintain its normal strength. Normally there is a balance between bone formation and the forces applied to the bone. In the case of a stress fracture, damage to the bone occurs from repetitive, submaximal, cyclical loading (Fowler, 1979). If this damage occurs faster than the reparative process can operate, then a partial loss in continuity of the bone occurs (Oosterhuis et al, 1984).

The onset of pain is usually insidious and relieved by rest. As the condition progresses, the pain occurs earlier in activity until participation is halted (Booher and Thibodeau, 1985, Fowler, 1979).

According to Gregg and Das (1982), children may be more susceptible to stress fractures, especially if they are involved in jumping sports because of the porosity of their bones.

A study conducted by Hughes (1985) looked for predisposing factors for metatarsal stress fractures in soldiers. The results indicated that a forefoot varus alignment and a tightness of the gastrocnemius and soleus muscles raised the likelihood of developing this problem. Tightness in the plantar flexors can lead to compensatory foot pronation at the subtalar joint in order to achieve the 10 degrees of dorsiflexion required for normal ambulation (Hughes, 1985).

Hamilton (1988), has reported that a cavus foot with a rigid, high arch and subsequently poor shock absorption may predispose individuals to metatarsal stress fractures.

6. Bursitis - Ankle

Bursae in the body are found where skin, tendons, ligaments or muscles repeatedly rub against bony points or ridges (Snell, 1979). Inflammation can occur when excessive pressure is applied to the bursa, or with trauma or unaccustomed exercise (Snell, 1979, Neale, 1981).

In the case of both the medial and lateral malleolus of the ankle, a bursa is located between the bone and the superficial layer of skin. Inflammation of these bursae can occur as a result of the direct pressure applied to them by the skating boot (Garrick, 1988, Smith 1985).

7. Medial Ankle and Knee Pain

Pain on the medial aspect of the ankle and knee can be a result of excess strain on the joint ligaments. Jesse (1980), has commented that a weak or excessively pronated foot with a valgus alignment of the heel places chronic strain on several structures including the medial knee and ankle ligaments. This author has also written that as the degree of foot pronation increases, the amount of ligament stress increases as well, especially if the subject has a genu valgum alignment (Jesse, 1980).

Shavelson and Lubell (1980), have reported a possible increased susceptibility to medial knee pain in the short side of individuals with a leg length discrepancy.

8. Anterior Knee Pain

The knee joint is the largest joint in the body and one of the most vulnerable to injury (Newell and Bramwell, 1984). With no bony stability, the knee joint must be stabilized by its surrounding tissues, all of which are subject to overuse injuries. Static stability comes from the ligaments, joint capsule, and menisci, whereas dynamic stability results from the muscles and tendons surrounding the joint.

The most common overuse injuries to the knee occur in and around its extensor mechanism which is composed of the quadriceps complex, the patella, and the patellar tendon and its insertion onto the tibial tubercle (Newell and Bramwell, 1984). Anterior knee pain syndrome falls into this category. However in the past, it has been referred to as chondromalacia patellae. This term refers clinically to lesions of the articular cartilage on the posterior surface of the patella (Goodfellow and Hungerford, 1976). It has been shown by several researchers that in the presence of anterior knee pain, the articular cartilage may or may not be affected. Also, these cartilaginous lesions can, and do occur with age, often without pain or other symptoms (Goodfellow and Hungerford, 1976). Furthermore, articular cartilage is devoid of nerve endings, therefore, the pain must be produced by some other factor, of which several sources have been suggested (Hughston et al, 1984, Insall, 1979, Insall, 1982, James, 1979).

The patella is contained as a sesamoid bone within the quadriceps mechanism. Under normal conditions, the posterior surface of the patella contacts the femoral condyles and glides smoothly through flexion and extension. During this movement, different areas of the patella make contact with the femur in a well recognized pattern and with a range of contact pressures (Andrish, 1985, Huberti and Hayes, 1984, Hughston et al, 1984). Any skeletal variation altering (1) the direction of pull of the quadriceps, (2) the attachment of the patellar tendon, or (3) the pulley system of the patella over the the femoral condyles, changes the forces acting on the patella (Booher and Thibodeau, 1985, Cailliet, 1983, Carson, 1985, James, 1979, Levine, 1979, Wilson, 1985, Kramer, 1986). Many authors believe this resulting variation in pressures on the subchondral bone to be one of the sources of pain (Hughston et al, 1984, Insall, 1979, James, 1979).

Before reviewing the anatomical alignment factors that may predispose an individual to anterior knee pain, it is important to note that describing the alignment as "malalignment" may not be appropriate (Reid, 1987). In most biological contexts, "normal" includes two standard deviations, therefore, "malalignment" may still in fact be within the normal range (Reid, 1987).

There are several anatomic variations that may contribute to anterior knee pain. Some of these occur alone and others in combination, all possibly contributing to the knee pain symptoms.

As recognized by several authors, a characteristic combination of alignment syndromes possibly leading to knee pain is often referred to in the literature as the "miserable malalignment". These will described in more detail in Section C and D. The list is as follows:

(1) Excessive femoral anteversion or internal hip rotation. Standing with the feet parallel reveals "squinting" patellae (patellae which are inclined toward the midline).

(2) Genu varum and often an associated genu recurvatum.

(3) Patella alta - A high riding patella which may reveal a prominent fat pad and thus a positive "camel sign" (a double hump over the knee joint when fully extended).

(4) Increased Q angle.

(5) External tibial rotation.

(6) Tibia varum seen more distally in the leg, altering the orientation of the ankle joint.

(7) Compensatory pronation of the foot at the subtalar joint.

This combination of alignment variations has been described by Hughston et al (1984), James (1979), Percy and Strother (1985), Wilson (1985), and Tiberio (1987). Levine (1979) also described these variations, although with the inclusion of genu valgum instead of genu varum. Each of these authors have implied that any or all of the above characteristics may contribute to anterior knee pain syndrome.

In a study of gymnasts, Andrish (1985), found that a "kneeing-in" posture (genu valgum), associated with femoral anteversion, proximal tibia vara, external tibial torsion, and an increase Q angle tended to alter the relationship of the patella and femur, leading to a lateral, incongruent patellofemoral articulation. In this authors experience, 30 percent of young people with anterior knee pain have had this combination of alignment characteristics (Andrish, 1985).

According to Hughston et al (1984) and Tiberio, (1987), rotational characteristics including excessive femoral anteversion and associated external tibial torsion increase the tendency of the knee extensor mechanism to laterally displace the patella. This is because both the origin (the anterior superior iliac spine) and the insertion (the tibial tuberosity) of the quadriceps mechanism are located lateral to the longitudinal axis in which the patella needs to travel.

Tachdjian (1972), has reported that patients with recurring lateral dislocation of the patella will often have genu valgum, some degree of external tibial torsion, and often an elongated patellar tendon.

As Gruber (1979), has pointed out, all muscles acting on the patella, with the exception of vastus medialis, have a tendency to draw the patella laterally. The vastus medialis has two components. The most medial component, the vastus medialis obliqus (VMO), has its fibres oriented more horizontally and is thought to be very important in resisting this lateral pull on the patella (Fox, 1975, Hughston et al, 1984, Lieb and Perry, 1968, Lieb and Perry, 1971). Hughston et al (1984) has stated VMO dysplasia may be genetically determined and could be the most significant anatomical finding for causation of lateral patellar dislocation and subluxation.

Patella alta (high riding patella), has been considered by some authors to be highly significant in the cause of anterior knee pain (Insall, 1979, Lancourt and Cristini, 1975, Percy and Strother, 1985). A study by Lancourt and Cristini (1975), compared the ratios of patellar length to patellar tendon length in patients with normal knees and those with knee pain and/or dislocating patella. They found the length of the patella to approximate the length of the tendon in normal subjects and the tendon to be longer in those with pain and/or dislocation.

There is conflicting evidence in the literature pertaining to the Q angle (quadriceps angle), and how it relates to anterior knee pain. Studies have been conducted that imply both an increase and a decrease in Q angle to cause high peak contact pressures in the patellofemoral joint (Huberti and Hayes, 1984). High contact pressures may be implicated in the production of pain at this joint.

Hughston et al (1984), and Percy and Strother (1985), have written that females who have a wide pelvis, also commonly have a genu valgus alignment and, therefore, a more laterally placed tibial tuberosity. This combination would have to be associated with coxa valga at the hip joint, and would lead to an increased Q angle and possible anterior knee pain (Reid, 1988). Insall (1979), found a higher Q angle in patients with anterior knee pain.

Hughston et al (1984) has written that many people with an increased Q angle are asymptomatic. Aglietti et al (1983), has shown evidence that some subjects with increased Q angles and patella alta are asymptomatic. In a study by Fairbank et al (1984), no significant difference was found in Q angle, genu valgum, and femoral anteversion between the symptomatic and the asymptomatic subjects. They concluded that chronic overloading, rather than anatomical malalignment, may be the dominant factor in anterior knee pain in adolescent subjects.

Most authors agree that the presence of primary or secondary subtalar joint pronation may contribute to anterior knee pain (Hughston et al 1984, James, 1979, Percy and Strother, 1985, Levine, 1979, Kramer, 1986, Ireland, 1987, Jesse, 1980, Tiberio, 1987).

9. Patellar Tendinitis

Patellar tendinitis is an inflammatory response to repeated and violent stress placed on the patellar tendon (Black and Alten, 1984, Ferretti, 1986, Newell and Bramwell, 1984). Activities that involve jumping are especially implicated in the aggravation of the symptoms because of the stress placed on the extensor mechanism of the knee (Cailliet, 1983).

The condition is characterized by an insidious onset of pain, tenderness and some swelling at one or more of the following attachment sites: (1) the proximal pole of the patella, (2) the distal pole of the patella, and (3) the tibial tuberosity (Ferretti, 1986). Ferretti (1986), studied the intrinsic and extrinsic factors that may be involved in the epidemiology of patellar tendinitis. The results showed that anatomical alignment factors were not important, whereas, the mechanical properties of the tendon and bone-tendon junctions may be considered.

Other research, cited in Ferretti (1986) has suggested that abnormality in the distribution of forces in the extensor mechanism may lead to symptoms of patellar tendinitis (Mariani et al, 1978, Santilli, 1975, Del Pizzo, 1983, Heckman and Alkire, 1984).

10. Osgood-Schlatter Syndrome

This condition involves the tibial tubercle attachment of the extensor mechanism in growing adolescents. It has been diagnosed with a variety of explanations such as osteochondritis of the tibial tubercle, a localized infection, an endocrine abnormality, and a traumatic process (Cailliet, 1983, Singer and Henry, 1985). However, recently, most authors agree that changes in the tibial tuberosity result from traction, reflecting increased forces within the extensor mechanism. According to Black and Alten (1984), Cailliet (1983), Ferretti (1986), Newell and Bramwell (1984), and Antich and Brewster (1985), repeated stresses on the patellar tendon cause a minor avulsion or microavulsions of the developing ossification center of the tibial tuberosity. The syndrome is aggravated by running and jumping activities, and appears most commonly near the beginning of the growth spurt of puberty (Cailliet, 1983, Hughston et al, 1984, Kujala et al, 1985, Newell and Bramwell, 1984).

It is possible that some anatomical factors may be important in the etiology of Osgood-Schatter's syndrome. Hughston et al (1984), has reported that traction forces on the patellar tendon, and thereby the growing tibial tuberosity may be increased by patella alta and tightness in the hamstring musculature. The reason for this is that with the swelling and enlargement of the tubercle that often accompanies this syndrome, the patellar tendon becomes anteriorly displaced, raising the patella from the distal end of the femur. This reduces the mechanical advantage of the quadriceps, resulting in more force required to achieve the same movements at the knee joint (Hughston et al, 1984).

Jakob et al (1981), has suggested that the condition of patella alta may be a residuum of Osgood-Schlatter's syndrome caused by lengthening of the tendon due to traction and/or scarring from the inflammatory response. Conversely, Lancourt and Cristini (1975) found the presence of patella infera in 20 patients with the condition compared to 80 normals.

Turner and Smillie (1981), have found external tibial torsion to be associated with lesions of the extensor mechanism including Osgood-Schlatter's syndrome.

11. Low Back Pain

The incidence of low back pain in figure skaters is frequent according to Smith and Micheli (1982), Smith (1985), Garrick (1985). Gymnasts and ballet dancers have been known to have high rates of spondylolysis, and the aesthetics of figure skating demand similar hyperlordotic posture. Marshall (1988) and Jesse (1980) have suggested that excessive pronation in the feet may lead to strain on the lower back musculature.

Since this study is concerned with the lower limbs of skaters, low back pain will not be dealt with extensively.

Summary

As mentioned earlier, it may be true that the most important risk factors related to overuse injuries are not in fact, anatomical in nature. However, the following list summarizes the review of literature in terms of the anatomical variations thought by some authors to contribute to the predisposition of individuals to certain types of injuries.

Plantar Fasciitis	- excessive foot pronation - tight Achilles tendon and plantar flexors - cavus foot
Achilles Tendinitis	- excessive foot pronation - tight plantar flexors - cavus foot - varus alignment of tibia, heel and/or forefoot
Peroneal Tendinitis	- excessive foot pronation - flat feet - valgus heel alignment
Shin Pain	- excessive foot pronation
Stress Fracture - (Metatarsal)	- excessive foot pronation - compensatory - tight plantar flexors - cavus foot - forefoot varus
Ankle Bursitis	- none reported
Medial Knee and Ankle Pain	- excessive foot pronation - valgus heel alignment - genu valgum - leg length difference
Anterior Knee Pain	- excessive foot pronation - genu varum and associated genu recurvatum - tibia varum - external tibial rotation - patella alta - "camel sign" - increased Q angle - excessive femoral anteversion - patellar "squinting"
Patellar Tendinitis	- none reported
Osgood-Schlatter's	- patella alta - tight hamstrings - external tibial torsion
Low Back Pain	- excessive foot pronation

(References for the above can be located in the preceding pages under the individual injury headings).

C. Anatomical Alignment and Structural Assessment

When reviewing the literature on skeletal variations, it becomes apparent that controversies exist pertaining to measurement techniques and normal values.

Leg Lengths

Measurement of true leg lengths is performed with a measuring tape lying supine in a neutral position in order to eliminate some of the potential error due to the musculature of the legs when standing (Eichler, 1977). The most common proximal landmark used for measurement is the anterior superior iliac spine at the tendinous insertion of sartorius, due to the difficulty in locating the proximal end of the femur (Eichler, 1977, Gogia and Braatz, 1986, Morscher and Figner, 1977, Parry, 1980). Distally the landmark used varies. Parry (1980) recommends the use of the medial malleolus, as do Booher and Thibodeau (1985). Gogia and Braatz (1986), used the medial malleolus and the anterior superior iliac spine and conducted a validity and reliability test. They compared the measurements taken by two therapists and then compared these values to those derived from x-rays. The results showed both a high degree of inter-tester reliability and measurement validity. On the other hand, Eichler (1977), has claimed that due to the shape of the leg surface, there is less error introduced when using the lateral malleolus as the distal landmark. Morscher and Figner (1977), also recommend the use of the lateral malleolus.

An alternative to measuring total, true leg length is to measure the thigh and lower leg lengths separately. The landmarks used for this method, as recommended by Parry (1980), and Morscher and Figner (1977), are as follows: (1) thigh and anterior superior iliac spine to lateral interarticular knee space, and (2) lower leg: medial interarticular knee space to medial malleolus. The medial surface is recommended to avoid the musculature of the gastrocnemious on the lateral side (Morscher and Figner, 1977).

Measurement of apparent leg lengths from the umbilicus to the medial malleolus can serve to detect pelvic obliquity, especially if the true leg length measures are equal (Hoppenfeld, 1976, Reid, 1987).

Quadriceps Angle (Q Angle)

The clinical definition of the Q angle is the intersection of a line from the anterior superior iliac spine to the center of the patella, with another line from the center of the patella to the tibial tubercle (Booher and Thibodeau, 1985, Huberti and Hayes, 1984, Larson, 1979, Percy and Strother, 1985). This can be seen in Figure 1.

Anatomically, the shaft of the femur is inclined laterally, forming approximately a six to seven degree angle with its vertical, mechanical axis (Larson,1979, Reid, 1987). The four quadricep muscles of the anterior thigh form a resultant vector, or direction of pull on the patella that does not coincide with the alignment of the patellar tendon. This angle, in the frontal plane, is the Q angle.

In the literature, the most common instrument used to measure the Q angle, is the manual goniometer (Carson, 1985, Hughston et al, 1984, James, 1979, Larson, 1979). The landmarks used are the anterior superior iliac spine, the center of the patella and the tibial tuberosity. The difficulty in locating these landmarks exactly, particularly the latter two, introduces a large error in measurement (Reid, 1987). Nevertheless, with practice, accuracy may be improved.

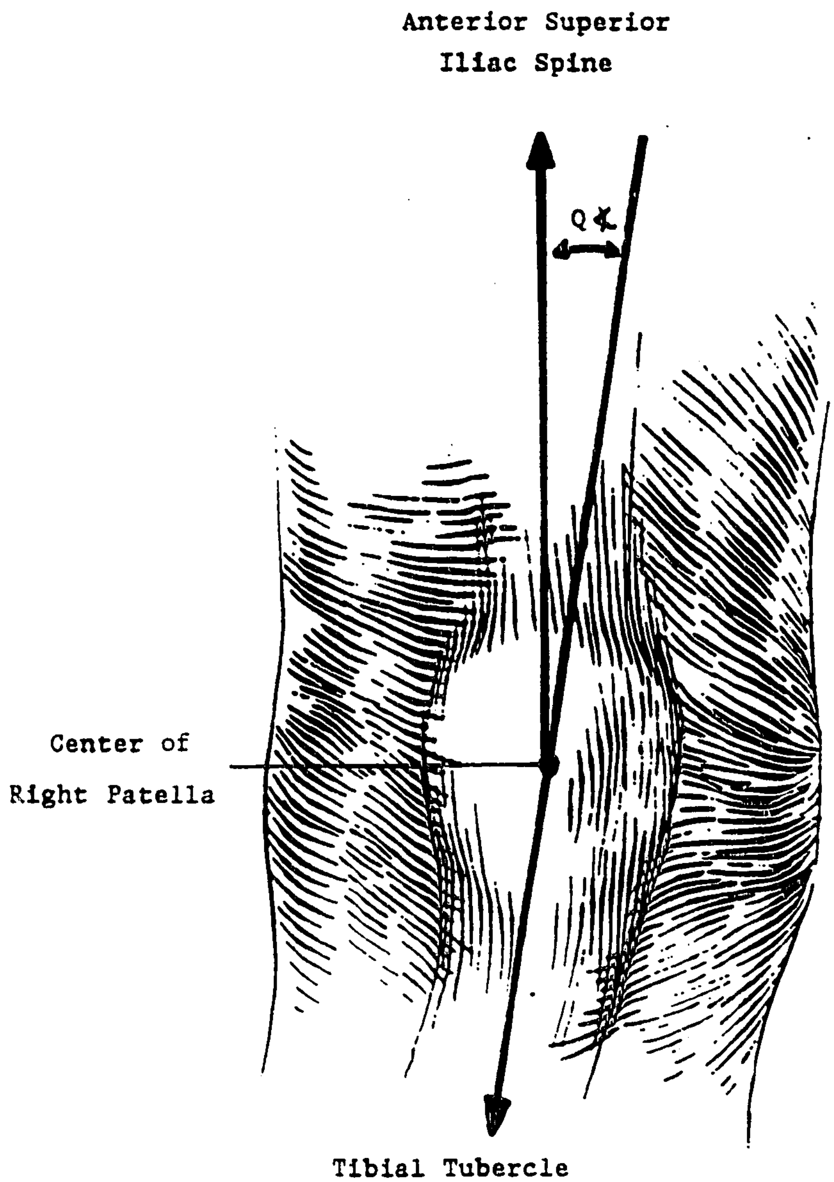

Figure 1. The Q angle - Formed between the line from the anterior superior iliac spine to the center of the patella, and a line from the center of the patella to the center of the tibial tubercule (adapted from Larson, 1979).

The position for measurement of the Q angle is not agreed upon in the literature, nor are the ranges that are considered normal. The following is a summary of the different positions used for measuring Q angle:

1) Standing, knees fully extended, medial borders of feet parallel and buttocks square (Fairbank et al, 1984, Booher and Thibodeau, 1985).
2) Standing, knees fully extended, feet naturally placed (Percy and Strother, 1985).
3) Supine, knees extended (Aglietti et al 1983, Carson et al, 1984, Carson, 1985, Huberti and Hayes,1984).
4) Supine, knees extended feet passively held together with toes vertical (Brown et al, 1984, Larson, 1979, Wilson, 1985).
5) Supine, knees extended, quadriceps contracted (Hughston et al, 1984).
6) Supine, knees flexed to 45 degrees (Henry and Craven, 1981).

Aglietti et al (1983), Insall (1979), Larson (1979), and Ireland (1987), have suggested that the normal angle for the Q angle is 15 degrees or less. Other authors have specified 15 degrees for women and 10 degrees for men (Carson et al, 1984, Carson, 1985, James, 1979). Hughston et al (1984), consider an angle greater than 10 degrees to be abnormal, whereas Levine (1979), has stated that an abnormal Q angle may be greater than 20 degrees. According to Reid (1987), the average Q angle measurements are 15 to 20 degrees for the active, athletic population of women.

Knee Joint Configuration

1. Genu Valgum

An individual with this type of alignment is often referred to as having knock knees. It is a deviation in the frontal plane which can originate at the femoral neck in its angle of inclination (Cailliet, 1983). This angle is formed by the axis throughout the neck of the femur and the axis of the femoral shaft. (See Figure 2a). These values have been shown to decrease with age, the most dramatic changes occurring between the ages of 2 and 7 years (Reid, 1987). At nine years, 138 degrees is common, at 15 years, 133 degrees, and in adults, 120 - 125 degrees is the normal range (Reid, 1987). A smaller angle causes the appearance of genu valgum. This can be seen in Figure 2d.

This type of deviation in alignment can be estimated by having the subject stand erect, knees together, and medial borders of the feet parallel. The distance between the medial malleoli, (Tachdjian, 1972), or the medial borders of the feet can then be measured (Arnheim, 1975, Wilson, 1985).

According to Reid (1987), the amount of valgus is delineated by (1) none - medial borders of feet touch, (2) mild - 1 to 5.0 cm between medial borders of feet, (3) moderate - 5.1 to 7.5 cm between feet, and (4) severe - 7.6 or more between feet.

2. Genu Varum

An individual with this type of alignment is usually referred to as having bowlegs. This is the opposite of the genu valgum and can be caused by a larger angle of inclination (Figure 2c) (Cailliet, 1983). It is often associated with internal tibial torsion as well, which may exaggerate the bowlegged look (Tachdjian, 1972).

To estimate the amount of deviation, the subject stands with the medial borders of the feet parallel and together (Arnheim, 1975, Wilson, 1985), or with the patellae facing straight forward and the malleoli touching (Tachdjian, 1972). The distance between either the knee joint line (Reid, 1987), or the medial femoral condyles (Tachdjian, 1972), is then measured.

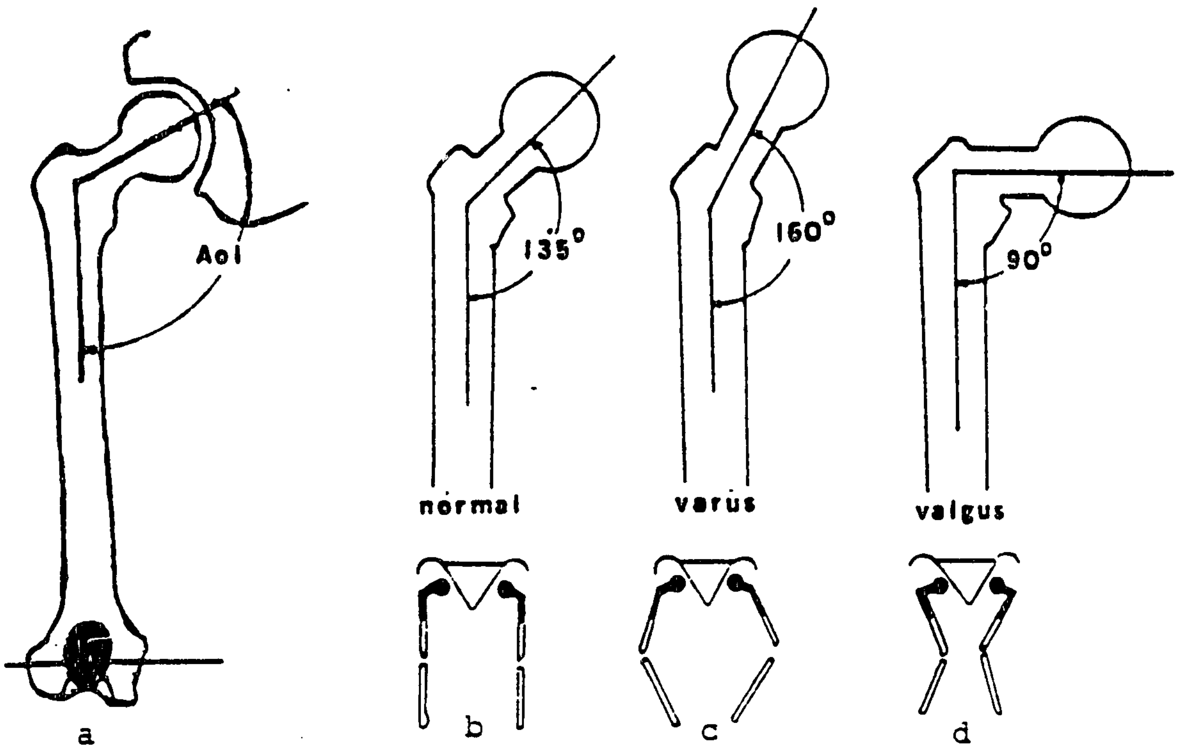

Figure 2: neck

a) The angle of inclination (AoI), between the axis of the femoral and the long axis of the shaft of the femur.

b) The angle of inclination for a normal knee alignment.

c) The angle of inclination for a varus knee alignment.

d) The angle of inclination for a valgus knee alignment.

(The above diagrams were adapted from Cailliet (1983)).

The amount of varus is delineated by Reid (1987), as follows: (1) none - knees are touching, (2) mild - 1 to 5.0 cm between knees, (3) moderate - 5.1 to 7.5 cm between knees, and (4) severe - 7.6 cm or more between knees.

3. Genu Recurvatum

This deviation in alignment occurs in the sagittal plane and is also referred to as hyperextension of the knees. It can be caused by excess strength in the quadriceps and gastrocnemius muscle groups, overpowering that of the hamstrings (Arnheim, 1975). However, it can also be an indication of general ligament laxity (Booher and Thibodeau, 1985, Marshall et al, 1980).

Wilson (1985) has described a method of measuring the amount of recurvatum using a long arm goniometer. The angle is measured at the lateral epicondyle of the femur, using the greater trochanter and the lateral malleolus as proximal and distal reference points. The degrees, as described by Reid (1987), were as follows: (1) none - 0 degrees, (2) mild - 1 to 5 degrees, (3) moderate - 6 to 10 degrees, and (4) severe - 11 degrees or more.

4. Patellar Position

The position of the patella can be used as a subjective measure to determine the possible presence or absence of both patella alta, and excessive femoral anteversion (internal femoral torsion).

It was mentioned earlier that patellae that are inclined toward the midline, when standing with the feet parallel, can be referred to as "squinting" patella. Carson (1985), and others (Arnheim, 1975, Carson, et al, 1984, Insall, 1979, James, 1979, Tachdjian, 1972), have stated that a greater than normal femoral anteversion may be initially detected with the presence of this "squinting" which is often associated with genu varum as well.

Carson et al (1984), Hughston et al (1984) and Percy and Strother (1985), believe that the position of the patella in terms of its height, may be indicant of the patellar tendon length. The term patella alta was used earlier to describe a high riding patella. According to these authors, this would suggest a longer patellar tendon.

The subjective evaluation of patellar position can be made with the subject sitting with legs hanging at 90 degrees. In this position, the patellar tendon is stretched to its fullest, but being inelastic, its actual length is not affected (Gruber, 1979, Lancourt and Cristini, 1975). Normally, the center of the patella faces forward, but with patella alta, the lower pole may protrude and the center may face more superiorly (Carson et al, 1984, Hughston et al, 1984, Percy and Strother, 1985).

Another method of subjectively assessing the patellar position was referred to earlier as detecting a positive or negative "camel sign". Hughston et al (1984), recommended that this be done with the subject standing or lying supine. The test is positive if there is a double hump present on the front of the knee which would indicate a prominent infrapatellar fat pad (Figure 3). Hughston et al (1984) suggests the reason for this is that the high riding patella leaves the fat pad partially uncovered.

Leg Heel Alignment

The methods described in the literature for measuring the alignment of the lower leg and heel are fairly consistent, but not validated. First, the subject must lie prone with feet extended over the end of the table. In this position, two lines are drawn on the skin: one bisecting the distal portion of the lower leg and the other bisecting the calcaneus (Hughes, 1985, Carson et al,

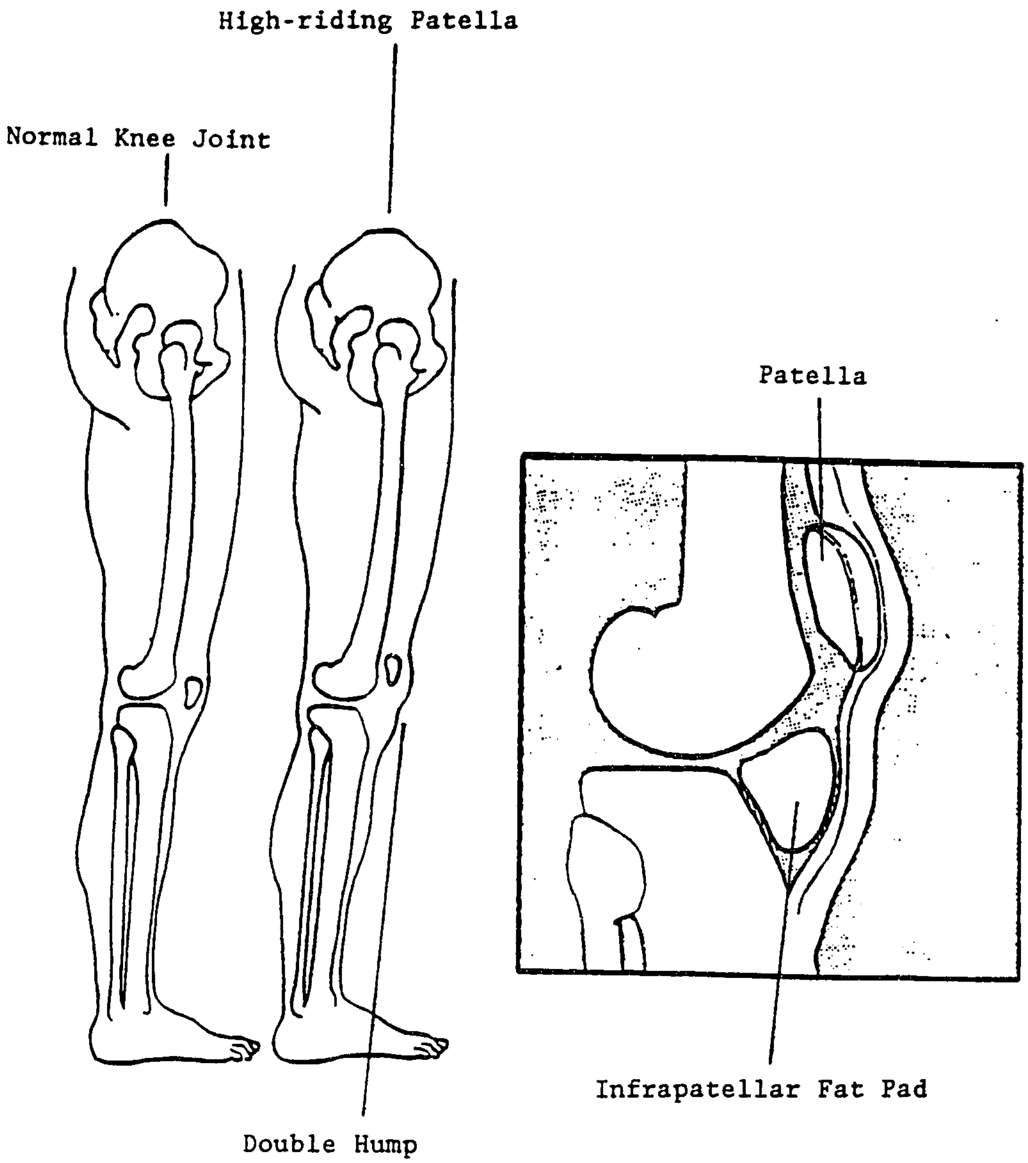

Figure 3. The "camel sign", or double hump over the knee as seen from a lateral view (adapted from Hughston et al, 1984).

1984, James, 1979, Stanley et al, 1978, Viitasalo and Kvist, 1983). Using either a protractor, or a goniometer, the angle at the intersection of these two lines can be measured. This can be done while the subject is lying prone, with the examiner placing the subtalar joint in its neutral position, or with the subject standing (Hughes, 1985, Carson et al, 1984, James, 1979, Stanley et al, 1978, Viitasalo and Kvist, 1983). Figure 4 illustrates both a normal and a valgus leg-heel alignment while standing.

According to James (1979) and Stanley et al (1978), the significance of measuring the alignment of the leg and heel is based on the following assumptions:

(1) there is a position (the neutral position) where the foot will function most efficiently with the least amount of stress and strain on the joints, ligaments and tendons;

(2) with weight bearing, the foot should functionally be positioned where the vertical axis of the heel is parallel to the longitudinal axis of the distal one-third of the tibia, and the plane of the metatarsal heads is perpendicular to the vertical axis of the heel; and

(3) these relationships should exist with the subtalar joint at or close to its neutral position.

Clinically, these authors have found two to three degrees of subtalar varus to be the most common unweighted, leg-heel alignment measurements.

The lack of validation of the leg-heel alignment measurements is in the relationship between these measurements and actual position of the subtalar joint, especially while standing (Reid, 1988).

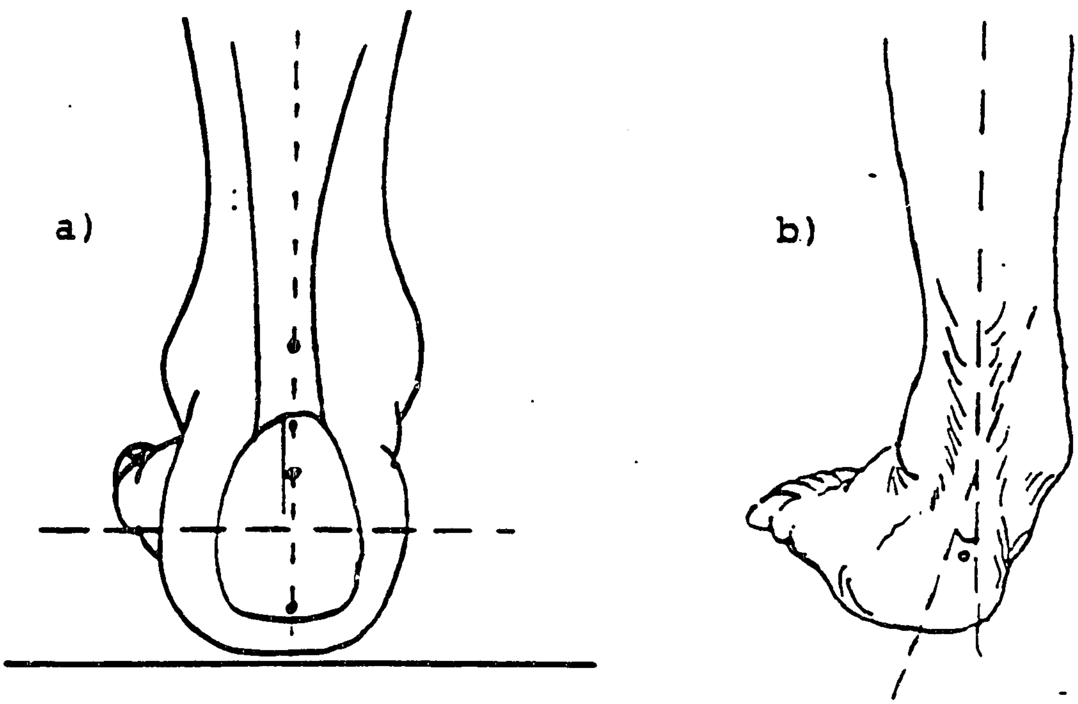

Figure 4. a) Normal position of the heel with respect to the lower leg (adapted from Stanley et al, 1978).

b) A valgus heel position (adapted from Hoppenfeld, 1976).

Foot Configuration

It is common, in the literature, to refer to a pronated foot. Pronation is not a biomechanical abnormality. It refers to a chain of events within the gait cycle that occurs to dissipate force (Marshall, 1988, Tiberio, 1987). Buchbinder et al (1979), Mann (1982), Donatelli, (1987) and Ramig et al (1980) have referred to excessive pronation, as the foot that pronates beyond 25% of the stance place. This results in the inability of the foot to effectively absorb the forces of weight-bearing, and thus could predisposean individual to certain types of injury. It is beyond the scope of this study to describe the biomechanics of the foot, since a dynamic assessment of gait will not be included.

Excessive pronation can be a compensatory motion secondary to one or more of the following conditions: (1) genu varum, (2) tibia varum, (3) triceps surae contracture, (4) subtalar or hindfoot varus, and/or (5) forefoot varus (Bordelon, 1983, Carson et al, 1984, Carson, 1985, James, 1979, Prost, 1979, Stanley, 1978, Subotnick, 1981). If the foot has a static, structural deformity in which the position of the bones in the foot is altered, lowering the longitudinal arch, it is referred to pes planus, or flat foot (Cailliet, 1983).

The cavus foot has a high longitudinal arch with a very inflexible subtalar joint, resulting in poor shock absorption (Booher and Thibodeau, 1985).

A subjective assessment of the height of the longitudinal arch can be done while standing. This can give the examiner an idea of how the longitudinal arch would appear during the midstance phase of the gait cycle.

D. Range of Motion Assessment

The assessment of joint and muscle range of motion will be reviewed pertaining to the hip and ankle joints only.

Femoral Torsion and Hip Rotation

The femur can be twisted on its longitudinal axis such that the femoral neck axis is rotated anteriorly or posteriorly in relation to the frontal or coronal plane of the femoral condyles. An anterior rotation of the femoral neck is referred to as anteversion or antetorsion, whereas a posterior rotation is called retroversion or retrotorsion (Tachdjian, 1972). Figure 5 depicts an anterior rotation of the femoral neck axis, and labels it the angle of anteversion (Cailliet, 1983). Cailliet (1983), and Stanish (1984), have both claimed that the normal range of this angle is between 15 and 25 degrees. A graph by Crane (cited in Tachdjian, 1972) shows a decreasing degree of normal femoral torsion with age in children up to nine years old. Another graph by Shands and Steele (cited in Tachdjian, 1972) shows the same trend in subjects up to age 20.

Clinically, measurement of the degree of hip rotation in extension can be useful (Cailliet, 1983, Carson et al, 1984, James, 1979, Staheki et al, 1985, Stanish, 1984, Tachdjian, 1974, Teitz, 1982). The method most commonly reported in the literature involves the subject lying prone with the knees flexed to 90 degrees, and the pelvis level (Carson et al, 1984, James, 1979, Staheli et al, 1985, Teitz, 1982). The feet are passively allowed to fall to the sides causing internal rotation at the hip joint. The angle of rotation is then measured with a goniometer. To measure external rotation, the feet are allowed to fall the opposite way and the degree of rotation is then measured. These measurements can also be made with the subject sitting, feet hanging

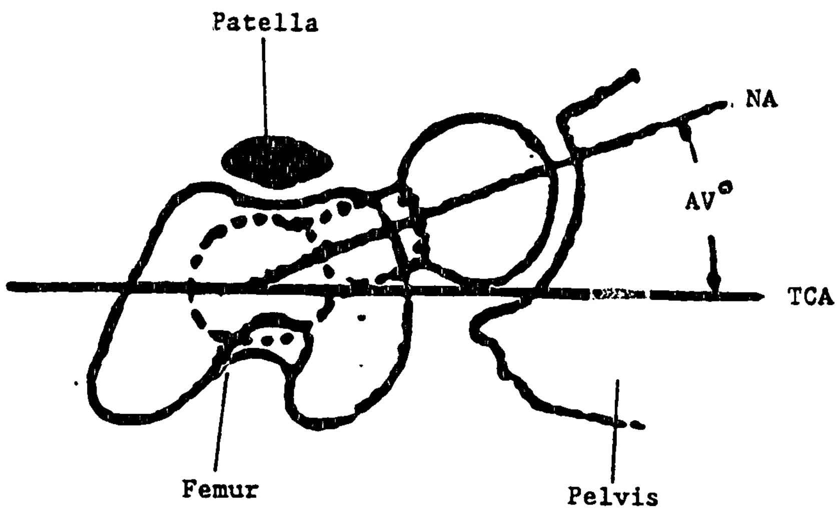

Figure 5. A superior view of the left hip joint indicating the angle of anteversion (AV), between the axis of the femoral neck (NA) and the transcondylar axis (TCA) (adapted from Cailliet, 1983).

freely. Stabilizing the thigh, the entire limb can be rotated internally and externally using the lower leg as a lever (Hoppenfeld, 1976). It must be stressed, however, that this range of hip rotation in extension is not limited exclusively by the amount of femoral torsion. Other factors such as the inclination of the acetabulum, and soft tissue limitations - capsule, ligaments, muscles and fascia around the hip joint, also limit this rotational range (Reid, 1987, Tachdjian, 1972).

There is considerable disagreement in the literature concerning the normal range of motion at the hip joint. Carson et al (194), and James (1979), have both stated that if the internal rotation is greater than the external rotation by 30 degrees or more, then excessive femoral anteversion is indicated. Teitz (1982), has stated the same, but without specifying how much greater the internal rotation must be to indicate excessive anteversion. Cailliet (1983), considers the normal range to be 35 degrees for internal rotation and 45 degrees for external rotation. He also says that if internal rotation is great, excessive femoral anteversion is indicated. Tachdjian (1972), has reported that normal internal and external rotation of the hips in childhood ranges from 35 to 45 degrees. With excessive femoral anteversion, internal hip rotation is exaggerated and may be as much as 90 degrees, whereas external rotation may be limited to neutral. James (1979), and Tachdjian, (1972), have both reported that most normal adults demonstrate greater external than internal rotation of the hips by approximately 10 degrees.

Another method of assessing rotational abnormalities was described previously and involves the detection of "squinting" patella. Gait assessment of the subject can also be helpful. Carson (1985), has suggested that deviation of the feet 10 degrees or more from the line of progression should be considered abnormal, and that this may be indicative of excessive femoral torsion and/or tibial torsion. However, it must be emphasized that excessive internal femoral torsion or anteversion can create an in-toed gait, but often, in an attempt to voluntarily correct this, the subject places the feet in the line of progression. This can lead to secondary adaptive changes such as lateral or external torsion of the tibia, and pronated feet due to a hindfoot valgus deformity (James, 1979, Stanish, 1984, Tachdjian, 1972).

Hamstring Flexibility

When measuring flexibility, it is difficult to isolate the hamstring muscle group, since the muscles of the lower back are also being stretched during hip flexion.

One method of measurement involves recording the maximum angle of hip flexion during a straight leg raise in the supine position (Antich and Brewster, 1985, Smith and Micheli, 1982).

Another method described by Reid et al (1987) involves both hip and knee flexion. The subject lies supine with one leg extended and straight and the other flexed maximally at the hip and knee. From this position, the knee is extended and the angle measured with the stationary arm of the goniometer on the long axis of the thigh, and the moving arm along the long axis of the lower leg. The center of rotation of the goniometer is the lateral femoral condyle.

Ankle Dorsiflexion

Dorsiflexion occurs at the ankle joint in the sagittal plane. It is the movement of the foot pulling upwards from the anatomical position. Generally a goniometer is used to measure this range of motion. Measurements can be taken with the subject lying supine and the knees fully extended, (Carson et al, 1984, Carson, 1985, James, 1979) or when sitting with the legs hanging (Booher and Thibodeau, 1985, Hoppenfeld, 1976, James, 1979). In the flexed knee position, the gastrocnemius is relaxed, and can be eliminated as a possible restriction on the range of dorsiflexion. It is important to stabilize the subtalar joint in a slightly inverted position while measuring because a larger angle of dorsiflexion may be perceived if pronation occurs (James, 1979).

Hoppenfeld (1976) has claimed that the range of dorsiflexion in the knee-flexed position should be the same or slightly greater than with the knees extended. In the literature, the normal range of motion is often reported to be between 10 and 15 degrees (Booher and Thibodeau, 1985, Carson et al, 1984). However, Hughston et al (1984), and Hoppenfeld (1976) have reported 25 and 20 degrees respectively.

III. METHODS AND PROCEDURES

A. Subjects

The subjects for the present study were female figure skaters from across Canada. The age requirement being 11 years or older as of September 1, 1987. All of the skaters requested to participate were currently competing at a level no lower than Juvenile "A". The subjects were recruited from the Royal Glenora Club in Edmonton and the 1988 National Singles Training Seminar held in Calgary.

The subjects tested were categorized into two groups with 50 subjects in each group:

Group I - Those skaters who so far during their competitive careers had reported no overuse injury problems.

Group II - Those skaters who were currently suffering from or had reported past overuse injury problems.

B. Equipment

The following is a list of the measuring instruments used for the physical examination:

Manual long arm gonimeter. This particular goniometer was specially adapted by Reid (1987) with a spirit level on each arm for accurate placement in both the vertical and horizontal planes.

Eight inch goniometer.

Tape measure - in millimeters.

Ball point pen for joint markings on the skin.

Two belts used for stabilizing the hips to the surface during the measurement of internal and external hip rotation.

Rubbing alcohol and cotton balls for the removal of pen marks on the skin following the measurements.

C. Experimental Design

Each subject was initially given a letter which briefly explained the purpose and procedures of the study. This was accompanied by the consent form for participation (Appendix A) and the questionnaire (Appendix B).

The data collection took place in three stages, which remained in the same order for all 100 subjects. First, the questionnaire was filled out. Second, the examiner interviewed the subject to ensure the accuracy of the answers to the questionnaire. Third, the examiner performed the physical examination of the subject.

The Questionnaire

The questions pertained to the subjects skating history and ability, training habits both on and off the ice, equipment, and history of injuries. The importance of accuracy in the subjects answers was emphasized verbally when the questionnaires were given out.

The Physical Examination

The subjects were asked to wear shorts and a T-shirt for the examination. The various measurements were taken consistently in the same order for all 100 subjects and were performed on a table with a hard contact surface. Where applicable, the measurements were taken on both the left and right sides.

1. Supine Position

The following measurements were taken with the subject lying supine, fully supported by the surface, and the feet vertical.

a. Leg Lengths

The subject was positioned with the legs straight, and feet pointing vertically. Using the ballpoint pen, the left and right anterior superior iliac spines were marked, as well as the medial interarticular joint spaces, (to be used later). The following measurements were then taken:

True Leg Length - From the anterior superior iliac spine (A.S.I.S.) to the inferior edge of the medial malleolus, on the same side.

Apparent Leg Length - From the center of the umbilicus to the inferior edge of the medial malleolus.

b. Quadriceps Angle (Q Angle)

With the subject remaining in the same position, marks were made at the center of both patellae, and tibial tuberosities, with the pen. The marks previously made on the anterior superior iliac spines were re-checked for accuracy. Using the long arm goniometer, the Q angle was measured on each leg with the centers of the patellae corresponding with the center of rotation of the goniometer.

c. Hamstring Flexibility

Keeping one leg on the surface, with the hip and knee fully extended, the opposite leg was flexed maximally at the hip and knee by having the subject pull the thigh to the chest. A pen mark was made at the lateral femoral condyle of the flexed leg and was used a the center of rotation of the goniometer. One arm of the goniometer remained stationary on the long axis of the thigh, while the other arm represented the long axis of the lower leg. The subject was instructed to hold the position of maximum hip flexion using the hands to assist, and then to extend the knee as far as possible in this position. The degree of knee extension was measured with the goniometer held by the examiner in the position described.

This procedure was repeated twice on both the left and right sides.

d. Camel Sign

A subjective assessment was made of the knee joints from a lateral view with the quadriceps relaxed. The presence or absence of a double hump on the anterior surface of the knee was recorded.

2. Prone Position

With the subject lying prone on the surface, with the feet hanging over the edge, the following measurements were taken:

a. Hip Rotation

The subjects hips were stabilized to the surface of the table with the use of a belt. Following this, pen marks were made on the inferior poles of both patellae with the knees flexed to 90 degrees. The left leg was then straightened while the right remained flexed.

First, the internal hip rotation was recorded by allowing the flexed leg to passively rotate outward. In this position, the degrees from vertical, according to the spirit level on one arm of the goniometer, were measured. The other arm represented the long axis of the lower leg, while the axis of rotation of the goniometer was the inferior pole of the patella. This procedure was then repeated with the other leg.

External hip rotation was measured in the same position, allowing the flexed lower leg to rotated inward. Again the degrees from vertical were measured with the goniometer. The procedure was then repeated on the other side.

b. Ankle Dorsiflexion

This measurement was first taken with the knees extended. The examiner held the subtalar joint in a slightly inverted position while passively dorsiflexing the ankle by applying pressure to the bottom of the foot. The eight inch goniometer was used to measure this angle on the lateral side of the ankle, with the axis of rotation being slightly inferior to the lateral malleolus, and its arms corresponding to the long axis of the lower leg, and the inferior border of the foot.

The measurement of ankle dorsiflexion was also taken in the same manner with the knee flexed to 90 degrees.

While the subject was lying prone, the markings for the measurement of the leg-heel alignment while standing were made. Using the pen, the long axis of both the calcaneus and the lower leg were drawn on the skin.

3. Standing on Assessment Table

With the subject standing on top of the surface of the table, the following measurements were taken:

a. Leg-Heel Alignment

The subject was asked to stand with both heels flush to the edge of the table, facing away from the examiner. The distance between the feet was measured to be eight centimeters for all subjects. Using the eight-inch goniometer, the alignment of the long axis of the calcaneus and the long axis of the lower leg was measured, with the axis of rotation being the intersection of these two lines.

b. Foot Configuration

With the subject in the same position as above, the longitudinal arch of each foot was subjectively assessed according to its height from the surface.

The examiner categorized the arches as flat (no arch), low, or medium to high, and recorded them as such.

c. Knee Joint Configuration

The subject was asked to face the examiner and place the feet parallel, and as close together a possible. In the case of genu valgum, the space between the medial malleoli was measured with the tape measure and recorded. If genu varum was present, the space between the medial interarticular knee joint spaces (previously marked with the pen), was measured and recorded.

With the subject turned sideways, with respect to the examiner, pen marks were made on the greater trochanter of the femur, the lateral femoral condyle, and the lateral malleolus. Allowing the subject to stand relaxed, the long arm goniometer was places with its axis of rotation on the lateral femoral condyle. Using the marked proximal and distal points, the degree of genu recurvatum (if present) was measured.

d. Patellar Position

The position of the patella was assessed previously with the subject lying supine. Here, while standing, facing the examiner, with the feet parallel, the direction of facing for each patella was recorded as, slightly inward, slightly outward, or straight forward.

4. Sitting on Assessment Table

The subject was asked to sit on the surface of the table, as far back as possible, allowing the lower legs to hang freely at 90 degrees. Again, the direction of facing for each patella was noted as slightly inward, slightly outward, or straight forward. In addition, the patellae were reported to be high-riding if they appeared to be angled upward with the inferior poles protruding.

5. Standing on Floor

a. Height

With the subject standing on the floor, heel against the wall, and eyes directed forward, the horizontal level on the arm of the goniometer was used to correctly place a mark on the wall corresponding to the top of the subjects head. The distance between the floor and the mark was then measured with the tape measure.

b. Weight

The weight of the subjects tested at the Royal Glenora Club was taken using a beam-type scale.

The weight of the those tested at the Training Seminar in Calgary was reported from memory by the subjects. (Each of these subjects had been fitness-tested and weighed within the previous five days.)

At the conclusion of the physical examination, the subjects were asked if they had yet begun having their menstrual periods regularly.

D. Organization of the Data

The data collected in the physical examination was recorded on data sheets (Appendix C).

Following the collection of data from all 100 subjects, a computer analysis of frequency data was performed. Based on these frequencies the results were reported descriptively, according to the three purposes of the study.

Box plots were made for selected variables to further illustrate the distribution of scores.

IV. RESULTS

In accordance with the purpose of this study, two major comparisons of the data were made. First, the structural and physical data obtained from the physical examination was compared between groups I and II. Second, this data obtained from the physical examination was used to compare subjects within group II, who had reported similar overuse injury problems. Following these two comparisons, the data collected from the questionnaires was examined in order to identify other factors which may have contributed to the distinction between groups I and II in terms of their injuries. In most cases, comparisons were made of the measurement mean values. Box and whisker displays were made of selected variables to illustrate their distribution of scores. A description of interpretation procedures for these displays can be found in Appendix D.

A. Comparison of Physical Data for Groups I and II

Leg Lengths

The mean values showed no apparent or true leg length discrepancies in either group. The means also reflected all leg length measures in group II to be greater than group I with differences ranging from 0.9 cm to 1.2 cm (Tables 1 and 2).

Quadriceps Angle

There was no difference greater than 0.5 degrees between the means of the Q angle of each leg for groups I and II. The differences between legs in each group reflected no greater than 0.4 degrees. The degree values ranged

Table 1. Measures of Central Tendency and Distribution for Selected Physical Measurements of Group I

Variable		Units	Mean	Mode	Minimum Value	Maximum Value	Median	Standard Deviation	Number of Cases	
Age		Years	14.5	14.0	10.0	18.0	14.0	2.0	50	
Height		cm	156.3	157.0	138.2	171.3	157.3	7.8	50	
Weight		kg	47.8	51.3	31.0	61.2	49.2	7.8	50	
Q Angle	L	Degrees	9.5	11.0	5.0	21.0	9.0	3.4	50	
	R	Degrees	9.8	12.0	4.0	20.0	10.0	3.3	50	
Genu Valgum		cm	3.2	1.0	1.0	5.0	3.5	2.0	3	
Genu Varum		Degrees	2.8	2.0	0.7	5.5	2.9	1.3	36	
Genu	L	Degrees	5.1	3.0	1.0	15.0	4.0	3.1	41	
Recurvatum	R	Degrees	4.9	2.0	1.0	15.0	4.0	3.0	42	
Leg-Heel	L	Degrees	6.1	5.0	0.0	15.0	5.0	2.6	50	
Alignment	R	Degrees	7.6	6.0	2.0	15.0	7.0	2.8	50	
Medial Hip	L	Degrees	39.1	30.0	11.0	61.0	39.0	10.6	50	
Rotation	R	Degrees	38.8	35.0	18.0	65.0	38.0	9.4	50	
Lateral Hip	L	Degrees	34.0	36.0	10.0	55.0	33.5	10.4	50	
		Degrees	37.9	30.0	15.0	61.0	37.5	10.6	50	
Ankle Dorsiflexion	L	Degrees	11.6	10.0	5.0	20.0	11.0	3.8	50	
Knee Extended	R	Degrees	12.8	15.0	4.0	21.0	13.0	3.9	50	
Ankle Dorsiflexion	L	Degrees	21.9	25.0	12.0	35.0	21.0	5.2	50	
Knee Flexed	R	Degrees	19.5	19.0	11.0	30.0	19.0	3.8	50	
Hamstring	L	Degrees	127.4	110.0	109.0	161.0	126.0	12.9	50	
Flexibility	R	Degrees	127.7	130.0	105.0	164.0	127.0	12.3	50	
True Leg	L	cm	81.7	83.0	67.8	91.5	82.0	4.4	50	
Length	R	cm	81.5	82.5	68.0	91.5	82.0	4.4	50	
Apparent Leg	L	cm	91.0	93.0	76.2	102.0	92.0	5.0	50	
Length	R	cm	91.0	92.0	76.7	102.0	92.0	5.0	50	

Table 2. Measures of Central Tendency and Distribution for Selected Physical Measurements of Group II

Variables		Units	Mean	Mode	Minimum Value	Maximum Value	Median	Standard Deviation	Number of Cases
Age		Years	15.0	14.0	11.0	22.0	15.0	2.1	50
Height		cm	159.0	147.9	137.2	174.7	159.4	7.8	50
Weight		kg	50.9	56.2	29.1	66.2	52.7	7.8	50
Q Angle	L	Degrees	9.0	8.0	1.0	16.0	9.0	3.1	50
	R	Degrees	9.4	10.0	2.0	16.0	10.0	2.9	50
Genu Valgum		cm	1.0	1.0	1.0	1.0	1.0	-	1
Genu Varum		cm	3.0	2.0	0.8	7.0	2.5	1.6	41
Genu	L	Degrees	6.2	4.0	1.0	15.0	5.0	3.2	43
Recurvatum	R	Degrees	5.8	5.0	1.0	15.0	5.0	3.3	44
Leg-Heel	L	Degrees	6.8	5.0	0.0	14.0	6.0	3.1	50
Alignment	R	Degrees	8.5	9.0	0.0	15.0	9.0	3.5	50
Medial Hip	L	Degrees	36.5	30.0	22.0	51.0	37.0	7.5	50
Rotation	R	Degrees	36.2	30.0	18.0	57.0	36.0	9.0	50
Lateral Hip	L	Degrees	30.6	30.0	15.0	44.0	30.5	7.6	50
Rotation	R	Degrees	34.2	25.0	21.0	50.0	33.5	7.8	50
Ankle Dorsiflexion	L	Degrees	11.5	10.0	5.0	20.0	11.0	3.9	50
Knee Extended	R	Degrees	12.6	10.0	6.0	25.0	11.0	4.1	50
Ankle Dorsiflexion	L	Degrees	21.1	25.0	11.0	28.0	20.5	4.2	50
Knee Flexed	R	Degrees	19.9	20.0	12.0	28.0	20.0	3.8	50
Hamstring	L	Degrees	126.9	132.0	70.0	160.0	126.5	15.6	50
Flexibility	R	Degrees	126.0	130.0	94.0	161.0	127.0	13.2	50
True Leg	L	cm	82.6	81.0	72.0	92.0	82.0	4.7	50
Length	R	cm	82.5	80.0	71.5	91.5	81.8	4.7	50
Apparent	L	cm	92.2	90.0	79.5	102.5	91.5	5.0	50
Leg Length	R	cm	92.2	90.0	79.5	102.5	91.5	5.1	50

from 9.0 to 9.8 degrees (Tables 1 and 2). Figure 6 reveals box and whisker displays of the Q angle values for the left and right sides in groups I and II.

Knee Joint Configuration

The incidence of the genu valgum alignment was very low, with three cases in group I, (mean value of 3.2 cm) and one case in group II (1.0 cm).

In group I, 72% had the genu varum alignment, with a mean value of 2.8 cm. Group II had this alignment in 82% of the subjects, with a mean value of 3.0 cm.

There were 22% (11 subjects) in group I and 16% (8 subjects) in group II who had neither a genu valgum nor a genu varum alignment (Tables 1 and 2).

The genu recurvatum alignment was present in group I with 82% (mean value, 5.1 degrees), on the left side, and 84% (mean value, 4.9 degrees), on the right side. In group II, the genu recurvatum alignment was present on the left side in 86% (mean value, 6.2 degrees) of the subjects and on the right side in 88% (mean value, 5.8 degrees) of the subjects.

The number of subjects in each group who did not have a measurable genu recurvatum alignment was 8 (16%) in group I and 7 (14%) in group II. There was 1 subject in each group who had a measurable genu recurvatum alignment on the right side, but not on the left. This accounts for the differences in percentages for each side (Tables 1 and 2).

The assessment of patellar position while standing revealed 20% in group I to have a "squinting" or inward tilt alignment in both patellae, while group II showed 32% in the left knee and 26% in the right to have the "squinting" alignment (Tables 3 and 4). (Tables 3 and 4 do not include separate notation for left and right values in the first two variables because they are identical).

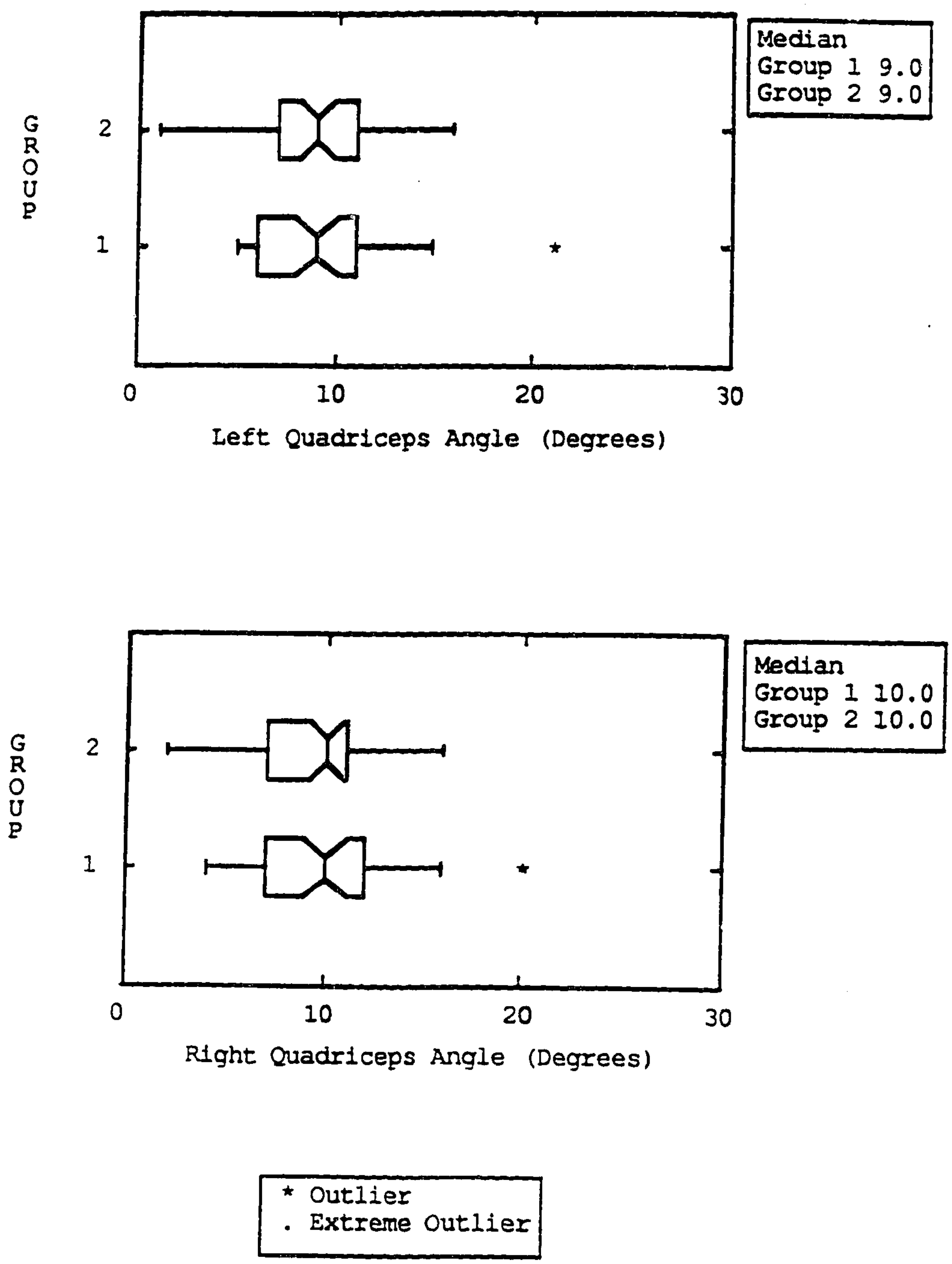

Figure 6. Box and Whisker Diagrams for the Distributions of Left and Right Q Angles in Groups I and II

Table 3. Patellar Position While Standing, Sitting and Lying Supine in Group I

	Supine	Sitting	Standing
Camel Sign (Positive)	12%	-	-
High-Riding Patella (yes)	-	28%	-
Direction of Facing Outward	-	L 82%	30%
	-	R 84%	26%
Forward	-	L 18%	50%
		R 16%	54%
Inward	-	L -	20%
		R -	20%

Table 4. Patellar Position While Standing, Sitting and Lying Supine in Group II

	Supine	Sitting	Standing
Camel Sign (Positive)	12%	-	-
High-Riding Patella (yes)	-	28%	-
Direction of Facing Outward	-	L 82%	30%
	-	R 84%	26%
Forward	-	L 18%	505
		R 16%	54%
Inward	-	L -	20%
		R -	20%

The assessment of patellar position while sitting with the legs hanging at 90 degrees showed 84% in group I and 80% in group II to have slightly outward facing of the right patellae. The values for the left patella were 82% and 76% respectively.

In this sitting position, the patella was reported to be high, or to have a protruding lower pole in 28% of the subjects in group I, and 26% in group II.

The height of the patella was also assessed by the presence or absence of a "camel" sign in the supine position. The results showed the "camel" sign present in 12% of group I and 20% of group II (Tables 3 and 4).

Leg-Heel Alignment

The alignment of the leg and heel, while standing, was valgus in all 100 subjects. The mean values were smaller for group I than group II. Group I had mean values of 6.0 degrees in the left and 7.6 degrees in the right, whereas group II had mean values of 6.8 degrees in the left and 8.5 degrees in the right. Both groups showed the mean values of the right side to be greater than that of the left (Tables 1 and 2). Box and whisker diagrams of the left and right leg-heel alignments in groups I and II are shown in Figure 7. The distribution of scores was quite different between the groups on both the left and right sides.

Longitudinal Arch of Foot

The assessment of the longitudinal arch of the foot while standing showed more incidences of low arches in group II. Group I had 34% in the left foot, and 36% in the right with low arches. Group II showed low arches in 44% of the left, and 46% of the right. Both groups had two cases of bilateral flat feet. Medium to high arches were reported for 62% of the left feet, and 60% of

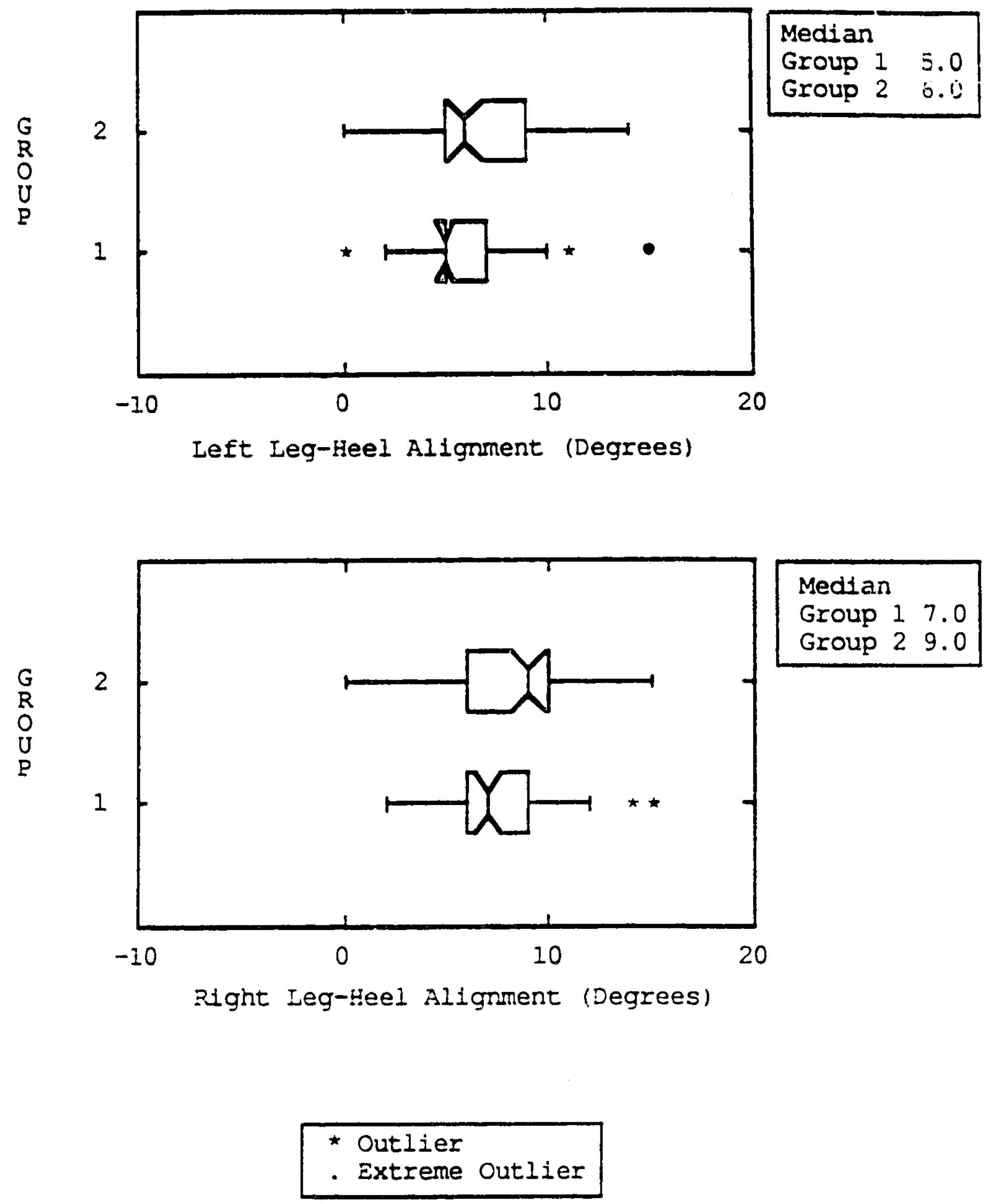

Figure 7. Box and Whisker Diagrams for the Distribution of Left and Right Leg-Heel Alignments in Groups I and II

the right in group I. Group II showed 52% of the left feet, and 54% of the right to have medium to high arches (Table 5).

Hip Rotation

Medial or internal hip rotation was greater in group I than group II, with mean differences of 2.6 degrees for both the left and right sides. A comparison of left and right mean values within each group, both showed a difference of only 0.3 degrees.

The mean degree values were 39.1 degrees for the left and 38.8 degrees for the right in group I, and 36.5 degrees for the left and 36.2 degrees for the right in group II.

Lateral or external hip rotation was also greater in group I than in group II, although the mean differences were 3.4 degrees and 3.8 degrees for the left and right sides respectively. The mean degree values were 34.0 degrees and 38.0 degrees for the left and right sides in group I, and 30.6 degrees and 34.2 degrees in the left and right sides for group II (Tables 1 and 2).

Hamstring Flexibility

The hamstring flexibility mean measures were 127.8 degrees for the left and 127.7 degrees for the right in group I. Group II showed 126.9 degrees for the left and 126.0 degrees for the right. There were no bilateral differences in the means for each group greater than 0.3 degrees (Tables 1 and 2).

Ankle Dorsiflexion

The mean values for the dorsiflexion measurements taken with the knees extended showed slight differences between the left and right sides in

Table 5. Height of Longitudinal Arches of Feet for Groups I and II

Longitudinal Arch of Foot	Group I		Group II		
	Left	Right		Left	Right
Flat	4%	4%		4%	4%
Low	34%	36%		42%	44%
Medium-High	62%	60%		54%	52%

both groups. There were no differences between groups for these measures. The values for group I were 11.6 degrees for the left and 12.8 degrees for the right. Group II showed 11.5 degrees for the left and 12.6 degrees for the right.

The dorsiflexion measurements taken with knees flexed to 90 degrees also showed differences between the left and right sides within each group. Between groups the maximum difference in the mean values was 0.8 degrees. The values for group I were 21.9 degrees for the left and 19.5 degrees for the right. Group II showed 21.1 degrees for the left and 19.9 degrees for the right.

A comparison of the mean values of the measurements taken in the knee extended, and knee flexed positions, revealed a difference of 10.3 degrees for the left and 6.7 degrees for the right in group I. In group II, the differences were 9.6 degrees for the left and 7.3 degrees for the right (Tables 1 and 2).

Figures 8 and 9 show box and whisker displays for the distributions of left and right dorsiflexion measurement scores in each of the knee extended and knee flexed positions for groups I and II.

Height, Weight, and Age

The mean values for height were 156.3 cm in group I and 159.0 cm in group II, a difference of 2.7 cm.

The mean values for weight were 47.8 kg in group I and 50.9 kg in group II, a difference of 3.1 kg.

The mean ages for the two groups differed by six months, the values being 14.5 years for group I and 15.0 years for group II. It was also found that 64% of the subjects in group I and 82% in group II had reached menarche (Tables 1 and 2).

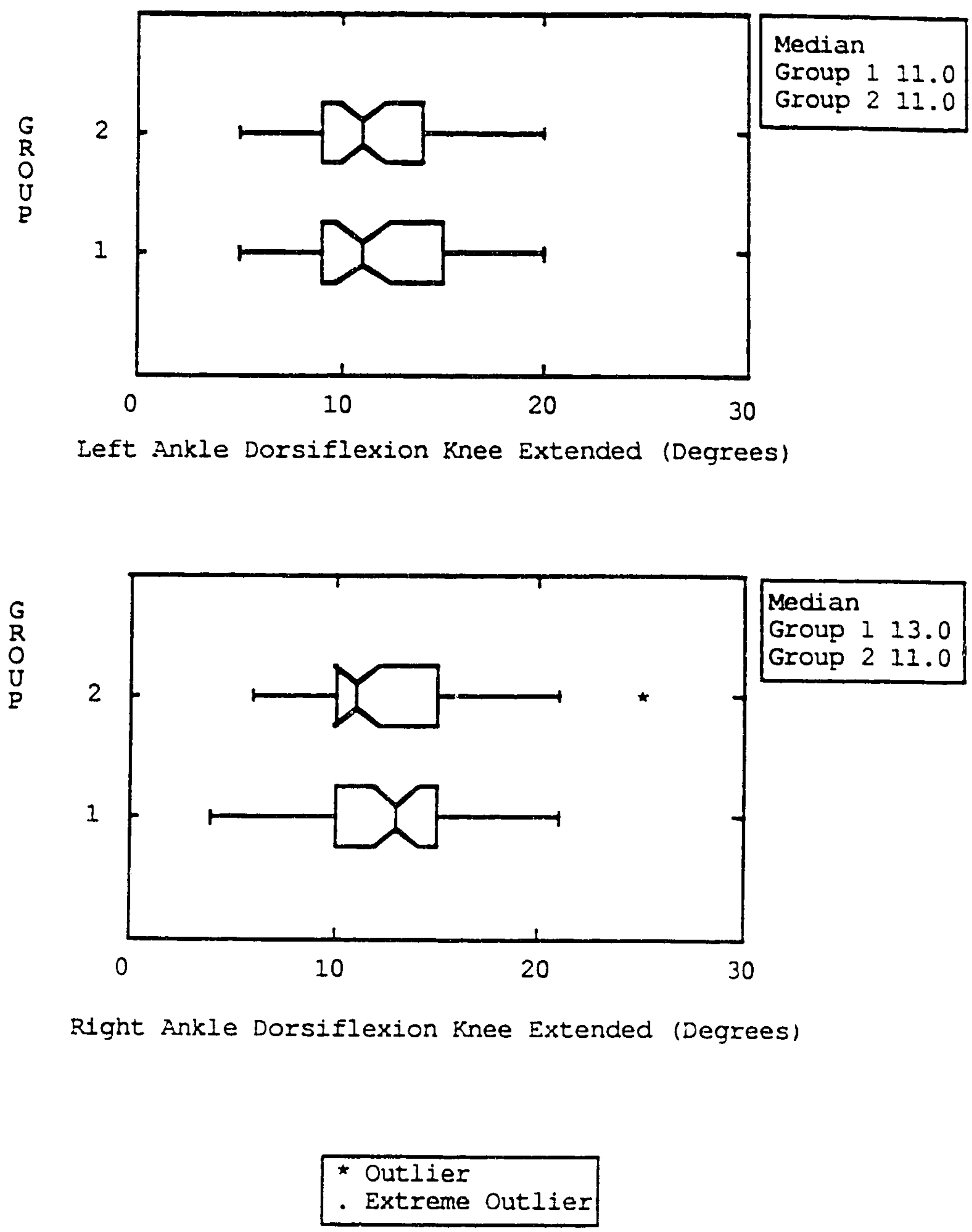

Figure 8. Box and Whisker Diagrams for the Distributions of Left and Right Ankle Dorsiflexion Measurements, Taken with the Knee Extended, in Groups I and II.

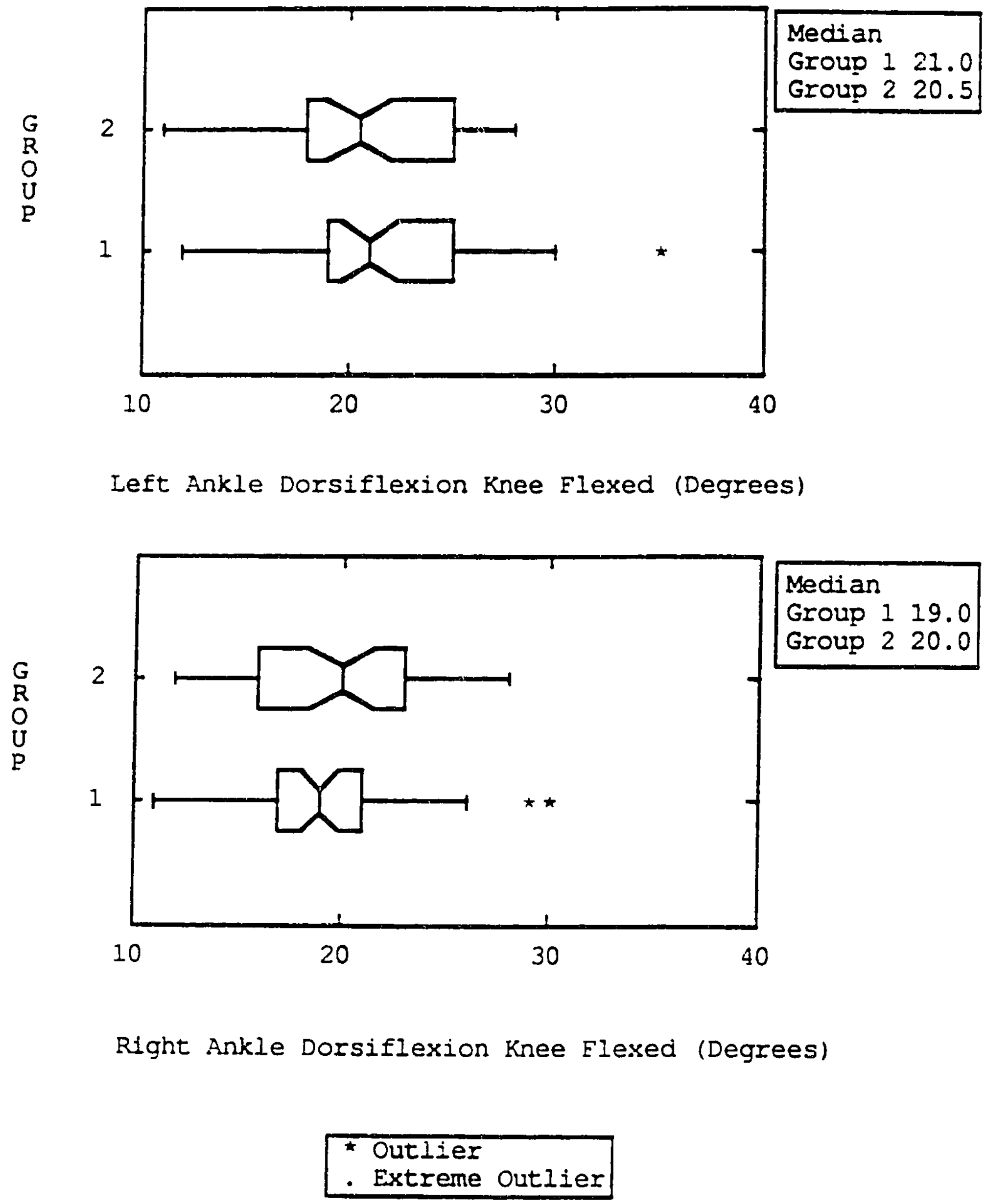

Figure 9. Box and Whisker Diagrams for the Distribution of Left and Right Ankle Dorsiflexion Measurements, Taken with the Knee Flexed, in Groups I and II.

B. Comparison of Physical Data for Selected Subjects in Group II

In group II, the injuries with the highest reported incidence, either unilaterally or bilaterally were, patellofemoral pain (42%), shin splints (26%), Achilles tendinitis (14%) and plantar fasciitis (14%). (Figure 10.) Table 6 lists each of the injuries for the left and right limbs reported in the results, as well as the number of bilateral cases. The total number of subjects affected by each injury and the percentage of the sample are also included.

Other, but less common injuries included ankle bursitis (12%), Osgood-Schlatter's Syndrome (10%), back pain (10%), and patellar tendinitis (8%). The physical data from the subjects affected by these injuries was not used for comparison due to the small number of cases.

Comparisons were made of the physical data between the subjects affected by the same injuries. The injuries used for this comparison were those with the highest reported incidence, mentioned above. The incidence data for each injury was divided into left and right side occurrences with bilateral cases being counted in both groups. The physical data of the subjects was also divided into left and right sides, and comparisons were then made. The assumption was, that if the physical measurements related to the injuries, then the left and right sides would show similar patterns. However it has been recognized that the numbers for these comparisons are very low, and therefore, it is unlikely that many patterns will be revealed.

The genu varum and valgum alignments were reported (where applicable), for the number of subjects affected either bilaterally or unilaterally.

The data for the following comparisons can be found in Tables 7 and 8.

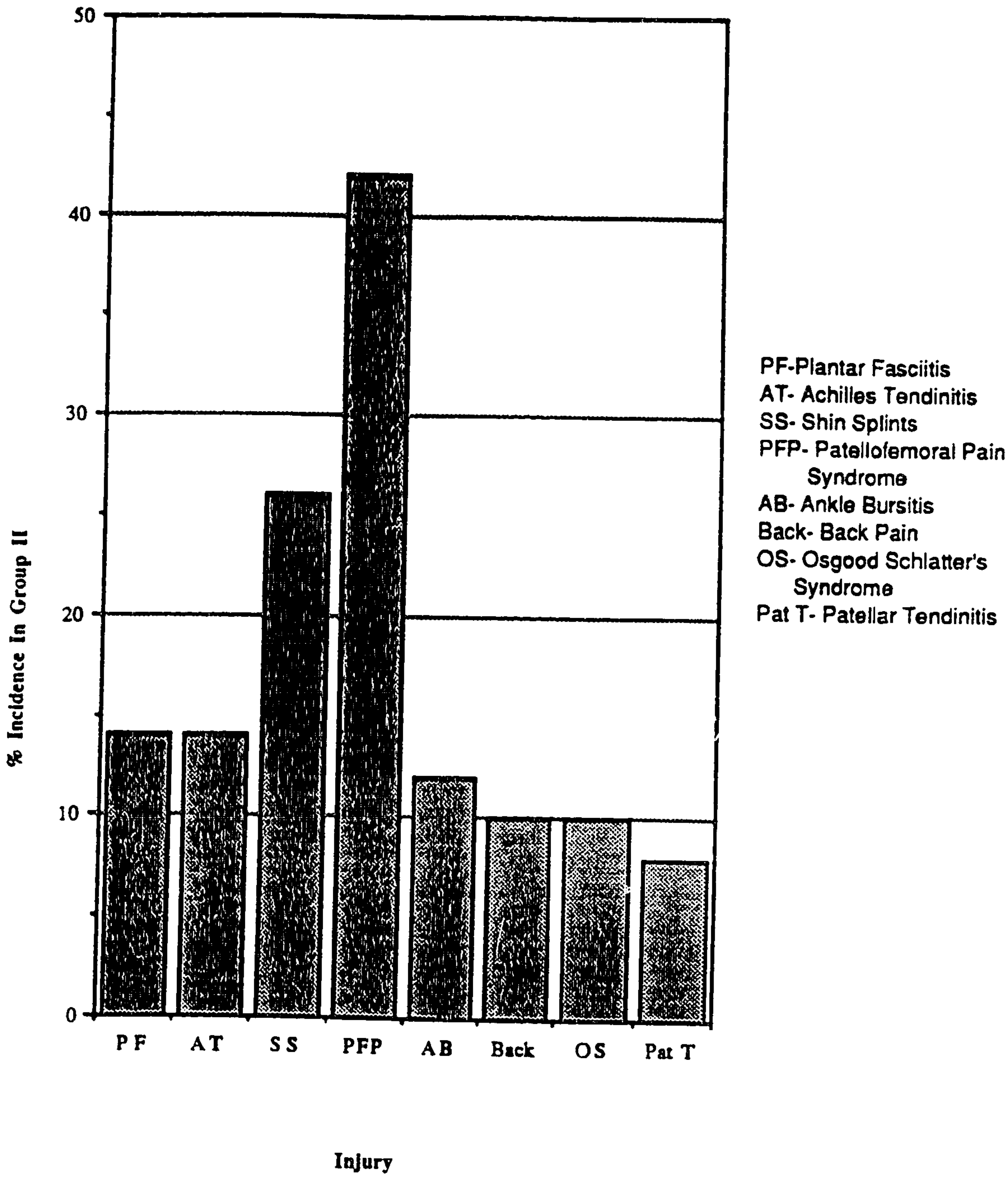

Figure 10 : Percentage of Bilateral or Unilateral Incidence of Injuries in Group II

Table 6. The Distribution of the Number of Incidences of Injuries Between the Left and Right Sides

Injury	Left Only	Right Only	Both Sides	Total Subjects	% of 50
Patellofemoral Pain	3	8	10	21	42
Shin Splints	2	3	8	13	26
Achilles Tendinitis	2	2	3	7	14
Plantar Fasciitis	1	4	2	7	14
Ankle Bursitis	4	1	1	6	12
Osgood-Schattler's Syndrome	0	2	3	5	10
Low Back Pain	-	-	-	5	10
Patellar Tendinitis	0	1	3	4	8
Peroneal Tendinitis	1	1	1	3	6
Medial Knee Pain	0	1	2	3	6
Metatarsal Stress Fracture	0	2	0	2	4
Fibular Stress Fracture	1	0	0	1	2
Medial Ankle Pain	0	0	1	1	2

Table 7. Distribution and Ranges for Selected Physical Measurements of Subjects that have had Shin Splints, Achilles Tendinitis or Plantar Fasciitis

Variable	Measurement Scale	Shin Splints No. of Cases Left	Shin Splints No. of Cases Right	Achilles Tendinitis No. of Cases Left	Achilles Tendinitis No. of Cases Right	Plantar Fasciitis No. of Cases Left	Plantar Fasciitis No. of Cases Right
		10	11	5	5	3	6
Longitudinal Arch of Foot	Flat	1	1	-	-	-	1
	Low	5	4	4	4	1	4
	Medium - High	4	6	1	1	2	1
Leg-Heel Alignment (Degrees)	0 - 5 Degrees	3	1	3	-	2	1
	6 - 10 Degrees	7	9	2	3	1	3
	>10 Degrees	-	1	-	2	-	2
Ankle Dorsiflexion (Knee Extended) (Degrees)	Range	6 - 20	10 - 25	10 - 17	12 - 17	8 - 14	7 - 20
	Mean	14.2	15.8	14.4	14.4	10.7	14.0
Ankle Dorsiflexion (Knee Flexed) (Degrees)	Range	16 - 26	15 - 25	18 - 28	17 - 23	18 - 24	15 - 24
	Mean	22.0	20.5	21.0	21.0	20.3	20.0

Table 8. Measurement Distribution of Knee Alignment in Subjects that have had Shin Splints, Patellofemoral Knee Pain or Achilles Tendinitis

Knee Alignment		Shin Splints	Patellofemoral	Achilles
			Pain Syndrome	Tendinitis
	Range	No. of Cases - 13	No. of Cases - 21	No. of Cases - 7
Genu Varum (cm)	0	3	5	1
	1 - 3	5	9	4
	4 - 7	5	7	2
Genu Valgum (cm)	Cases	0	1	0

Shin Splints

There were 10 incidences of shin splints reported for the left leg and 11 for the right (Table 6).

1. Longitudinal Arch of Foot

On the left side, there were 5 cases of low arches and 4 of medium to high arches. On the right side, there 4 low arches and 6 cases of medium to high arches. Both sides had one case of a flat foot (Table 7).

2. Leg-Heel Alignment

Of the 10 cases of left leg shin splints, 3 had a valgus heel alignment of between 0 and 5 degrees, and 7 had a valgus heel alignment of between 6 and 10 degrees. On the right side, the valgus heel alignment was between 0 and 5 degrees for 1 case, between 6 and 10 degrees for 9 cases, and greater than 10 degrees for 1 case (Table 7).

3. Ankle Dorsiflexion

The measurements of ankle dorsiflexion taken with the knee extended revealed a range of 6 to 20 degrees, with a mean of 14.2 degrees among the cases of left shin splints. The cases of right shin splints showed a range of 10 to 25 degrees, with a mean of 15.8 degrees of ankle dorsiflexion.

With the ankle dorsiflexion measurements taken with the knee flexed, the degrees of motion were greater. The left shin splint cases showed a range of 16 to 26 degrees with a mean of 22.0 degrees. The cases with right shin splints showed a range of 15 to 25 degrees and a mean of 20.5 degrees (Table 7).

4. Knee Joint Alignment

The comparison of knee joint alignment was made between the 13 subjects that had been troubled by shin splints either unilaterally or bilaterally. Of these subjects, 5 had a genu varum alignment of between 1 and 3 cm, and another 5 were between 4 and 7 cm. Three of the subjects did not have the genu varum alignment (Table 8).

Patellofemoral Pain Syndrome

There were 13 incidences of patellofemoral pain syndrome reported for the left side and 18 for the right (Table 6). The data for the following comparison can be found in Table 9.

1. Quadriceps Angle (Q angle)

The Q angles for the left knees were less than 10 degrees for 9 of the cases, and between 10 and 15 degrees for the remaining 4 cases. On the right side, 8 of the knees had Q angles of less than 10 degrees, and 10 knees had Q angles of between 10 and 15 degrees (Table 9).

2. Knee Joint Configuration

Of the left knee pain cases, 3 had a positive camel sign. There were 4 positive signs within the right cases.

The patellar position while standing showed 3 of the left and 5 of the right knees with squinting patellae. There were 7 of the left and 8 of the right knees, with slightly outward facing patellae and the remainder in each group had patellae that faced forward.

While sitting, 5 of the left knee cases revealed a high-riding patella, while 7 of the right cases revealed the same.

Table 9. Distributions and Ranges for the Physical Measurements of Subjects that have had Patellofemoral Knee Pain

Variables	Measurement Scales	Patellofemoral Pain Left	Patellofemoral Pain Right
		No. of Cases - 13	No. of Cases - 18
Longitudinal	Flat		1
Arch of Foot	Low	2	4
	Med - High	11	13
Leg-Heel	0 - 5	5	4
Alignment	6 - 10	8	10
(Degrees)	>10		4
Q - Angle	<10	9	8
(Degrees)	10 - 15	4	10
	>15		
Genu	0	2	3
Recurvatum	1- 5	6	10
(Degrees)	6 - 10	4	3
	11 - 15	1	2
Patellar Position	Outward	7	8
Standing	Forward	3	5
	Inward	3	5
Patellar Position	Outward	12	15
Sitting	Forward	1	3
	Inward		
Patellar Height	# Yes	5	7
(Sitting)			
Camel Sign	# Yes	3	4
Ankle Dorsiflexion			
Knee Extended	Range	6 - 20	8 - 25
(Degrees)	Mean	11.2	12.5
Ankle Dorsiflexion	Range	16 - 28	15 - 27
(Knee Flexed)	Mean	20.6	20.1
(Degrees)			
Medial Hip	Range	25 - 50	22 - 57
Rotation	Mean	37.9	39.1
(Degrees)			
Lateral Hip	Range	19 - 44	21 - 50
Rotation	Mean	32.2	37.6
(Degrees)			
Hamstring Flexibility	Range	115 - 145	108 142
(Degrees)	Mean	129.01	126.7

Of the 13 incidences of the left knee pain, 2 did not have a genu recurvatum alignment. However, 6 cases had this alignment and measured between 1 and 5 degrees, 4 were between 6 and 10 degrees, and 1 was between 11 and 15 degrees of genu recurvatum. On the right side, 3 of the 18 incidences of right knee pain did not have a genu recurvatum alignment, whereas 10 measured between 1 and 5 degrees, 3 measured between 6 and 10 degrees, and 2 were between 11 and 15 degrees (Table 9).

The knee joint alignment was compared among the 21 subjects that had experienced knee pain either unilaterally or bilaterally. Nine subjects had a genu varum alignment of between 1 and 3 cm and 7 subjects had this alignment between 4 and 7 cm. The remaining 5 subjects did not have genu varum, but one of these subjects had a genu valgum alignment of 1.0 cm (Table 8).

3. Leg-Heel Alignment

The leg-heel alignments were all valgus to varying degrees. On the left side, 5 of the cases were between 0 and 5 degrees, and the remaining 8 were between 6 and 10 degrees. On the right side, 4 of the knee pain cases had a valgus heel alignment of between 0 and 5 degrees, 10 were between 6 and 10 degrees, and the remaining 4 measured greater than 10 degrees (Table 9).

4. Longitudinal Arch of Foot

Two of the cases with left knee pain had low arches and 11 cases had medium to high arches. Of the right knee pain cases, 1 had flat feet, 4 had low arches, and 13 had medium to high arches (Table 9).

5. Ankle Dorsiflexion

The measurement of ankle dorsiflexion with the knee extended revealed a range of between 6 and 20 degrees (mean = 11.2 degrees) for the left knee pain cases. The right cases measured between 8 and 25 degrees with a mean of 12.5 degrees.

With the knee flexed during the measurement of ankle dorsiflexion, the range for the left knee cases was between 16 and 28 degrees, with a mean of 20.6 degrees. On the right side, the range was between 15 and 27 degrees, with a mean of 20.1 degrees (Table 9).

6. Hip Rotation

The means of the degree values for medial hip rotation were very similar between the left and right sides. On the left, the range was between 25 and 50 degrees with a mean of 37.9 degrees. The right showed a range between 22 and 57 degrees with a mean of 39.1 degrees.

The lateral hip rotation means showed a greater difference between the left and right sides. The left range was between 19 and 44 degrees with a mean of 32.2 degrees, and the right was between 21 and 50 degrees with a mean of 37.6 degrees (Table 9).

7. Hamstring Flexibility

The cases of left knee pain had a range of hamstring flexibility between 115 and 145 degrees with a mean of 129.0 degrees. On the right side, the range was between 108 and 142 degrees with a mean of 126.7 degrees (Table 9).

Achilles Tendinitis

There were 5 incidences of Achilles tendinitis on each of the left and right sides (Table 6).

1. Longitudinal Arch of Foot

Of the 5 incidences on the left side, 4 subjects had a low arch, and one, a medium to high arch. The same result was found among the 5 incidences on the right side (Table 7).

2. Leg-Heel Alignment

The leg-heel alignment was valgus in all cases and the distribution of measurements was the same for the left and right sides. Three cases on each side had a leg-heel alignment of between 0 and 5 degrees and the remaining 2 for both sides measured between 6 and 10 degrees (Table 7).

3. Ankle Dorsiflexion

The measurement of ankle dorsiflexion with the knee extended revealed a range of between 10 and 17 degrees on the left side and between 12 and 17 degrees on the right side. Both sides had the same mean value of 14.4 degrees.

With the knee flexed, the ankle dorsiflexion measurements ranged between 18 and 28 degrees on the left side and between 17 and 23 degrees on the right. The mean value of 21.0 degrees was the same for both sides (Table 7).

4. Knee Joint Configuration

Of the seven subjects in total that had experienced Achilles tendinitis either unilaterally or bilaterally, 4 of them had a genu varum alignment of between 1 and 3 cm, 2 were between 4 and 7 cm, and 1 did not have a genu varum alignment (Table 8).

Plantar Fasciitis

There were 3 incidences of plantar fasciitis in the left foot and 6 in the right (Table 6).

1. Longitudinal Arch of Foot

Of the 3 cases in the left foot, 1 had a low arch and 2 had medium to high arches. Of the right foot cases, 1 foot was flat, 4 had low arches, and 1 had a medium to high arch (Table 7).

2. Leg-Heel Alignment

The leg-heel alignment was valgus in all cases. On the left side, 2 subjects measured between 0 and 5 degrees, and 1 measured between 6 and 10 degrees. The right side revealed 1 subject with a measurement of between 0 and 5 degrees, 3 measured between 6 and 10 degrees, and 2 subjects measured greater than 10 degrees (Table 7).

3. Ankle Dorsiflexion

The measurement of ankle dorsiflexion with the knee extended showed values of 8, 10 and 14 degrees among the cases of left plantar fasciitis. The mean value was 10.7 degrees. On the right side, the measurements revealed a range from 7 to 20 degrees and a mean of 14.0 degrees.

With the knee flexed during measurement, the ankle dorsiflexion values on the left side were 18, 19, and 24 degrees, with a mean of 20.3 degrees. The right cases revealed a range of 15 to 24 degrees and a mean of 20.0 degrees (Table 7).

C. Comparison of Questionnaire Data for Groups I and II

Competitive Level and Years Experience

The mean values for the number of years competing revealed little difference between the groups. Group I showed 4.4 years and group II showed 4.5 years of competitive experience (Tables 10 and 11). Despite this similarity of means, the distribution of scores was quite different for each group. Figure 11 displays box and whisker diagrams for these distributions showing that group II had 3 extreme outliers on the high end of the scale, and 3 more outliers at the bottom end of the scale. In comparison, the range of scores for group I was very narrow. The diagrams also show a difference in the 75th percentile values for each group, with group II being lower.

With respect to the competitive level achieved, 78% of the subjects in group I, and 84% of those in group II were competing at the Novice level or higher. Group II reported 1 subject, (2%), to be not currently competing (Table 12).

Level of Difficulty - Jumps

The most difficult jump performed successfully 7/10 times showed a small difference between groups. In group I, 32% of the subjects could perform a double axel, and 22% could perform a triple jump 7/10 times. Group II showed that 28% of the subjects could do a double axel, and 18% could do a triple jump 7/10 times (Figure 12).

Table 10. Number of Competitive Years, Training Frequency and Warm-up Time for Group I

Variables	Mean	Mode	Min. Value	Max. Value	Median	Stand. Dev.
Number of Years Competing	4.4	5.0	<1.0	8.0	4.5	2.1
Free Skate Sessions/Week	9.6	10.0	5.0	18.0	10.0	3.3
Days off/Week	1.1	1.0	0.0	2.0	1.0	0.7
Weeks off/Year	5.7	5.0	2.0	12.0	5.0	2.0
Warm-Up Time Before Free Skate Sessions (min.)	7.0	5.0	0.0	30.0	5.0	5.5

Table 11. Number of Competitive Years, Training Frequency and Warm-up Time for Group II

Variable	Mean	Mode	Min. Value	Max. Value	Median	Stand. Dev.
Number of Years Competing	4.5	4.0	<1.0	16.0	4.0	3.0
Free Skate Sessions/Week	9.7	6.0	5.0	16.0	10.0	3.0
Days off/Week	1.0	1.0	0.0	2.0	1.0	0.7
Weeks off/Year	6.6	6.0	2.0	20.0	6.0	3.4
Warm-Up Time Before Free Skate Sessions (min.)	7.2	10.0	0.0	25.0	5.0	5.2

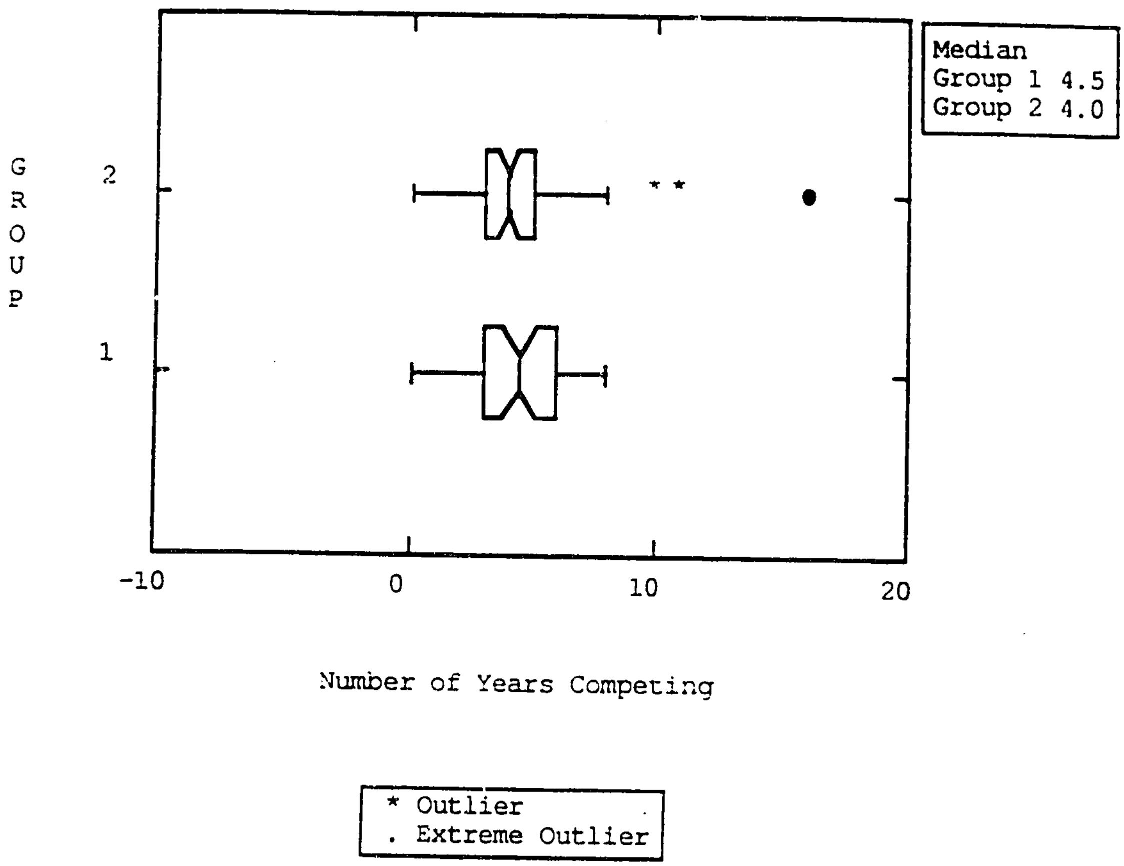

Figure 11. Box and Whisker Diagrams for the Distribution of the Number of Years Competing in Groups I and II

Table 12. Competitive Level of Subjects in Groups I and II

	Group I	Group II
Senior	6%	12%
Junior	34%	32%
Novice	38%	40%
Pre-Novice	20%	6%
Juvenile	2%	8%
Not Competing	0%	2%

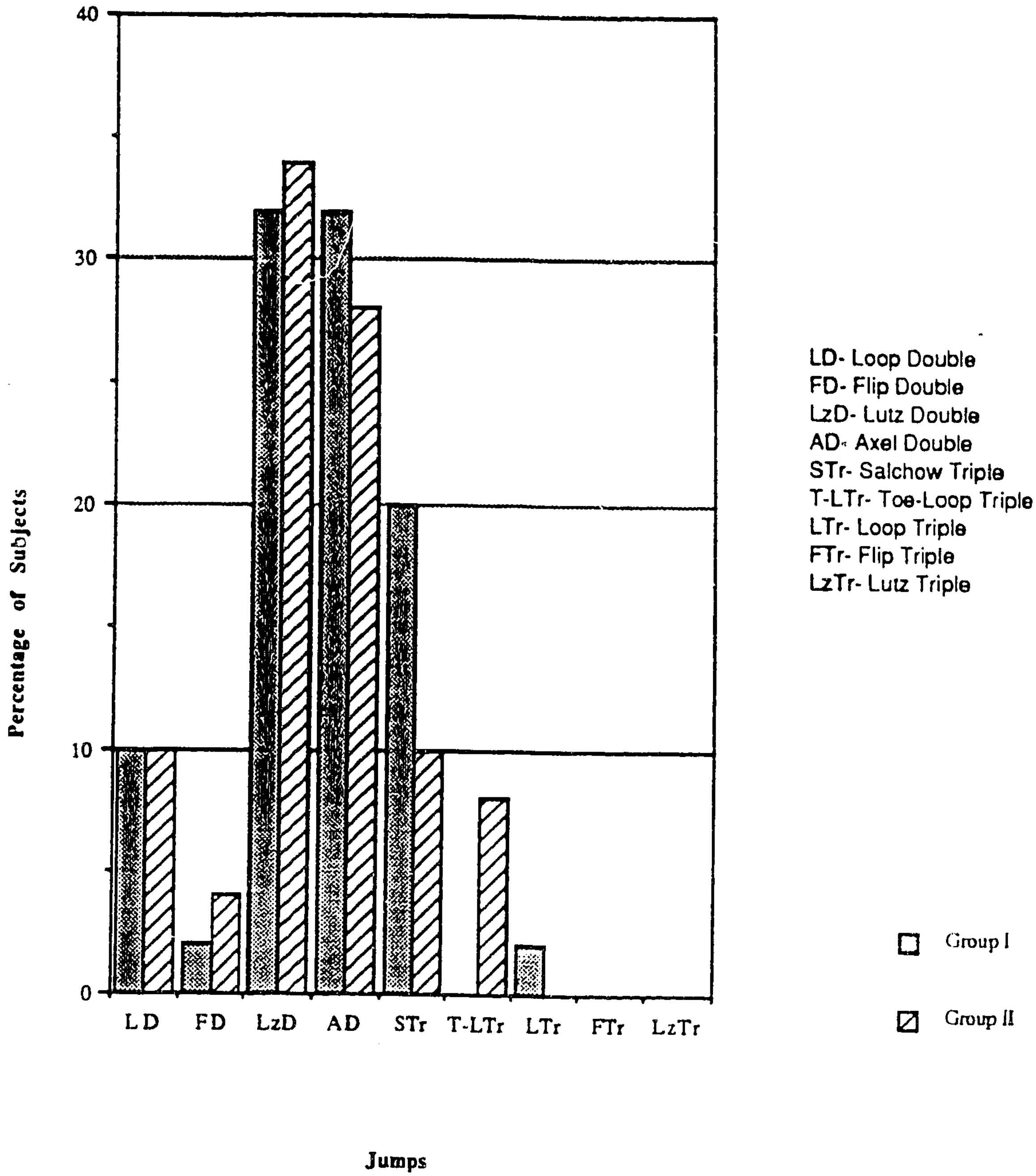

Figure 12 : Most Difficult Jump Successful 7/10 Times for Subjects in Group I and II

The difficulty of the jumps practiced, although inconsistent in success rate, reflected 74% in group I and 80% in group II practicing triple jumps (Figure 13).

Off-ice Training and Warm-up

In group I, 50% of the subjects reported doing an off-ice training and conditioning program all year round. Group II reported 56%. In group I, 20% of the subjects had never used an off-ice conditioning program, whereas group II reported this for 12% of its subjects. Approximately 30% of the subjects in both groups reported having used off-ice conditioning programs inconsistently (Table 13).

Warm-up time or time spent stretching before free skating sessions was reported as a mean of approximately 7 minutes for both groups (Table 10 and 11). The distributions were very much the same for both groups. This can be seen in Figure 14.

Training Intensity

The mean number of free skating sessions per week was 9.6 for group I and 9.7 for Group II (Figure 15). The number of days off per week also showed little difference, with 1.1 day for group I and 1.0 days for group II.

The number of weeks off per year reflected 5.7 for group I and 6.6.weeks for group II (Table 10 and 11).

Use of Orthotics

In group I, 20% of the subjects reported wearing orthotics in their skates and 14% reported wearing them in their shoes. Group II showed 36%

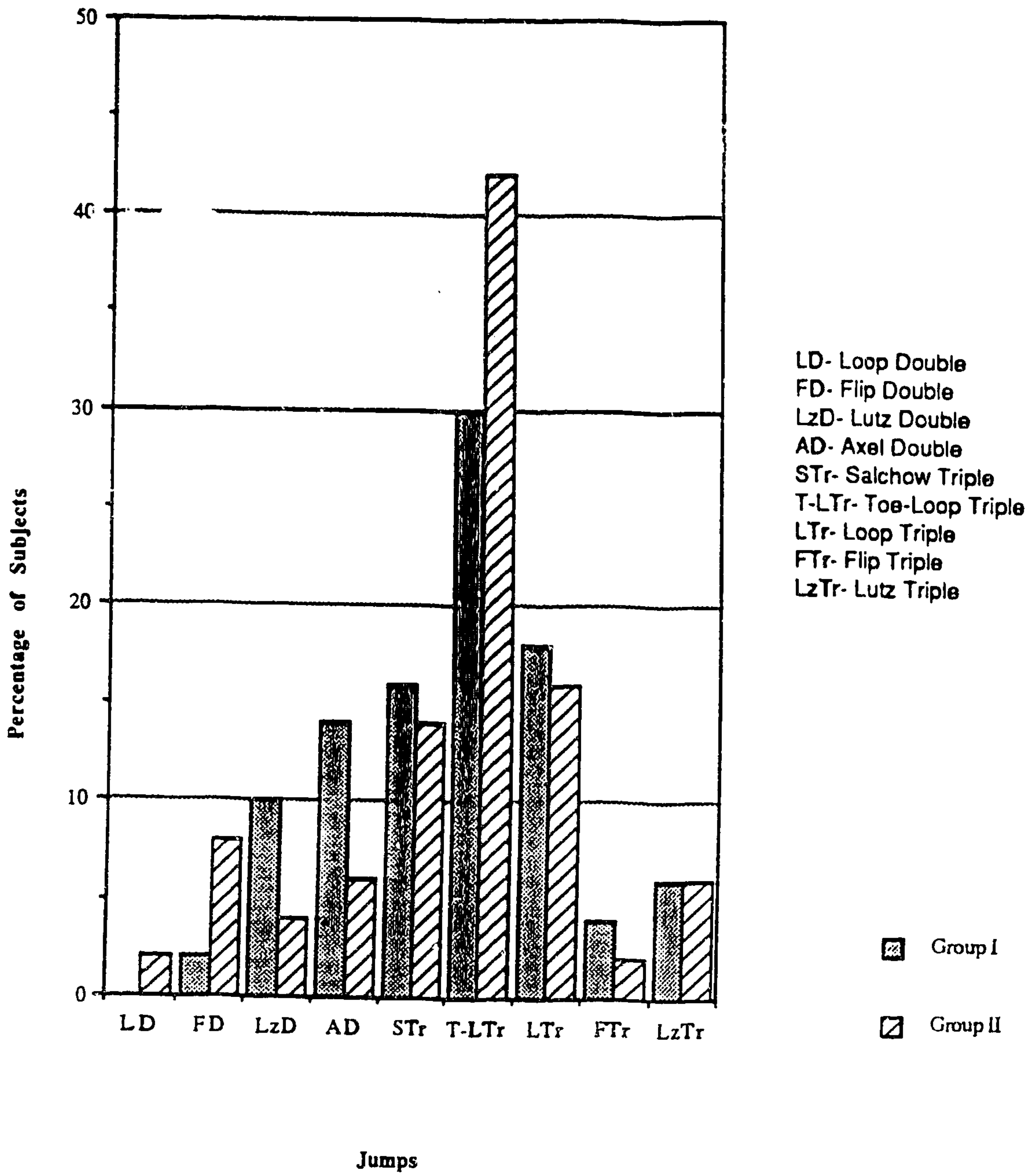

Figure 13 : Most Difficult Jump Practiced and Inconsistent for Group I and II

Table 13. Off-ice Training Habits and Use of Orthotics in Groups I and II

		Group I	Group II
Off-Ice Training Program	Always	50%	56%
	Sometimes	30%	32%
	Never	20%	12%
Orthotics in Skates (Yes)		20%	36%
Orthotics in Shoes (Yes)		14%	26%

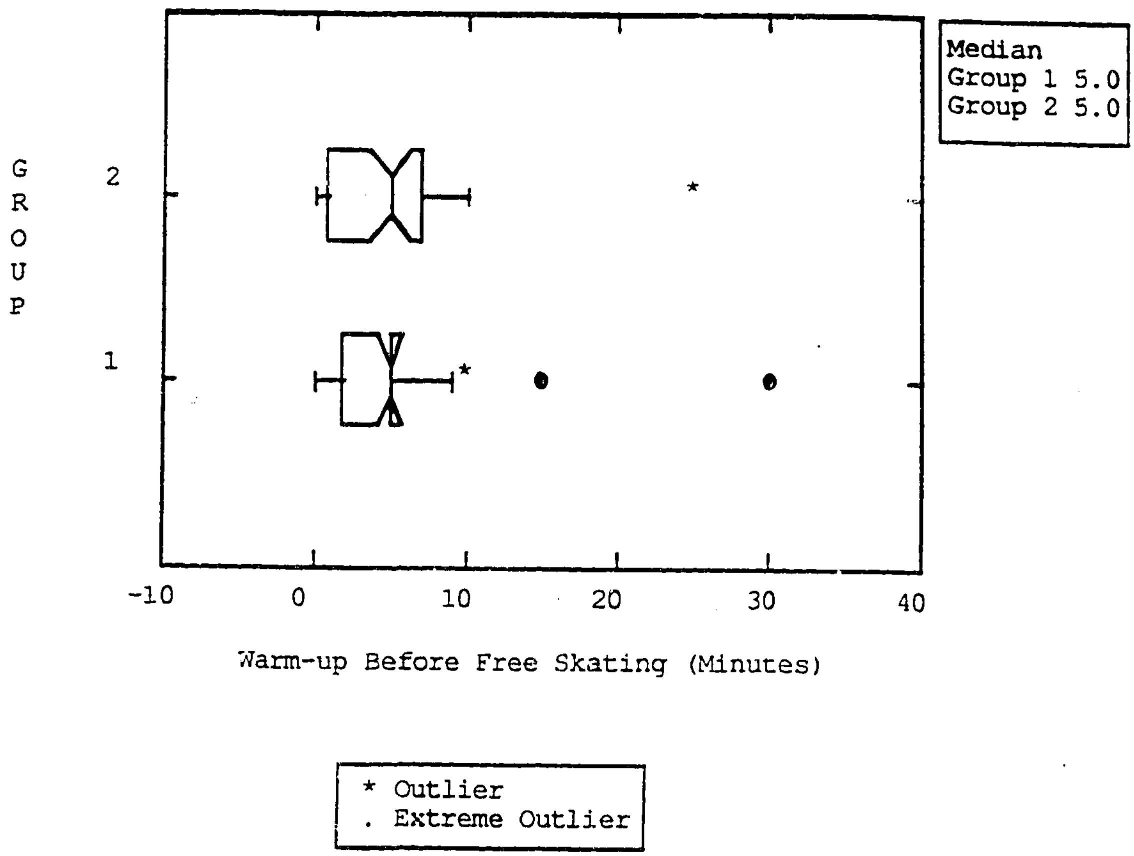

Figure 14. Box and Whisker Diagrams for the Distribution of Warm-up Time Spent Before Free Skate Sessions in Groups I and II

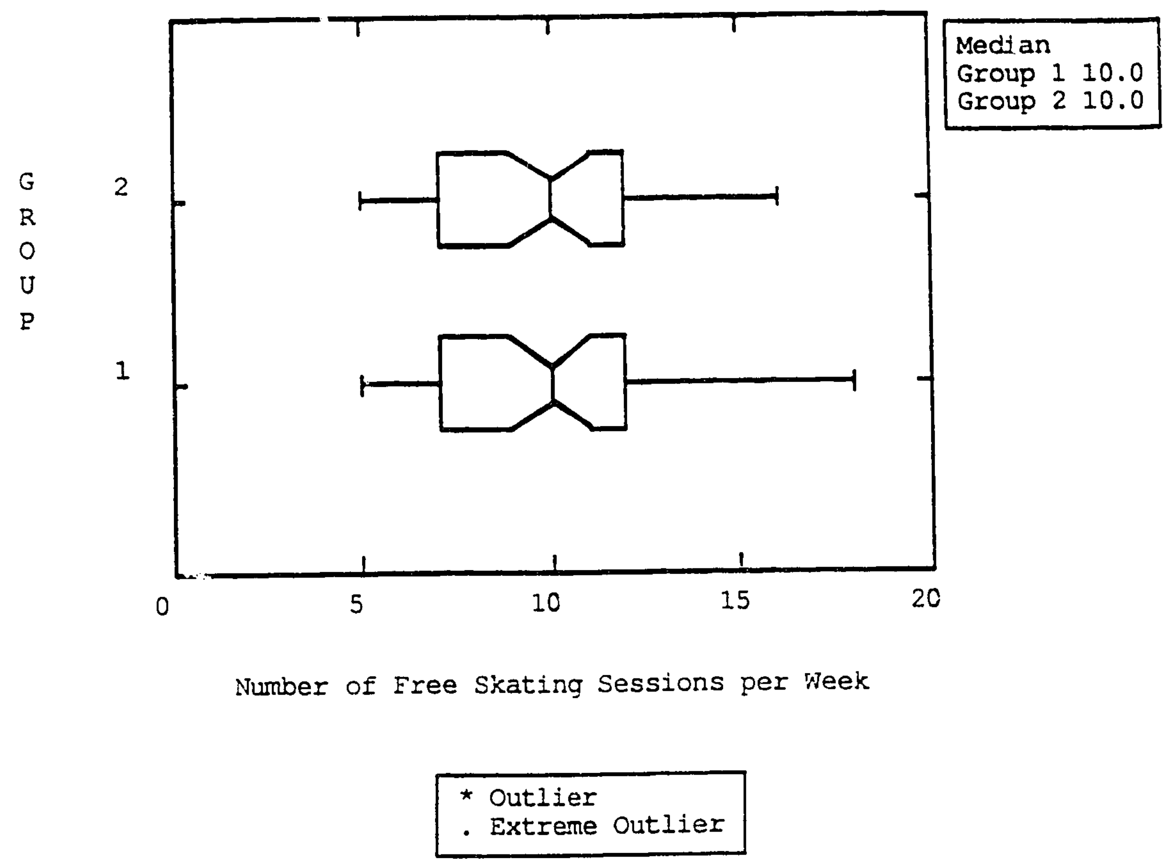

Figure 15. Box and Whisker Diagrams for the Distribution of the Number of Free Skating Sessions per Week in Groups I and II

wearing orthotics in their skates and 26% wearing them in their shoes (Table 13).

V. DISCUSSION

A. Comparison of Physical Data for Groups I and II

The following comparisons were made largely of the mean values, also with consideration of the measurement distributions. Some differences considered important were found between the two groups.

Age, Height, Weight, and Menarche Reached

A comparison of the mean ages of groups I and II has shown a difference of half a year, with group II being older. This difference may also contribute to the fact that these older subjects were both taller and heavier than group I. Another predictable difference between the groups which may be attributed to this extra 1/2 a year in age, was that 82% of group II and only 64% of group I had reached menarche.

In terms of physical measurements, it was not surprising that the mean values for both apparent and true leg lengths were greater in group II, owing to the groups greater mean height.

Quadriceps Angle

The mean values of the Q angles for both groups were very much alike, but differed slightly in the distribution of values around the mean (Figure 6). Group I showed a higher 75th percentile value on the right side and also a greater range of values between the 75th and the 25th percentiles on this side.

The mean values for each group varied between approximately 9 and 10 degrees which falls into an acceptable range according to several authors (Aglietti et al, 1983, Insall, 1979, Larson, 1979, Ireland, 1987, Hughston et al, 1984, Levine, 1979).

Knee Joint Configuration

The knee joint configuration showed 72% in group I and 82% in group II to have a genu varum alignment. The mean measurement between the knee in both groups was within the mild category, according to Reid (1987).

There were only 3 subjects in group I and 1 subject in group II that had a genu valgum alignment. The number of subjects with neither genu varum nor valgum was only 11, (22%), in group I and 8, (16%), in group II.

The genu recurvatum alignment, which is often associated with genu varum, was present in more than 80% of the subjects in both groups. The mean values fell within the moderate category, according to Reid (1987). When this alignment was measured, the examiner did not specify how the subject was to stand, only in which direction to face. As a result, the values measured reflected a more natural stance for each subject. This may also expain why one subject in each group had a measurable genu recurvatum alignment on only the right side. Eight subjects in group I and 6 in group II did not have the genu recurvatum alignment in either leg.

The position of the patella was assessed while lying supine to detect a positive or negative camel sign. Only 12% in group I and 20% in group II revealed a positive sign (Tables 3 and 4). In the literature, this sign was said to reflect a high-riding patella (Hughston et al, 1984). The height of the patella was also assessed with the subject sitting. In group I, 28% were noted to be high riding, and group II, 26% were noted for the same. These percentages were quite high and probably do not reflect the true percentage of the population with patella alta. The direction of facing for each patella was also recorded while sitting. There was a very high percentage of patellae facing slightly outward. In group I, 82% (left) and 84% (right), and in group II, 76%

(left) and 80% (right). A discrepancy between legs was found in 3 subjects. There were no patellae facing slightly inward while sitting.

With the subjects standing, the patellar positions revealed more subjects in group II with "squinting" or inward facing patellae (Table 3 and 4).

Leg-Heel Alignment

The leg-heel alignments measured while standing with the feet 8 cm apart were valgus to varying degrees for 100% of the subjects. The mean degree values were in approximately the 6 to 9 degree range, with both groups showing a slight difference in the means between the left and right sides. Figure 7 shows the distributions of the left and right measurements in groups I and II. A high 75th percentile value on both the left and right sides and a broader range of measurements is shown for group II.

Foot Configuration

There was a greater percentage of subjects in group II with low arches, and a greater percentage of subjects in group I with medium to high arches (Table 5). The greatest differences were found in the left foot comparison. Excessive foot pronation can be a compensatory motion secondary to other conditions such as genu varum, or tight plantar flexors (Bordelon, 1983, Carson et al, 1984, Carson, 1985, James, 1979, Prost, 1979, Stanley, 1978, Subotnick, 1981). It may be that the high incidence of genu varum is reflected in the percentage of subjects with low arches. However, the foot assessment was performed in the static position, so one cannot be sure. Also, the 100% incidence of a valgus heel alignment may have influenced the perception of the longitudinal arches while standing.

Hip Rotation

Group I had greater mean values of medial and lateral hip rotation than group II, although the difference between the groups was greater for lateral rotation. There was a small difference between the left and right sides in both groups for the lateral rotation values. Group I showed a broader range of scores for both medial and lateral rotation (Tables 1 and 2).

Both groups have shown a greater mean value for medial hip rotation than lateral hip rotation. According to the literature, most "normal" adults demonstrate the opposite to this (James, 1979, Tachdjian, 1972). Teitz (1982) has stated that a greater medial than lateral hip rotation may indicate excessive femoral anteversion. Also, Cailliet has given "normal" values of 35 degrees for medial, and 45 degrees for lateral hip rotation. According to this, the skaters have excess medial rotation, and are deficient in lateral rotation. Skaters generally practice more moves requiring a toe-in position, particlarly in school figures. This may contribute to the difference in these hip rotation measurements and the tendency to have greater medial range of motion in the hip.

Hamstring Flexibility

The mean values for hamstring flexibility have shown very little difference between the groups and between left and right sides. The measurement of this variable was quite subjective owing to the position of measurement and to subject participation.

Ankle Dorsiflexion

The ankle dorsiflexion measurements, taken with the knee extended, showed a difference in the range of values around the median between groups

I and II on the left side. With the knee flexed the scores on the left side were much the same between the groups. On the right side, the 75th percentile of group II was higher and the distribution broader than group I (Figures 8 and 9). Figures 8 and 9 show the distributions of the values for dorsiflexion. Similarity between groups in Figure 8 is obvious, however, Figure 9 shows a broader range of scores for group II. In both groups, the right side was more flexible by 2.4 degrees in group I and 1.2 degrees in group II.

The differences in the degrees of dorsiflexion in the knee-extended and knee-flexed positions between groups I and II ranged from approximately 7 to 10 degrees. For both groups, the mean values (averaged between left and right sides) were approximately 12 degrees with the knee extended and 21 degrees with the knee flexed. Hoppenfeld (1976) has stated that dorsiflexion measure should be much the same, or slightly greater in the flexed-knee position, with 20 degrees being an average score. Hughston et al (1984) has reported 25 degrees to be normal, however there was no mention of the position of measurement. Booher and Thibodeau (1985), and Carson et al (1984) have reported a normal range to be between 10 and 15 degrees, although again, without reference to the position of measurement.

B. Comparison of Physical Data for Selected Subjects in Group II.

It was mentioned previously that the comparisons made within group II were weak due to the small number of subjects. Because the data was divided into left and right sides for comparison, the numbers were further reduced.

Shin Splints

Table 6 will remind the reader that there were 13 subjects that had been troubled by shin splints either bilaterally or unilaterally. By totalling the incidences on each side, there were 10 on the left and 11 on the right. These were the numbers used for comparison.

1. Longitudinal Arch of Foot

According to several authors, the single most common predisposing factor for shin splints has been thought to be excessive foot pronation (Hickey, 1980, Jesse, 1980, Viitasalo and Kvist, 1983, Bates, 1985, Myburgh, 1988, Santopietro, 1988). When subjectively assessing the longitudinal arches within this group, it was found that 6/10 or 60% of the left cases and only 5/11 or 46% of the right cases had either a low arch or a flat foot. The remaining cases in each group had medium to high arches (Table 7).

2. Leg-Heel Alignment

A valgus heel alignment was found to varying degrees in all of the subjects. Within the left cases, 70% had a valgus heel alignment of between 6 and 10 degrees. On the right side, 82% of the cases fell within this range, and 1 case measured greater than 10 degrees. The presence of a valgus heel alignment can influence the subjective appearance of the arch of the foot while standing, such that it appears lower.

3. Ankle Dorsiflexion

As seen in Table 7, the ranges of dorsiflexion of the ankle were similar for the left and right sides. With the knee extended for measurement, the means were between 14 and 16 degrees for both sides, which is adequate according to Carson et al (1984) and Booher and Thibodeau (1985). With the knee flexed during measurement, the means were between 20 and 22 degrees for the left and right sides. This has also been considered adequate (Carson et al, 1984).

4. Knee Joint Alignment

Of interest is the fact that 10 of the 13 shin splint subjects had a genu varum alignment. Five of these subjects measured between 1 and 3 cm, and another 5 measured between 4 and 7 cm which may be considered moderate according to Reid (1987) (Table 8).

Patellofemoral Pain Syndrome

There were 21 subjects that had experience patellofemoral pain syndrome either bilaterally or unilaterally. For comparison the incidences were totalled for each side, giving 13 cases on the left, and 18 on the right (Table 6). Table 9 gives a summary of the data for the left and right groups.

1. Knee Joint Configuration

The incidence of both a positive camel sign and a high-riding patella while sitting was very low. Insall (1979), Lancourt and Cristini (1975), and Percy and Strother (1985), have suggested that a high riding patella may be a predisposing factor to patellofemoral pain.

The patellar position while standing showed a very low incidence of "squinting" patellae (facing slightly inward). Some authors have suggested this characteristic to be indicant of an excessive femoral anteversion (Insall, 1979, James, 1979, Tachdjian, 1972, Arnheim, 1975).

Genu recurvatum was present in 84% of the cases on both sides, although to different degrees. Using the guidelines set out by Reid, (1987), 46% of the left cases and 55% of the right had a mild genu recurvatum alignment (1 - 5 degrees). The remaining cases were either moderate 6 - 10 degrees or severe (Table 9).

Genu varum is often associated with genu recurvatum and was found in 16 of the 21 subjects with patellofemoral pain (76%). Nine of these subjects (43%) fell into the mild category of 1 to 3 cm, and 7 (34%) were in the moderate category of 4 - 7 cm (Reid, 1987). Hughston et al (1984), James (1979), Percy and Strother (1985), Tiberio (1987) and Wilson (1985), have reported that a varum alignment and an often associated genu recurvatum may lead to patellofemoral problems. Levine implied that a genu valgum alignment was a determining factor in the development of patellofemoral pain. There was one case of genu valgum among the 21 subjects.

2. Quadriceps Angle

In the left group, more of the cases had a Q angle of less than 10 degrees than of 10 to 15 degrees. In the right group, close to an equal distribution was found of Q angles less than 10 degrees and between 10 and 15 degrees. There is a lot of disagreement in the literature concerning the Q angle and how it may relate to patellofemoral knee pain. The data in this comparison does not show any similarities between the left and right sides.

3. Longitudinal Arch of Foot

The findings for the longitudinal arch showed the majority of the cases as having a medium to high arch, which is contrary to what the literature has suggested. Very few cases on each side had low or flat arches (Table 9).

4. Leg-Heel Alignment

The leg-heel alignment was between 6 and 10 degrees of valgus for 62% of the subjects in the left group and 56% in the right. The cases in the right group also included 4 subjects with a valgus alignment greater than 10 degrees.

5. Hip Rotation

Very little difference was found in the mean values for medial hip rotation between the left and right sides. However, there was a difference for lateral hip rotation. The values were comparable to those found for the uninjured subjects in this study. The medial rotation means for each side were greater than the lateral rotation values which was also found earlier in the comparison of Groups I and II.

6. Hamstring Flexibility

There was no significant difference between the left and right mean values for this measurement. The mean values were comparable to those found in the uninjured group I.

Achilles Tendinitis

There were only 7 subjects in group II that had been troubled by Achilles tendinitis. Totalling the incidences on the left and right sides gave 5 cases for each. Because of the small number of cases, few comments can be made pertaining to the measurement comparisons (Table 7).

A low arch was found in 4/5 cases for both the left and right sides. Over pronation is the most commonly reported predisposing factor for Achilles tendinitis in the literature (Hamilton, 1988, Clement et al, 1984, Jesse, 1980, Subotnick, 1980, Hickey, 1980).

The leg heel alignment measures were varied in distribution between the left and right sides such that no relationship existed.

The means of the ankle dorsiflexion measurements taken in both the knee extended and knee flexed position were the same for the left and right sides. These mean values of 14.4 degrees (knee extended) and 21 degrees (knee flexed) were within an acceptable range according to Booher and Thibodeau (1985) and Carson et al (1984). This finding is contrary to the literature which has suggested that tightness in the plantar flexors may lead to Achilles tendinitis (Santopietro, 1988, Hamilton, 1988, Frey and Shereff, 1988).

A varus alignment of the legs was present in 6 of the 7 subjects with the majority of these measuring between 1 and 3 cm. Frey and Shereff (1988), Subotnick (1988) and Clement et al (1984) have suggested a varus alignment may cause additional strain on the Achilles tendon.

Plantar Fasciitis

Only 7 subjects from group II had experienced problems with plantar fasciitis. There were 6 cases on the right and only 3 cases on the left (Table 6).

The findings do not show any consistent patterns nor do they contain many predictable values. This is most likely due to the small number of subjects.

The higher incidence of plantar fasciitis in the right foot may be related to the greater number of skaters that jump to the left, thus landing on their right foot. It is the authors experience that a much greater percentage of skaters jump in this direction.

C. Comparison of Questionnaire Data for Group I and II

Years of Competitive Experience and Current Level

From Tables 10 and 11 and Figure 11 it is evident that despite the similar mean values of competitive years experience between groups I and II, the range of scores were very different for each group. It could be, that the outlying values on the high end of the scale represent skaters in group II who have experienced overuse problems which were largely due to the number of years training, rather than any anatomical or physical predisposing factors.

The competitive level of the skaters in each group, as shown in Table 12 also reflects the distribution of years experience. The outliers in group II no doubt contribute to the higher percentage of skaters competing at the senior level in that group. There was an equal percentage (72%) in each group of subjects competing at either the Novice or Junior level. This is not surprising since the number of competitors that reach the Senior level are relatively few.

Level of Difficulty - Jumps

A skater is always working on new, more difficult jumps to gain skill and consistency. As a result, there is a difference between the level of difficulty of the jumps a skater can do successfully 7/10 times and those jumps practiced which are successful less often. Figures 12 and 13 illustrate this difference for both groups. The level of difficulty of the jumps increases from left to right on the bottom scale of each figure.

Approximately an equal percentage of subjects in each group are successful with one or two triple jumps. "Triple" or "double" refers to rotations in the air, whereas the specific name of a jump refers to the nature of its take-off. Triple jumps require more strength and agility to perform. Both groups are shown to be working on all the triple jumps (except triple axel) to improve consistency.

Even though group I has smaller means for age, height, weight, and physical maturity, no differences are shown in the level of difficulty of jumps performed and practiced.

Off-ice Training and Warm-up

The two groups were very similar in the percentage of subjects that reported doing an off-ice training and conditioning program all year round. In group I, 20% of the subjects reported never doing an off-ice training program. However, this relates closely to the 22% of the group who compete at a level lower than Novice. Often the addition of an off-ice program to the training regime of a skater occurs at the Novice level. The same relationship was found for group II.

A box and whisker diagram of the time spent warming up before free skate sessions for group I and II can be seen in Figure 14. The distribution of values for each group is very similar with the exception of the outliers on the high end. Table 10 reveals the mode to be 5 minutes for group I and 10 minutes for group II.

Training Intensity

It was not surprising that most of the subjects took one day off per week from their training. Training intensity does not vary greatly in the number of days per week, but in the number of free skate sessions per week. Figure 15 shows the similarity of groups I and II in this respect. The mean number of free skate sessions was between 9 and 10 for both groups.

The number of weeks taken off each year, including holidays and planned rest periods were slightly greater for group II (Table 10 and 11). The median and modal values were the same within both groups. For group I, 5 weeks was the most common number of weeks taken off, and for group II it was 6 weeks. It was difficult for the subjects to remember accurately how many weeks were taken off because often the amount of rest had changed each year. The competitive season may be longer or shorter depending on the competitive level and on the success in qualifying events.

Use of Orthotics

In group II, more of the subjects reported wearing orthotics in their skates (36%) and shoes (26%) than in group I (Table 13). The types used exclusively were custom built arch supports. This high percentage of subjects using orthotics in group II may relate to the treatment of injuires in the past. However, it was not recorded when the subjects began wearing the orthotics, therefore the success of these devices in preventing injuries remains unclear.

VI. SUMMARY AND CONCLUSIONS

Purpose

Chronic, overuse injuries can rob a figure skater of valuable training time and/or competitive opportunities. It has been recognized that injuries of the overuse variety can result in significantly longer periods of inactivity compared to some acute injuries (Brock and Striowski, 1986, Garrick, 1988). Figure skaters, like all competitive athletes, dislike having to succumb to an injury and will often delay reporting the problem. As a result, the rehabilitation time required may be extended. The purpose of this study was to examine the anatomical alignment, physical characterisitcs, and training habits of female figure skaters, and to search for possible predisposing factors to overuse injury.

Methods and Procedures

Questionnaries were given to 100 female competitive figure skaters from across Canada. Fifty of the subjects were unjuried (Group I) and 50 had a history of one or more overuse injuries (Group II). The questions pertained to skating history and ability, training habits both on and off the ice, equipment, and history of injuries. Following the questionnaire, a physical examination of each subject was performed using a manual goniometer and a tape measure. Measurements related to the anatomical alignment and range of motion in the lower limbs were taken in the same order for each subject.

Data Analysis

Because this was a first order study aimed at producing a broad base of information, the computer analysis of the data was for frequency distributions only. The results were reported in a descriptive sense to reveal any existing patterns in the data accumulated. Comparisons were made of the physical data between the two groups of 50 subjects and also between the subjects in group II who had experienced similar overuse problems. The questionnaire data was compared between these two groups as well.

Results

The results were divided into three sections, the first being concerned with a comparison of the physical data between the two groups of 50 subjects. The mean values for each variable were used for comparison. It was found that the subjects in group II were older, taller, heavier, and more physically mature than the subjects in group I. Both groups had a high incidence of the genu varum and genu recurvatum alignments. They also measured a valgus alignment of the leg and heel to varying degrees in each group. There were more incidences of low arches in group II and there was no significant difference in ankle dorsiflexion measurements or Q angles between the groups. Both groups had a greater medial than lateral hip rotation.

The second section of results was concerned with the comparison of physical data between subjects in group II that had experienced similar overuse injury problems. When comparing the subjects with shin splints, it was found that most subjects had a moderate valgus heel alignment. A genu varum alignment was common with an equal distribution between mild and moderate degrees and surprisingly few subjects had low arches. The comparison of those subjects with patellofemoral pain showed both a genu varum and a genu valgum alignment to be common. A valgus heel alignment was also common within the moderate category. Low arches were not common and the Q angles showed no predictable patterns. Of the subjects with Achilles tendinitis, most had low arches and a genu varum alignment. No patterns were found when comparing the subjects with plantar fasciitis.

The final section of results was dedicated to the comparison of the questionnaire data between groups I and II. It was found that the number of competitive years for each group was close to being the same and there was an equal percentage from each group competing at the Novice or Junior level. The difficulty of the jumps practiced and performed by each group was the same, and 50% of group I and 56% of groups II reported doing off-ice conditioning year round. The two groups spent close to the same mean number of minutes warming up before free skate sessions. There was no significant difference in the number of free skate sessions per week nor days off per week. However, group II had more weeks off per year. Group II showed a higher percentage of subjects wearing orthotics in their shoes and skates.

Discussion

The discussion involved further description of the results and was divided into three sections in accordance with the three purposes of the study. Additional insight into the findings was given when available and necessary.

Conclusions

On the basis of the present study, the following conclusions were made, based on the presence or absence of material differences. The term "material" was chosen by the author to describe those differences that were of sufficient magnitude to be considered of importance.

1. There was no material difference in the means of the Q angles between group I and II.
2. The genu varum alignment was present in 72% of the subjects in

group I and 82% in group II.

3. The genu recurvatum alignment was present in greater than 80% of the subjects in both groups.

4. The assessment of patellar position for groups I and II revealed no material differences.

5. A valgus leg-heel alignment while standing was found for all subjects, and mean values were similar between groups I and II.

6. No material difference was found in the longitudinal arches between groups I and II.

7. Mean values for medial hip rotation were greater than mean values for lateral hip rotation in both groups.

8. No material difference was found for the ankle dorsiflexion measurements between the two groups.

9. No material differences were found in the physical data between the subjects with similar overuse injuries.

10. The training variables examined, revealed no material differences between groups I and II.

11. Within the 100 subjects, 50% had experienced a minimum of 1 overuse injury during their competitive career.

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APPENDIX A

CONSENT FORM FOR

PARTICIPATION

CONSENT FORM FOR PARTICIPATION

I,____.
(please print)

agree to participate in a study of female figure skaters conducted by the University of Alberta, Department of Physical Education and Sport Studies. I understand that I am free to withdraw consent and to discontinue participation in the project at any time. I understand that the data and information to be derived will be confidential and that under no circumstances will I be indentified by name in the manuscript or in any other documents. I understand that I am free to deny answer to specific items on the questionnaire. I understand that I will follow the procedures listed below and I have had the opportunity to question and discuss these procedures.

Procedures to be followed:

1) Administration of a questionnaire pertaining to personal skating history, ability, training habits and history of injuires.
2) Measurements of lower limbs using a tape measure and a goniometer.

I acknowledge that I have read this form and I understand the procedures to be followed and I consent to participate.

Date:_______________________ Signature:_______________________

Witness:_____________________ Signature:_______________________
Parent or Guardian if participant is under 18 years.

APPENDIX B

QUESTIONNAIRE

QUESTIONNAIRE

Part A:

Yr/Mth/Day

Name____________________________ Age_____ Birthdate / /

Address____________________________ Telephone__________________

City____________________________ Postal Code__________________

Part B: <u>Skating History and Ability</u>

1. Are you currently skating competitively?____________________

   If yes, what level?____________________________

   If no, when did you last compete?____________________

   What level?______________________________

2. How many years has it been since your first year in Juvenile "A"_______
3. Were any of these competitive years missed due to injury?__________
4. What is your most difficult jump, i.e. successful for 7/10?__________
5. What other difficult jumps are you working on?________________
6. Can you do a spread eagle?____________________________

Part C: <u>Training Habits, Off-Ice</u>

7. Have you ever been put on a consistent off-ice training program_______
8. When?____________________________________
9. How long were you on this program?____________________
10. What type of activity was included?____________________
11. How many workouts per week?________________________
12. Did you have, or develop any injuries during this time?__________

    If yes, what where they?________________________

13. Are you currently on an off-ice training program?________________

14. Is it the same as above?______________________________

    If yes, move to Part D.

15. If no, how long have you been on this program?________________

16. What type of activity is included?________________________

17. How many workouts per week?__________________________

18. Do you currently have any injuries?______________________

Part D: Training Habits, On-Ice

19. Do you warm-up and stretch before your free skating sessions?________

20. Do you do this off or on the ice surface?____________________

21. How many days per week do you skate?______________________

22. How many free skating sessions do you skate per week?____________

23. How many weeks per year do you not skate?____________________ (average).

Part E: Equipment

24. What make are the skates you are wearing now for free skating?________

25. For how long have you been wearing this make of skate?____________

26. What make did you wear before?____________________________

27. Do you have any orthotic devices in your skates?________________

    Describe them.__________________________________

28. Do you have any orthotic devices in your shoes?________________

    Describe them.__________________________________

Part F: <u>History of Injuries</u>

Please try to remember all of the injuries you have had since you began skating competitively at the Juvenile level. Exclude those to the upper body.

1. What was injuried?______________________________See Diagram.

   How was it injured?________________________________

   ____

   When?____

   Did you have medical attention?__________________________

   Did you stop skating?______________For how long?____________

   Did you have physical therapy?__________________________

   Did this ever re-occur?______________________When?__________

2. What was injuried?______________________________See Diagram.

   How was it injured?________________________________

   ____

   When?____

   Did you have medical attention?__________________________

   Did you stop skating?______________For how long?____________

   Did you have physical therapy?__________________________

   Did this ever re-occur?______________________When?__________

3. What was injuried?______________________________See Diagram.

   How was it injured?________________________________

   ____

   When?____

   Did you have medical attention?__________________________

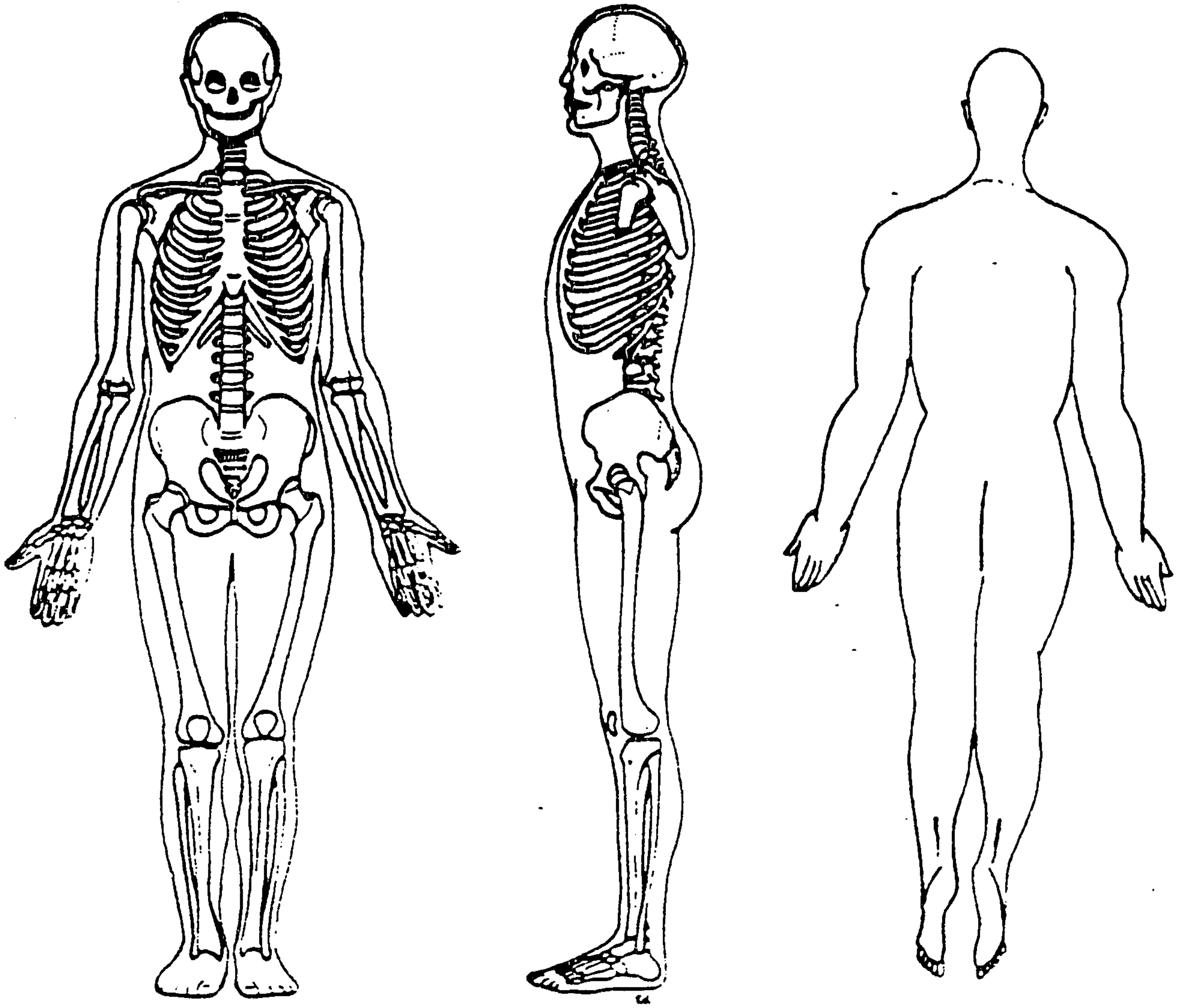
   Did you stop skating?______________For how long?____________

   Did you have physical therapy?__________________________

   Did this ever re-occur?______________________When?__________

Diagrams

A. Front
B. Side
C. Back



A B C

APPENDIX C

DATA-COLLECTION FORM

Data Sheet Name:________________________

Supine Evaluation

1. Leg Lengths			
	Left	Right	Comments
Apparent			
True Leg			
Upper Leg			
Lower Leg			

2. Q-Angle			
	Left	Right	Comments
Q-Angle			

3. Hamstring Flexibility			
	Left	Right	Comments
Knee Extension			

4. Patellar Placement			
	Left	Right	Comments
"Camel Sign"			

Prone Evaluation

5. Hip Rotation			
	Left	Right	Comments
Medial			
Lateral			

6. Ankle Dorsiflexion			
	Left	Right	Comments
Knees Extended			
Knees Flexed			

7. Leg-Heel Alignment			
	Left	Right	Comments
Prone			
Standing			

Standing Evaluation

8. Longitudinal Arch			
	Left	Right	Comments
Normal Stance			
Standing on Toes			

9. Knee Joints			
	Left	Right	Comments
Genu Valgum			
Genu Varum			
Genu Recurvatum			
Patellar Position			
(squinting)			

Sitting

10. Patellar Position			
	Left	Right	Comments
Direction of Facing			

11. Quadriceps Development			
	Left	Right	Comments
V.M.O.			

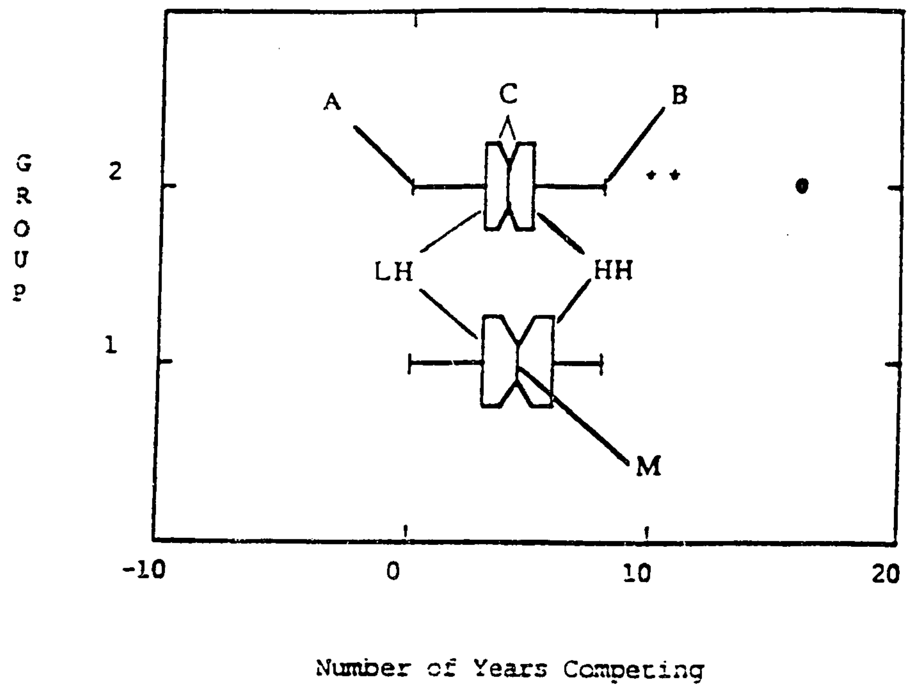
12. Height______________________________

13. Weight______________________________

14. Menarche Reached?________________ Regular?__________________________

APPPENDIX D

DESCRIPTION OF BOX AND WHISKER DIAGRAMS



A - B Range = Difference Between Highest and Lowest Values.

M Median = The Middle Value

C = 95% Confidence Interval for the Median

HL - 25th Percentile = Lower Hinge

HH - 75th Percentile = Upper Hinge

* - Outlier = Values Between Inner and Outer Fence

● - Extreme Outlier = Values Beyond Outer Fence

Calculations, Page 121

Calculations

H-Spread = difference Between Values and Hinges
Step = 1.5x H-Spread
Inner Fence = 1 Step Outside Hinges
Outer Fence = 2 Steps Outside Hinges