A Biomechanical Analysis Theorizing the Effects of Long Term Meniscectomy on Q Angles and Pronation/Supination of the Foot During Running

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A BIOMECHANICAL ANALYSIS THEORIZING THE EFFECTS OF LONG TERM MENISCECTOMY ON Q ANGLES AND PRONATION/SUPINATION OF THE FOOT DURING RUNNING

by

Richard R. Squires

A Thesis
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A BIOMECHANICAL ANALYSIS THEORIZING THE EFFECTS OF LONG TERM MENISCETOMY ON Q ANGLES AND PRONATION/SUPINATION OF THE FOOT DURING RUNNING

Richard R. Squires, M.A.
Western Michigan University, 1983

The objective of the study was to investigate the relationship of pronation/supination and Q angles of the right and left legs of subjects with meniscectomies. A biomechanical analysis was employed using two high speed camera, digitizing equipment, and a computer. Statistical analysis was performed to determine any significant differences.

Analysis of variance found a difference between medial and lateral, and control and medial groups in the pronation/supination test at heel strike with shoes. A difference among subjects and legs also was found at heel strike without shoes.

Analysis of variance found differences in average Q angles of the medial and lateral groups at each test. A difference also was found between the control and lateral groups at midstance with shoes, and between the control and medial groups with shoes.

Apparently, shoes have a definite effect on pronation/supination at heel strike. It could be questioned if original Q angle differences caused eventual lower leg problems leading to a meniscectomy.
ACKNOWLEDGMENTS

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Appreciation is also extended to the Western Michigan University Sports Staff for their help in finding suitable subjects. Special thanks go to the subjects themselves who volunteered for the study.

Finally, I would like to thank my parents for their unwavering support and encouragement throughout the study. It would not have been possible without them.

Richard R. Squires
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CHAPTER I

INTRODUCTION

Athletes in general know and fear a knee injury. Many athletes who have suffered a knee injury experience problems that persist throughout life. Whether the problem is arthritis, ligaments, bursa, tendonous, cartilage related or several of these combined, the trauma experienced can be tremendous.

The knee is a complicated joint. In addition to muscle and bone, it contains ligaments and cartilage. Ligaments provide stability and security for the knee. Articular cartilage covers the ends of bones and allows them to glide smoothly over each other. Meniscal cartilage, both lateral and medial, fills the space on either side of the joint and deals primarily with support and shock absorption.

The delicate, coordinated and complex movement of the ligaments and menisci together are essential for a fully stable knee.

Years after a simple meniscectomy, pain, trauma, and normal motions can be hindered. Therefore, more conclusive evidence on long term effects must be determined. The effects of a torn meniscus can be troublesome. With displacement of all or part of the meniscus, there is a blocking of the normal flexion-extension pattern. The normal pattern of walking and running is altered. The joint surfaces are forced together and surface friction is increased causing erosion. Following a meniscectomy, there can be up to a 3-fold increase in stress across the joint. (Krause, 1976) Many people fail to realize

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the important function menisci have in knee stability and weight bearing.

Flexion and extension occur in the meniscofemoral compartment of the knee joint. Radiological changes in the knee suggested important weight bearing functions of the meniscus in postmeniscectomy patients. (Fairbank, 1948) Studies including that of Walker (1975) show that an intact lateral meniscus transmits over half the load across the lateral compartment in the extended knee and at least half the load is transmitted on the medial side through the medial meniscus.

Statement of the Problem

The problem of the study was to investigate the relationship of stride patterns of the right and left leg. The investigation involved a biomechanical analysis of the following subproblems:

1. Identification of kinematic parameters of the lower limbs of subjects without knee injuries.

2. Identification of kinematic parameters of the lower limbs of subjects with meniscus damage.

Purpose of the Study

The purpose of this investigation was to provide scientific information concerning performance characteristics of subjects with meniscus damage. The results from a biomechanical analysis of subjects with meniscal damage could be used in the rehabilitation process as well as the prevention of long term effects.
Significance of the Study

Few studies were available on the effects a meniscectomy had on a running stride. Those who have a meniscectomy seem to have unusual wear patterns on their running shoes, and seem to have an awkward, inefficient running pattern in the lower extremity on the side the meniscectomy was performed.

Tests and studies have stated conclusively that meniscectomy may not always be the answer after a damaged meniscus is discovered. Vehvansen and Aalto (1979) stated that clinical follow-up examinations in some patients had led to unnecessary meniscectomies. Lassonen (1976), Zaman (1981), Powers (1979), McGinty (1977), and Price (1978), all agree.

Delimitations

The study was delimited to nine male subjects jogging in a controlled environment. The subjects had a specific knee related problem; a lateral or medial meniscectomy. Three subjects had a lateral meniscectomy, three subjects had a medial meniscectomy, and three subjects were used as a control group and had no related knee problems. The controlled environment consisted of: (a) subjects on a treadmill; (b) subjects jogging at their own speeds; (c) subjects jogging in a closed room; and, (d) subjects fully aware that the filming was taking place.

In relation to the specific knee problem: (a) lateral meniscectomy patients had meniscal related problems; and (b) surgery was
specific to lateral meniscectomy only.

Medial meniscectomy patients all had some degree of cruciate ligament damage and were selected on the basis of: (a) minor rather than major degree of ligament damage; and (b) homogeneous degree of damage to the cruciate ligament.

Limitations

The study was limited in the following manner: (a) subjects had individual healing times; (b) surgery was performed by different surgeons; (c) surgeons performed slightly different techniques; and (d) original injuries occurred while performing different athletic movements.

Assumptions

The study was based on the following assumptions: (a) surgery on the subjects was properly diagnosed and the surgeons were competent; (b) the reliability and validity of the instrumentation was sufficient; (c) personnel involved in the study were competent, and (d) subjects were in good physical health during the study and gave their best effort.

Hypotheses

The following is a list of hypotheses that were tested in this study.

1. There is a greater degree of pronation/supination between the legs of subjects with meniscectomy during the support phase.
2. There is a greater degree of pronation/supination between the control group and the meniscectomy groups during the support phase.

3. There is a difference in the average Q angle between legs of subjects with meniscectomy during the support phase.

4. There is a difference in the average Q angle between the control group and the meniscectomy groups during the support phase.

Definition of Terms

The following is a list of terms utilized in the study that have unique and important meaning for the reader.

1. Arthrogram - Radiography of a joint; term often used to describe the radiograph after arthrography. (Critchly, 1978)

2. Arthrography - Radiography of a joint after injection of air or oxygen or of a fluid contrast medium into the joint space in order to visualize cartilage and the limits of the joint cavity. (Critchly, 1978)

3. Arthroscope - A type of endoscope used for arthro-endoscopy. (Critchly, 1978)


5. Biomechanics - The science of the forces acting internally or externally on the living organism or cell. (Critchly, 1978)

6. Heel Strike - The instant the heel of the foot meets the running surface.

7. Meniscectomy - The excision of the semilunar cartilages of the knee joint. (Critchly, 1978)

9. Midstance - The instant the hips are over the supporting foot in the running stride.

10. Osteoarthritis (arthritis, arthrosis) - A degenerative disease of the joint. (Critchly, 1978)

11. Pronation - To land and be supported on the medial edge of the foot/shoe. Measured in degrees from the vertical.


14. Supination - To land and be supported on the lateral edge of the foot/shoe. Measured in degrees from the vertical.

15. Q angle - The angle formed between the center of the knee, the total center of gravity, and the head of the greater trochanter.
CHAPTER II

REVIEW OF LITERATURE

The problem of the study was to investigate the relationship in stride patterns of the right and left legs of subjects with meniscal damage. The review of literature will be divided as follows: (a) the nature of menisci surgery; (b) open meniscectomy; (c) partial meniscectomy; (d) resection; (e) arthroscopy; (f) age groups; (g) women; (h) mechanical changes; (i) muscular changes; and (j) the biomechanics of running.

The Nature of Menisci Surgery

Isolated meniscectomy is not a benign procedure, and many patients can expect postoperative trauma, pain, instability, and even subsequent surgery. New techniques for the removal of damaged menisci are being studied, and highly advanced pioneer studies of replacement and artificial cartilage show the promise that athletes may someday be rid of postoperative trauma.

Menisci related problems were most often divided into two categories: open meniscectomy or arthroscopy.

Menisectomy was the popular choice for a number of years, but with the advancement of the technique of arthroscopy, open meniscectomy is becoming a popular option in meniscus surgery.

Operative arthroscopy has become increasingly accepted as the method of choice for many knee disorders, particularly in the field
of meniscus surgery. (Gillquist, 1980) When a meniscus tear is sus-
pected, arthroscopy is done routinely because it is now evident that
the diagnostic accuracy of arthroscopy in experienced hands is at
least 20% greater than the accuracy of traditional clinical diagnostic
procedures. (Casscells, 1980)

The review of literature stated that the postoperative morbidity
was much less with arthroscopic surgery than that seen with open
meniscectomy. Correspondingly, the economic losses, including hospital
costs, and time off work were also less.

Another finding was the number of cases where meniscectomy proved
to be, or was suspected of being the wrong choice of surgery. Out of
a study involving 30 knee injuries, the meniscus surgery was regarded
as being ineffective in 15 subjects. (Lassonen, 1976)

Open Meniscectomy

Open meniscectomy was the popular method of surgery for knee dis-
orders for many years. Meniscectomy often resulted in a lengthy stay
in the hospital, high medical costs, and an ugly leg scar.

Sonne-Holm, Fledelius, and Ahn (1980), showed that 15% of 142
patients studied had given up sports, while 12% had to restrict their
sporting activities. Although 46% of the patients had no complaints,
those that complained said that instability and pain upon weight
bearing started immediately after the operation.

Fox, Blazina, and Carlson (1979) found that 210 patients out of a
total of 816 with medial meniscectomy needed subsequent surgery. They
stated:
These 210 secondary operations should not be interpreted as an indictment of medial meniscectomy, but instead they are suggestive of the underlying damage to the articular surfaces, meniscal tissues, or stabilizing structures. These subclinical problems appeared to assume significant functional importance in the postmedial meniscectomy period. (p. 163)

They then stated however:

The fact that 210 patients of a group of 816 patients who underwent a 'simple meniscectomy' had subsequent intervention is a finding of considerable importance. (p. 162)

Yocum's (1979) research dealt with the time factor between time of injury and time of surgery. It appeared that the longer the interval between injury to the meniscus and its incision, the less satisfactory were the results.

Lauuttamus's (1979) study investigated the long term effects of meniscectomy. The observation period was five to 20 years. The main purpose of the study was to investigate the appearance of osteoarthritis. Fourteen of the 43 patients studied had signs of osteoarthritis. The development of osteoarthritis was correlated with the physical findings and subjective complaints. Osteoarthritis proved to be related to the clinical findings, but not to subjective complaints.

Noble (1975) reviewed the knees of 172 postoperative meniscectomy patients to study the objective and subjective results. All of the patients had complaints about pain, night pain, instability, but the most common finding was that of joint line tenderness. All but 7% were considered "cured" or "improved," yet nearly half of these patients had persistent complaints. The objective physical findings frequently failed to match with the patients opinion of their knees.

It was concluded in Lassonen and Wilppula's (1976) research that
17 out of 30 operations could have been avoided with optimal clinical and arthrographic analysis and with careful operative technique. Four of the patients were regarded as having the wrong choice of therapy, 11 had ineffective therapy, and the remaining two patients had a degenerative osteoarthritis developing sometime after the operation. This was regarded as the cause of recurring symptoms.

Partial Meniscectomy

Studies by Cargill and Jackson (1976) and McGinty, Marvin, and Guess (1977) showed a strong favoritism to a partial meniscectomy over a full meniscectomy. Laxity was found in 72% of those with partial meniscectomy, but all other aspects of the testing in Cargill and Jackson's (1976) study showed more favorable results with the simpler operation.

Those patients, in both studies, had a shorter hospital stay, less expense, and spent less time on crutches. According to McGinty et al (1977), subjects with a total meniscectomy had four times greater incidence of postoperative complications. The studies suggested that partial meniscectomy gave better subjective functional and anatomical results.

Dandy's (1978) study showed no serious complications in 30 patients, but suggested that further research be done on the long term results of the technique of partial meniscectomy.

The studies seemed to suggest that unless a total meniscectomy is more advantageous, a partial meniscectomy is the choice of treatment.
Meniscus Resection

Several research articles lend support to resecting non-damaged portions of a meniscus. In Price and Allen's (1978) study, 36 patients were reexamined one to six years after surgical repair of 40 acute ruptures of the medial ligament of the knee. In all patients, the meniscus was avulsed from the bone, and unless the meniscus was excised because of severe damage, it was resected. Thirty-three of these patients showed no signs of limitations at the time of follow-up, 16 had no instability, and 21 had no anterior rotatory instability. Price and Allen (1978) concluded that unless there were significant advantages of a total meniscectomy, an intact or nondamaged meniscus should not be removed.

Carson (1979) investigated resecting through the use of arthroscopic techniques. The goal of his work was to resect the posterior two-thirds of a meniscus. He found that the immediate postoperative morbidity was much less than that found with total meniscectomy. Economic losses, including time off work and hospital costs were significantly less. He found that the short term results compared favorably with those of meniscectomy in terms of relief of pre-operative symptoms.

DiStefano's (1980) article dealt with most aspects of meniscal surgery; total, partial, open, arthroscopic, and resectioning. In regard to resectioning, he stated:

In the wake of meniscectomy, certain predictable time-related events afflict the joint, i.e., instability, and degenerative arthrosis. These eventualities are less pronounced following partial resection, and lend credence and support to the concept of subtotal meniscectomy. (p. 146)
In Fujikawa, Iseki, and Mikura's (1981) study, seven children underwent partial meniscectomy of the lateral meniscus. This procedure modified the discoid meniscus to the normal semi-lunar shape. The results of their surgery were excellent clinically, radiologically, and arthroscopically. The resected meniscus functioned normally, and the patients' rehabilitation was shortened to half the time needed with a total meniscectomy. All the studies reviewed seem to indicate that an intact or nondamaged part of a meniscus should be retained.

Arthroscopy

More surgeons have turned to arthroscopy for disorders of the knee. It is now technically possible to operate all meniscus lesions endoscopically. (Gillquist, 1980) Schweitzer (1981) recommended that all patients needing meniscus surgery do so by means of arthroscopy.

The technique of arthroscopy was developed in Linköping, Sweden, and involves the use of a special knife that passes through a flexible Teflon sleeve.

DiStefano stated:

Meniscal surgery has taken on a new dimension with the advent of arthroscopy, which permits initial sparing and continued observation of meniscal lesions of questionable significance, as well as low morbidity...in trained hands. (p. 146)

Cassells (1980) stated:

Arthroscopy has been most helpful in making an accurate diagnosis, planning a surgery, and in some cases, avoiding unnecessary surgery. When a meniscal tear is suspected

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and arthrotomy contemplated, arthroscopy is done routinely because it is now evident that the diagnostic accuracy of arthroscopy in experienced hands is at least 20% greater than clinical diagnostic accuracy. (p. 142)

Cassells (1980) went on to say that arthroscopy is an excellent research and therapeutic tool, but it requires special training and more than average skill.

The principles for the removal of flap tears, bucket-handle tears, and for subtotal meniscectomy were described in Gillquist's (1980) article. He stated that the selection of the type of operation is specific to the patient. His results in his first 200 cases were good or excellent in the majority of patients.

Matsui, Moriya, and Kitahara (1979) used arthroscopy to study, evaluate, and reveal the problems in 48 patients with postoperative problems. Their arthroscopic study dealt with knee operations not specific to meniscectomy. The use of the arthroscope was a valuable research tool. Carson (1979) stated:

Immediate postoperative morbidity is astonishingly less than that seen with open meniscectomy. Economic losses, including medical costs and time off work, were significantly less, and short term results compare favorably with those of conventional meniscectomy in regard to relief of symptoms and restoration of function. (p. 627)

Age Groups

Several review articles dealt with meniscal injuries of specific age groups; children, and those older than 40 years of age. Zaman and Leonard (1981) concluded that meniscectomy is not a benign procedure in children. They reviewed 59 knees in 49 patients with a mean follow-up period of 7.5 years. There was an equal number of operations on both
sexes, and according to the literature, a high proportion of lateral meniscectomies. A good result was noted in 68% of the boys and only 29% of the girls. Only 27% of the patients had normal radiographs, and 19% had signs of early arthritis. The researchers found that the preoperative diagnosis was correct in only 65% of the cases studied. Zaman and Leonard (1981) suggested that preoperative assessment should include arthroscopy and arthrography.

Vahvanen and Aalto (1979) studied the postoperative results in 42 meniscectomies at the average of 5.6 years after the operation. During follow-up, 11 patients had complaints of pain. Examination revealed four of the 11 who had the lateral meniscus removed experienced degenerative changes. Indications, according to the researchers, were that some of the meniscectomies were unnecessary, and those done were not always satisfactory.

Intensive preoperative evaluation and conservative management of meniscal lesions in children were the suggestions of Medlar, Maniberg, and Lyne (1980) after their postoperative study of 26 children. The 26 children showed signs of ligamentous laxity, early degenerative arthritis, and complained of pain. Only 42% of those studied demonstrated good or excellent results. The average follow-up period was 8.3 years.

Jones, Smith, and Reich (1978) studied the effects of medial meniscectomy in patients over the age of 40 years. Forty-nine patients were studied one to 12 years postoperatively. Pain was found in 62.2% of those with degenerative tears and in 75% of those with traumatic tears. Arthritis was found to be significantly more severe.
on the operative side. The medial joint space was thinner in the
patients with degenerative tears than those with traumatic tears.
Relatively more varus angle was found on the operative side than on
the uninvolved side.

Injuries in the Knees in Women

A study by Powers (1979) dealt exclusively with the injuries in
women. He explained anatomical and physiological differences in the
knee joints of men and women. Because of these differences (reduced
muscle mass and increased mobility), injuries in women differed from
injuries in men. Meniscal injuries are uncommon in women, but sprains
and strains occur more frequently. Powers (1979) said that internal
derangements of the knee in women were often the result of their hyper-
mobility. Meniscal tears in women are over-diagnosed and could result
in unnecessary meniscectomy. Arthroscopy could increase the accuracy
of clinical diagnosis. Powers (1979) went on to say:

Injuries in the knee in women may be reduced by better
education as to the type injury sustained, by better
protection to the knee in supporting activities, and
by screening those women who might be more susceptible
to injury. (p. 124)

Even in the hands of experienced surgeons, women with knee injuries
must be dealt with carefully and with conclusive clinical diagnostic
procedures.

Mechanical Changes

Krause, Pope, Johnson, and Wilder (1976) reviewed the mechanical
changes that took place in the knee after meniscectomy. A compression
testing machine was used to transmit increasing loads at various rates across 12 canine and 12 human cadaver knees. Tests were originally done on knees with both menisci intact, and were repeated with one of the menisci removed, and then with both of the menisci removed. The results showed that the stress acting across the joint increased significantly after meniscectomy, and that menisci perform a load-transmitting and energy-absorbing function in the knees.

Muscular Changes

A test was performed by Campbell and Glenn (1979) that studied the foot-pounds of torque produced in a normal knee and a rehabilitated postmeniscectomy knee. The purpose of the test was to test that no significant difference in torque would be manifested between the normal knee and the rehabilitated knee.

Foot-pounds of torque of the knee flexors and knee extensors of eight rehabilitated patients who had meniscectomies were obtained isometrically at 60 and 210 degrees per second by the use of an isokinetic machine. The mean torque developed by the rehabilitated knee was 10 to 12% less than the mean torque developed by the normal knee. A significant difference was found. The study suggested that physical therapists pay attention to rehabilitation of the knee flexors and the use of techniques that promote power, endurance, and strength.

Biomechanics of Running

Pronation and supination were mentioned by Cavanagh (1980). Discussed was how pronation/supination are each a normal phase in the
running stride. However, too much pronation or supination can cause injury. In accordance, the Q angle changes with pronation/supination and can cause knee injury.

Brody's (1980) research went into a detailed explanation of the causes, effects, and specific treatments for running injuries. Thirty percent of the injuries studied in his clinic were knee related. His study included a discussion of the biomechanical factors in running.

Pronation and supination are complex motions that include all the structures of the lower extremity. According to Brody (1980):

Pronation unlocks the foot for surface adaptation and shock absorption during running, and supination locks the foot, allowing stabilization at heel strike and propulsion at toe off. Thus the foot acts as both a loose adapter and a rigid lever.

...Any interference with the sequential timing and extent of pronation and supination places abnormal stress on the lower extremity. (p. 3-4)

He stated that some runners toe in or out which increases the amount of pronation or supination. An orthotic device may be needed to passively stabilize the foot and reduce abnormal motions.

The Q angle changes with pronation and supination. When the foot pronates, the Q angle is reduced; conversely, when the foot supinates, the Q angle increases. Any Q angle over 20° is considered abnormal. (p. 8)
CHAPTER III

PROCEDURES

The problem of the study was to investigate the relationship in stride patterns of the right and left legs of subjects with meniscal damage. Procedures are presented as follows: (a) subjects; (b) pilot study; (c) instrumentation; (d) procedures for collecting data; (e) digitizing procedures; and, (f) statistical analysis.

Subjects

Nine subjects, between the ages of 18 and 27 years, were located with the help of the Sports Medicine Staff at Western Michigan University. All subjects, with the exception of the control group, had knee related problems. Three lateral and three medial meniscectomy patients were studied. The control group consisted of three men, none who had previous history of knee injury. All subjects with medial meniscectomy had minor cruciate ligament damage. All subjects with any other history of knee problems were eliminated from the study. All subjects were in good physical health at the time of filming.

Pilot Study

Purpose

A pilot study completed in April, 1982, investigated the following methodology: (a) the potential for using a two dimensional biomechanical
analysis to measure the degree of pronation/supination of the foot in running; (b) positions during the support phase that could be measured and that best represented the pronation/supination of the foot; (c) the effect of fatigue on the degree of pronation/supination; and, (d) the cinematographical techniques (film speed, lighting conditions) essential to this investigation.

Subject

The pilot study included one subject, a 24 year old male, who had undergone a lateral meniscectomy on the left leg. The subject was four years postoperative and jogged 20-25 miles a week on a regular basis.

Procedures

Filming took place at the biomechanics lab at Western Michigan University. One camera placed in the posterior position was used. Eight separate film sequences were taken at five minute intervals. The toe off phase was eliminated in the statistical analyses because of inconsistent results. Statistical analysis comparing the average angle of pronation/supination of the heel strike and midstance phase of the right and left feet were then completed. An alpha of .05 was chosen for accepting or rejecting the null hypothesis.

Results

The pilot study revealed the following facts concerning the methodology: (a) fatigue was not a factor; (b) a camera speed of 100
frames per second was adequate for the study; (c) the anterior/posterior view was adequate, but a sagittal view was also needed; and, (d) the positions required for measuring pronation/supination were heel strike and midstance.

Statistical results showed a significant difference in the lower extremities for both the heel strike and the midstance phases at the .05 alpha level. The null hypothesis was rejected. The mean angles of pronation/supination are reported in Table 1. It should be noted that the left leg was the operative leg.

### Table 1

#### Average Angle at Heel Strike and Midstance

| Trial | Heel Strike | | | Midstance | | |
|-------|-------------|-------------|-------------|-------------|-------------|
|       | Right Leg   | Left Leg    | Right Leg   | Left Leg    | |
| 1     | 2.8303      | 12.5110     | 2.6427      | 13.5220     | |
| 2     | 5.1612      | 7.9385      | 4.4322      | 10.5689     | |
| 3     | 7.3446      | 11.5636     | 4.3454      | 14.5759     | |
| 5     | 6.0039      | 8.3251      | 4.1555      | 9.4207      | |
| 6     | 4.6093      | 11.6993     | 5.3161      | 11.0628     | |
| 7     | 6.4953      | 11.0887     | 5.1395      | 8.2589      | |

**Instrumentation**

The instrumentation used in the study included a treadmill, a Numonics Electronic Graphics Calculator with digitizing option, a Vanguard High Speed Film Projector, two Photo-Sonics 1-PL Cameras, and a computer program written in FORTRAN.
Procedures for Collecting Data

Subjects were tested on pre-determined dates. The cameras were positioned to film the subject's frontal and sagittal planes, as indicated in Figure 1. Film speed was set at 100 frames per second. The subjects ran for approximately 10 minutes on the treadmill which was set at seven miles per hour. Two separate film sequences were taken of each subject: one with shoes on, one without shoes.

The film analysis involved establishing the X, Y coordinates of selected anatomical points on the lower extremities with a computerized digitizing system. Three consecutive strides were analyzed at each interval filmed. A stride consisted of a right foot support to left foot support phase. Four frames from each stride were digitized; (a) heel strike right foot; (b) midstance right foot; (c) heel strike left foot; (d) midstance left foot; and (e) displacement. From this data centers of gravity, Q angles, and degrees of pronation/supination for each of the intervals were recorded, stored and calculated on Western Michigan University's DEC-10 computer.

The three consecutive strides per film interval were averaged. The average angle for heel strikes of the right leg was statistically compared to the average angle for heel strike of the left leg. Likewise, the same procedure was performed at the midstance phase. This procedure was performed with both film sequences: with shoes and without shoes.

Digitizing Procedures

The film analysis took place in the biomechanics lab at Western
Figure 1. Treadmill and Camera Positioning for Filming Sessions
Michigan University. Biomechanical digitizing procedures were used to find twenty segmental points on the body. These points determined the angles of pronation/supination, Q angle, and the center of gravity. A special program was written to calculate the angle of pronation/supination. See Appendix A.

Statistical Analysis

Statistical analysis was completed using two completely randomized factorial designs (Kirk, 1968). The design had three variables that represented fixed effects; independent, dependent, and moderator variables. The study included three independent groups to which subjects belonged with three levels, legs with two levels, and phases with two levels. The dependent variable was degree of pronation/supination for the first ANOVA and the Q angle for the second ANOVA. Several assumptions were met when ANOVA was used. They are: (a) the subjects constituted a random sample from a common population; (b) the treatments A and B (lateral and medial) represented fixed effects; (c) the sample populations were normal; and (d) the variance of the subject cells were normal.

The actual computer program utilized was the UCLA Biomechanical Package; BMD08V. An alpha = .05 was used to determine significant differences in the groups and differences in the legs of the subjects. If a post hoc test is warranted, a Tukey HSD test will be used to determine differences among levels.
CHAPTER IV

ANALYSIS OF DATA

The problem of the study was to investigate stride patterns of the right and left legs of subjects with meniscal damage. The investigation utilized nine male subjects who attended Western Michigan University and were recruited with assistance of the Sports Medicine Staff. The data were collected using cinematographical techniques which employed two high speed cameras positioned to film the frontal and sagital planes of the subjects while they ran on a treadmill. Analysis of data was divided as follows: (a) Pronation/Supination; (b) Q Angle; (c) Displacement; and (d) Discussion.

Pronation/Supination

The hypothesis that there was a greater degree of pronation/supination between the legs of subjects with a meniscectomy was not supported in all cases with the exception of heel strike/shoe off. The hypothesis that there would be a greater degree of pronation/supination between the control group and the meniscectomy groups was not supported with the exception of heel strike/shoe on.

Shoes On

Heel Strike

An analysis of variance was done at heel strike with shoes on.
The ANOVA summary table is presented in Table 2.

Table 2
Analysis of Variance-Heel Strike Shoe On

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>6.77</td>
<td>2</td>
<td>3.39</td>
<td>.33</td>
</tr>
<tr>
<td>Treatment</td>
<td>139.78</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>121.94</td>
<td>2</td>
<td>60.97</td>
<td>5.89*</td>
</tr>
<tr>
<td>Legs</td>
<td>3.11</td>
<td>1</td>
<td>3.11</td>
<td>.30</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>14.73</td>
<td>2</td>
<td>7.37</td>
<td>.71</td>
</tr>
<tr>
<td>Residual</td>
<td>108.35</td>
<td>10</td>
<td>10.35</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group - no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and noninjured); and (d) Conditions X legs interaction effect. Dimensions subjects, legs, and conditions X legs interaction, indicated no significant differences. Conditions, with 2 and 10 degrees of freedom, required a critical value of 4.10 to reject the null hypothesis. Since the obtained F value for the conditions was 5.89, the null hypothesis was rejected at the .05 level of significance.

The Tukey Honest Significant Difference (HSD) procedure for multiple comparisons was computed in order to find where differences between the conditions occurred. Comparisons were made be-
tween: (a) control and medial groups; (b) control and lateral groups; and (c) medial and lateral groups. Results of the HSD procedure indicated significant differences existed: (a) between the control and medial groups; and, (b) between the medial and lateral groups. With 3 and 6 degrees of freedom, a critical q value of 4.83 was necessary for significance at the .05 level. The obtained q values were 4.91 and 5.98 respectively. The obtained q for the control group compared to the lateral group was 1.98 indicating no difference. The obtained q's used to determine Tukey HSD are presented in Table 3.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>X control</th>
<th>X medial</th>
<th>X lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12.90</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>7.99</td>
<td>4.91*</td>
<td>0</td>
</tr>
<tr>
<td>Lateral</td>
<td>13.88</td>
<td>1.08</td>
<td>5.98*</td>
</tr>
</tbody>
</table>

*p < .05

Midstance

An analysis of variance was done at midstance with shoes on. The ANOVA summary table is presented in Table 4.
Table 4
Analysis of Variance-Midstance Shoe On

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>25.82</td>
<td>2</td>
<td>12.91</td>
<td>.44</td>
</tr>
<tr>
<td>Treatments</td>
<td>127.71</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>117.16</td>
<td>2</td>
<td>58.58</td>
<td>1.99</td>
</tr>
<tr>
<td>Legs</td>
<td>2.20</td>
<td>1</td>
<td>2.20</td>
<td>.07</td>
</tr>
<tr>
<td>Conditions X Leg</td>
<td>8.35</td>
<td>2</td>
<td>4.17</td>
<td>.14</td>
</tr>
<tr>
<td>Residual</td>
<td>294.15</td>
<td>10</td>
<td>29.42</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group-no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X legs interaction effect. No significant differences in pronation/supination existed between the subjects, conditions, legs, or conditions X legs interaction. Since none of the obtained F values surpassed their corresponding critical F values of 4.96 and 4.10, no evidence existed that warranted the rejection of the null hypothesis. No further statistical analysis was made on midstance with shoes on.

Shoes Off

Heel Strike

An analysis of variance was done at heel strike with shoes off.
The ANOVA summary table is presented in Table 5.

### Table 5

**Analysis of Variance-Heel Strike Shoe Off**

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>53.79</td>
<td>2</td>
<td>25.90</td>
<td>4.86*</td>
</tr>
<tr>
<td>Treatments</td>
<td>51.64</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>14.04</td>
<td>2</td>
<td>7.02</td>
<td>1.27</td>
</tr>
<tr>
<td>Legs</td>
<td>35.67</td>
<td>1</td>
<td>35.67</td>
<td>6.45*</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>1.93</td>
<td>2</td>
<td>.96</td>
<td>.17</td>
</tr>
<tr>
<td>Residual</td>
<td>55.25</td>
<td>10</td>
<td>5.53</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

Sources of variation for the analysis were: (a) Subjects (nine males); (b) Conditions (Control - no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X leg interaction effect. The conditions and conditions X legs interaction indicated no significant differences. The source of variation for subjects was significant. With 2 and 10 degrees of freedom, a critical F value of 4.10 was necessary; since the obtained F value for the subjects was 4.86, the null hypothesis was rejected. The source of variation for legs was significant. With 1 and 10 degrees of freedom, a critical F value of 4.95 was necessary; the obtained F value for the legs was 6.45, and the null hypothesis was rejected. The sources, subjects and leg effects were significant.
due to the inherent variability between subjects and their legs. A post hoc test was not warranted.

**Midstance**

The ANOVA summary table for midstance with shoes off is presented in Table 6.

**Table 6**

*Analysis of Variance-Midstance Shoe Off*

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>45.86</td>
<td>2</td>
<td>22.93</td>
<td>2.51</td>
</tr>
<tr>
<td>Treatments</td>
<td>54.60</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>18.50</td>
<td>2</td>
<td>9.25</td>
<td>1.01</td>
</tr>
<tr>
<td>Legs</td>
<td>33.29</td>
<td>1</td>
<td>33.29</td>
<td>3.65</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>2.81</td>
<td>2</td>
<td>1.41</td>
<td>.15</td>
</tr>
<tr>
<td>Residual</td>
<td>91.24</td>
<td>10</td>
<td>9.12</td>
<td></td>
</tr>
</tbody>
</table>

*p* < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group - no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X legs interaction effect. No significant differences in pronation/supination existed between the subjects, conditions, legs, or conditions X legs interaction. Since none of the obtained F values surpassed their corresponding critical F values of
4.96 and 4.10, no evidence existed that warranted the rejection of the null hypothesis. No further statistical analysis was made on midstance with shoes off.

Mean values for the heel strike and midstance phases of the pronation/supination analysis are presented in Appendix C.

Q Angle

A Randomized Block Factorial analysis was performed to determine differences in the average Q angles of the test subjects, both with shoes on and shoes off. The Tukey HSD multiple comparisons test was employed where appropriate to determine significant differences between means.

The hypothesis that a difference in the average Q angles exist between the legs of subjects with a meniscectomy was tested. A second hypothesis, that a difference in the average Q angles exist between the control group and the operative groups was also tested.

The first hypothesis was not supported by the analysis of variance. Significant differences, however, were found between the conditions in all the data tested for the second hypothesis.

Shoes On

Heel Strike

The ANOVA summary table for Q angle-heel strike with shoes on is presented in Table 7.
Table 7

Analysis of Variance - Q Angle - Heel Strike Shoe On

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>5.67</td>
<td>2</td>
<td>2.84</td>
<td>.62</td>
</tr>
<tr>
<td>Treatments</td>
<td>83.86</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>75.67</td>
<td>2</td>
<td>37.84</td>
<td>8.19*</td>
</tr>
<tr>
<td>Legs</td>
<td>.57</td>
<td>1</td>
<td>.57</td>
<td>.12</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>7.62</td>
<td>2</td>
<td>3.81</td>
<td>.82</td>
</tr>
<tr>
<td>Residual</td>
<td>46.21</td>
<td>10</td>
<td>4.62</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group - no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X legs interaction effect. The subjects, legs, and conditions X legs interaction indicated no significant differences. Conditions, with 2 and 10 degrees of freedom required a critical value of 4.10 to reject the null hypothesis. Since the obtained F value for the conditions was 8.19, the null hypothesis was rejected at the .05 level of significance.

The Tukey HSD procedure for multiple comparisons was computed in order to find where differences between the conditions occurred. Results of the HSD procedure indicated significant differences existed: (a) between the medial and lateral groups; and (b) between the control and medial groups. With 3 and 6 degrees of freedom, a critical q value...
of 2.60 was necessary for significance at the .05 level. The obtained q values were 4.85 and 2.87 respectively. The obtained q of the control group compared to the lateral group was only 1.98 indicating no difference. The obtained q's used to determine Tukey HSD are presented in Table 8.

Table 8

Obtained Q Values Determining Significant Differences of Conditions—Q Angle-Heel Strike Shoe On

<table>
<thead>
<tr>
<th></th>
<th>( \bar{X} ) control</th>
<th>( \bar{X} ) medial</th>
<th>( \bar{X} ) lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>( \bar{X} = 22.25 )</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>( \bar{X} = 25.12 )</td>
<td>2.87*</td>
<td>0</td>
</tr>
<tr>
<td>Lateral</td>
<td>( \bar{X} = 20.27 )</td>
<td>1.98</td>
<td>4.85*</td>
</tr>
</tbody>
</table>

*\( p < .05 \)

Midstance

The ANOVA summary table for Q angle-midstance with shoes on is presented in Table 9.
Table 9
Analysis of Variance-Q Angle-Midstance Shoe On

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>24.64</td>
<td>2</td>
<td>12.32</td>
<td>4.09</td>
</tr>
<tr>
<td>Treatments</td>
<td>75.96</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>67.29</td>
<td>2</td>
<td>33.64</td>
<td>11.17*</td>
</tr>
<tr>
<td>Legs</td>
<td>4.42</td>
<td>1</td>
<td>4.42</td>
<td>1.46</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>4.25</td>
<td>2</td>
<td>2.12</td>
<td>.70</td>
</tr>
<tr>
<td>Residual</td>
<td>30.09</td>
<td>10</td>
<td>3.01</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group - no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X legs interaction effect. The subjects, legs, and conditions X legs interaction indicated no significant differences. Conditions with 2 and 10 degrees of freedom required a critical value of 4.10 to reject the null hypothesis. Since the obtained F value for the conditions was 11.17, the null hypothesis was rejected at the .05 level of significance.

The Tukey HSD procedure for multiple comparisons was computed in order to find where differences between the conditions occurred. Results of the HSD procedure indicated significant differences existed: (a) between the medial and lateral groups; and (b) between the control and lateral groups. With 3 and 6 degrees of freedom, a critical q value...
of 3.22 was necessary for significance at the .05 level. The obtained q values were 6.12 and 3.85 respectively. The obtained q value of the control group in comparison with the medial group was 2.27 indicating no difference. The obtained q values used to determine Tukey HSD are presented in Table 10.

Table 10

Obtained Q Values Determining Significant Differences of Conditions-Q Angle-Midstance Shoe On

<table>
<thead>
<tr>
<th>Condition</th>
<th>X control</th>
<th>X medial</th>
<th>X lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>X = 24.29</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>X = 26.56</td>
<td>2.27</td>
<td>0</td>
</tr>
<tr>
<td>Lateral</td>
<td>X = 20.44</td>
<td>3.85*</td>
<td>6.12*</td>
</tr>
</tbody>
</table>

*p < .05

Shoes Off

Heel Strike

The ANOVA summary table for Q angle-heel strike with shoes off is presented in Table 11.
Table 11  
Analysis of Variance—Q Angle-Heel Strike Shoe Off

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>5.67</td>
<td>2</td>
<td>2.83</td>
<td>.61</td>
</tr>
<tr>
<td>Treatments</td>
<td>83.84</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>75.67</td>
<td>2</td>
<td>37.83</td>
<td>8.18*</td>
</tr>
<tr>
<td>Legs</td>
<td>.56</td>
<td>1</td>
<td>.56</td>
<td>.12</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>7.61</td>
<td>2</td>
<td>3.80</td>
<td>.82</td>
</tr>
<tr>
<td>Residual</td>
<td>46.20</td>
<td>10</td>
<td>4.62</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group—no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X legs interaction effect. The subjects, legs, and conditions X legs interaction indicated no significant differences. Conditions with 2 and 10 degrees of freedom required a critical value of 4.10 to reject the null hypothesis. Since the obtained F value for the conditions was 8.18, the null hypothesis was rejected at the .05 level of significance.

The Tukey HSD procedure for multiple comparisons was computed in order to find where differences between the conditions occurred. Results of the HSD procedure indicated a significant difference existed between the medial and lateral groups. With 3 and 6 degrees of freedom, a critical q value of 4.11 was necessary for significance at the .05
level. The obtained q value was 4.67. The obtained q values for the control group compared to the medial group and the lateral group were 2.27 and 3.94 respectively, indicating no differences. The obtained q values used to determine Tukey HSD are presented in Table 12.

Table 12

Obtained Q Values Determining Significant Differences of Conditions—Q Angle—Heel Strike Shoe Off

<table>
<thead>
<tr>
<th>Condition</th>
<th>$\bar{x}$ Control</th>
<th>$\bar{x}$ Medial</th>
<th>$\bar{x}$ Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>$\bar{x}$ = 24.22</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>$\bar{x}$ = 24.95</td>
<td>2.27</td>
<td>0</td>
</tr>
<tr>
<td>Lateral</td>
<td>$\bar{x}$ = 20.28</td>
<td>3.94</td>
<td>4.67*</td>
</tr>
</tbody>
</table>

*p < .05

Midstance

The ANOVA summary table for Q angle—midstance with shoes off is presented in Table 13.
Table 13
Analysis of Variance-Q Angle-Midstance Shoe Off

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>23.32</td>
<td>2</td>
<td>11.66</td>
<td>1.54</td>
</tr>
<tr>
<td>Treatments</td>
<td>131.28</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>114.79</td>
<td>2</td>
<td>57.39</td>
<td>7.61*</td>
</tr>
<tr>
<td>Legs</td>
<td>.81</td>
<td>1</td>
<td>.81</td>
<td>.13</td>
</tr>
<tr>
<td>Condition X Leg</td>
<td>15.68</td>
<td>2</td>
<td>7.84</td>
<td>1.03</td>
</tr>
<tr>
<td>Residual</td>
<td>75.47</td>
<td>10</td>
<td>7.54</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

The dimensions of the analysis were: (a) Subjects (nine males); (b) Conditions (control group - no knee injuries, medial meniscectomy group, and lateral meniscectomy group); (c) Legs (injured and non-injured); and (d) Conditions X legs interaction effect. The subjects, legs, and conditions X legs interaction indicated no significant differences. Conditions with 2 and 10 degrees of freedom required a critical value of 4.10 to reject the null hypothesis. Since the obtained F value for the conditions was 7.61, the null hypothesis was rejected at the .05 level of significance.

The Tukey HSD procedure for multiple comparisons was computed in order to find where differences between the conditions occurred. The results of the HSD procedure indicated a significant difference existed between the medial and lateral groups. With 3 and 6 degrees of freedom, a critical q value of 3.22 was necessary for significance at the .05
level. The obtained q value was 4.72. The obtained q values for the control group compared to the medial group and the lateral group were 2.00 and 2.72 respectively indicating no differences. The obtained q values used to determine Tukey HSD are presented in Table 14.

Table 14

<table>
<thead>
<tr>
<th>Conditions-Q Angle-Midstance Shoe Off</th>
<th>X control</th>
<th>X medial</th>
<th>X lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>X = 24.01</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>X = 26.01</td>
<td>2.00</td>
<td>0</td>
</tr>
<tr>
<td>Lateral</td>
<td>X = 21.29</td>
<td>2.72</td>
<td>4.72*</td>
</tr>
</tbody>
</table>

*p < .05

Mean values of the heel strike and midstance phases of the Q angle analysis are presented in Appendix D.

Displacement

The average horizontal displacement of the center of gravity of the foot from the total body center of gravity was measured. This displacement data indicates the degree of pronation/supination resulting from the stride patterns assumed by the subjects. The greater the displacement, the greater the pronation and vise versa supination. A diagram of the horizontal displacement is shown in Figure 2. The displacement was measured in feet and the mean displacements are presented in Table 15.
Figure 2. Displacement Design
Table 15
Average Displacement

<table>
<thead>
<tr>
<th></th>
<th>Heel Strike Shoe On</th>
<th>Heel Strike Shoe Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured (feet)</td>
<td>Non-Injured (feet)</td>
</tr>
<tr>
<td>Control*</td>
<td>.059</td>
<td>.238</td>
</tr>
<tr>
<td></td>
<td>.038</td>
<td>.238</td>
</tr>
<tr>
<td>Medial</td>
<td>.198</td>
<td>.078</td>
</tr>
<tr>
<td></td>
<td>.198</td>
<td>.069</td>
</tr>
<tr>
<td>Lateral</td>
<td>.159</td>
<td>.119</td>
</tr>
<tr>
<td></td>
<td>.071</td>
<td>.079</td>
</tr>
<tr>
<td>Average</td>
<td>.158</td>
<td>.145</td>
</tr>
<tr>
<td></td>
<td>.102</td>
<td>.128</td>
</tr>
</tbody>
</table>

|                  | Midstance Shoe On | Midstance Shoe Off |
|                  | Injured (feet)     | Non-Injured (feet)  |
| Control*         | .096                | .233                 |
|                  | .050                | .214                 |
| Medial           | .175                | .063                 |
|                  | .155                | .063                 |
| Lateral          | .151                | .116                 |
|                  | .067                | .124                 |
| Average          | .140                | .137                 |
|                  | .067                | .124                 |

*The control group's left leg represents their injured leg.

No statistical analysis was done on the displacement measurements, but it appeared that there were differences. These differences are listed as follows: (a) between injured and non-injured legs, with shoes on; (b) between injured and non-injured legs with shoes off; (c) between conditions; and (d) between averages.
Between Legs/Shoes On

The greatest displacement was seen between the legs of the control subjects, .170 foot. There was also a displacement difference between the legs of the medial and lateral groups, .12 and .04 foot respectively, although not as great as the difference for the control group. In the cases of the medial and lateral groups, the displacements were smaller for the non-injured leg versus the injured leg (.198 versus .078 and .159 versus .119 respectively).

Between Legs/Shoes Off

The greatest displacement was seen between the legs of the control subjects, .2 foot. With the medial group, the displacement was less with the non-injured leg, .069 foot versus .198 foot. With the lateral group, the displacement was less with the injured leg, .071 foot and .079.

Between Conditions Shoes/On and Shoes/Off

The greatest difference was between the control and medial groups, particularly with the non-injured legs, .238 control versus .078 medial with shoes/on and .238 control versus .069 medial with shoes/off. Other differences appeared: (a) between the non-injured leg of medial and lateral groups, with shoes; .078 and .119 foot respectively, and (b) between the injured leg of the medial and lateral groups without shoes, .198 and .071 foot respectively.
Between Heel Strike and Midstance

The average displacements between the heel strike and midstance phases appeared to be relatively uniform. However, with shoes, or without shoes, there was a great difference in displacements, particularly with the injured legs (.158 and .102 foot respectively for heel strike and .140 and .067 respectively for midstance).

Discussion

Based on the results of this study, there are differences in the pronation/supination of the feet at heel strike after long term meniscectomy. Also, there are differences in the average Q angles between patients with a medial or lateral meniscectomy at heel strike and midstance as well as between the control and lateral groups at midstance with shoes and the control and medial groups at heel strike with shoes. Two possible interpretations exist for the data. First, original differences in Q angles could have led to lower leg problems and finally meniscectomy. Second, the meniscectomy led to differences in the pronation/supination at heel strike and to differences in the Q angle due to compensations for a missing menisci.

The analysis of the heel strike phase of pronation/supination indicated several differences. Without shoes, these differences were between the subjects and between the injured and non-injured legs. This could be accounted for by the inherent variability between subjects and between legs. It is unknown why no differences were found between subjects and legs in other controlled situations. Perhaps shoes make
the difference. Shoe manufacturers and shoe research has indicated
different shoe models correct for pronation and supination.

It was at heel strike with shoes on that the most pertinent signifi-
cant differences were found for the pronation/supination tests. These
differences were found between the conditions. Although no differences
were found between the control and lateral groups, differences were
found between: (a) the control and medial groups; and (b) the medial
and lateral groups. This finding appeared to be most relevant as,
realistically, most people run with shoes on. The literature revealed
that: (a) pronation at heel strike is associated with a medial menisc-
ectomy, (b) supination is associated with a lateral meniscectomy, and
(c) a normal gait pattern exhibits a degree of supination at heel
strike. Therefore, the differences found between: (a) the medial and
lateral group, and (b) the control and medial group, were opposite
(one tended to pronate the other supinate) in nature. Based on the
above facts a small difference would be expected between the degree
of supination found in the control group and the lateral meniscectomy
group.

Several interesting results were found in the Q angle tests. There
were differences in all situations tested, unlike the pronation/supina-
tion tests. Possibly, original differences in the Q angle eventually
caused problems in the lower legs. This, however, cannot be proved
conclusively in the scope of this study. It was interesting to find
that no other treatment differences existed except at the conditions.

It was hypothesized that there would be differences in the Q
angles between the control and operative groups. This was proved only
at heel strike without shoes and midstance with shoes; both differences were found between the control group and lateral group. Although not hypothesized, there was a significant difference between the medial and lateral groups in all the tested situations. Perhaps the pronation/supination associated with medial and lateral meniscectomies is caused by differences in Q angles. From a logical point of view the Q angle and the range of motion of the ankle determine the placement of the leg during the stance phase. The placement of the leg during the stance phase is related to the direction forces act through the knee joint. The direction may relate to the injury. From this line of thought it appears that Q angles alone do not cause an injury. Instead the injury is a result of the relationship between the Q angle and the range of motion of the ankle.

From the results of this investigation, it appears that the shoes the subjects wore had a definite effect on the test results. This finding could be invaluable to the subject and/or shoe manufacturer for the purpose of prevention and rehabilitation.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

The problem of the study was to investigate the relationship in stride patterns of the right and left legs of subjects with a meniscectomy. It was the intent of this study to compare subjects with a meniscectomy to a control group with respect to two dependent variables; pronation/supination and Q angles.

The investigation utilized nine male subjects who attended Western Michigan University and were found through the help of the Sports Medicine Staff. Three of the subjects made up the control group, three the long term medial meniscectomy group, and three the long term lateral meniscectomy group. The data were collected through a cinematographical technique which employed two high speed cameras placed perpendicular to the frontal and sagittal planes of the subjects while they ran on a treadmill. The film was digitized and analyzed. Mean angles were computed for pronation/supination and Q angles and groups were compared statistically. Where post hoc tests were warranted, the Tukey Honest Significant Difference for multiple comparison procedure was utilized.

Findings

The analysis of variance proved several significant differences in the pronation/supination test. These are listed below:

45
1. There was a significant difference between subjects at heel strike without shoes. The obtained F was 4.86, compared to the critical F of 4.10 (p < .05).

2. There was a significant difference between the injured and non-injured legs at heel strike without shoes. The obtained F was 6.45, compared to the critical F of 4.10 (p < .05).

3. There was a significant difference between the operative conditions at heel strike with shoes. The obtained F was 5.89, compared to the critical F of 4.10 (p < .05).

4. The Tukey HSD multiple comparisons procedure found differences between the control and medial groups. The obtained q was 4.91, compared to the critical q of 4.83 (p < .05).

5. The Tukey HSD multiple comparisons procedure found differences between the medial and lateral groups. The obtained q was 5.98, compared to the critical q of 4.83 (p < .05).

6. There were no significant differences between the control and lateral groups.

7. There were no significant differences at the midstance phases.

8. There were no significant differences in any other treatment variables.

The analysis of variance also proved several significant differences occurred in the Q angle tests. These are listed as follows:

1. There were significant differences in all the Q angles tested: (a) Heel strike shoe on: obtained F = 8.19; (b) heel strike shoe off: obtained F = 8.18; (c) midstance shoe on: obtained F = 11.17; and (d) midstance shoe off: obtained F = 7.16. All were compared to the
critical F of 4.10 (p .05).

2. The Tukey HSD multiple comparisons procedure found differences between all the medial and lateral groups; (a) heel strike shoe on: obtained q = 4.85; (b) heel strike shoe off: obtained q = 4.67; (c) midstance shoe on: obtained q = 6.12; and (d) midstance shoe off: obtained q = 4.72. All were compared to critical q's of 2.60, 4.11, 3.22 and 3.22 respectively (p < .05).

3. A significant difference was seen between the control and the medial group at heel strike with shoes. An obtained q of 2.87 was compared to a critical q of 2.50 (p < .05).

4. A significant difference was seen between the control and the lateral group at midstance with shoes. An obtained q of 3.85 was compared to a critical q of 3.22 (p < .05).

5. There were no significant differences in any other treatment variables.

Conclusions

Within the limitations of the investigation the following conclusions are justified:

1. Shoes altered the degree of pronation/supination observed in the running strides of subjects with medial or lateral meniscectomies.

2. During the heel strike phase, differences occurred between the medial and lateral meniscectomy groups with respect to pronation/supination.
3. Q angle differences were consistent for the medial and lateral meniscectomy groups at both phases, heel strike and midstance, of the running stride.

Recommendations

Further studies are recommended in which larger and more varied subject populations are tested. It is recommended that such studies include various models of running footwear so that specific differences in the stride can be studied. Such research may define the appropriate shoes each individual subject should wear to reduce harmful degrees of pronation or supination.

It would be very helpful if the degree of pronation/supination and Q angle measurements could be taken prior to a meniscectomy. This, however, is doubtful to ever happen as no one can predict who will sustain a meniscal injury.

It is also recommended that research be done to determine if original Q angles led to meniscectomy or if post-operative meniscectomy patients have altered Q angles to compensate for a missing menisci. Also, the relationship between: (a) Q angles, (b) the range of motion of the ankle joint, and (c) the horizontal displacement between the center of gravity of the foot and the total body center of gravity, should be investigated.

As a final suggestion, a copy of the results of this and further studies should be useful to athletic shoe manufacturers and orthopedic surgeons who deal with knee related injuries and surgery.
APPENDIX A

Computer Program Used to Compute Pronation/Supination

```
DIMENSION X(2),Y(2),A(5)

5 WRITE(5,100)
100 FORMAT('RIGHT=1; LEFT FOOT=2')
READ(5,200)N

200 FORMAT(II)
   IF(N.NE.1) GO TO 30
   DO 10 I=1,2
      WRITE(5,300)
         300 FORMAT(' INPUT HEEL FOLLOWED BY ACHILLIES TENDON')
   DO 20 II=1,2
      READ(5,400)X(II),Y(II)
         400 FORMAT(2F)
   CONTINUE
   A(I)=ATAN((X(2)-X(1))/(Y(2)-Y(1)))*57.295779
   CONTINUE
   AVE=(A(1)+A(2)+A(3)+A(4)+A(5))/5.0
   WRITE(5,500)((A(M),M=1,5),AVE)
         500 FORMAT(5(Fl0.5)/'AVE RAGE=',Fl0.5)
   GO TO 60

30 IF(N.NE.2) GO TO 5
   DO 40 L=1,5
      WRITE(5,600)
         600 FORMAT(' INPUT HEEL FOLLOWED BY ACHILLIES TENDON')
   DO 50 LL=1,2
      READ(5,400)X(LL),Y(LL)
         50 CONTINUE
      A(LL)=(ATAN((X(2)-X(1))/(Y(2)-Y(1))))*57.295779
      CONTINUE
      AVE=(A(1)+A(2)+A(3)+A(4)+A(5))/5.8
      WRITE(5,700)((A(M),M=1,5),AVE)
         700 FORMAT('DO YOU WANT TO CALCULATE ANOTHER ANGLE?'
               'YES=1; NO=2')
   IF(J.EQ.1) 5,70
   IF(J.EQ.2) 80,60
   STOP
END
```

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APPENDIX B

Computer Program Used to Determine Q Angle

DIMENSION
10 WRITE(5,100)
100 FORMAT(’ INPUT C/G, HIP, AND CENTER OF KNEE ’)
DO 20 I=1,3
READ(5,200) x(I),y(I)
200 FORMAT(2F)
20 CONTINUE
AX1=X(2)-X(3)
AY1=Y(2)-Y(3)
ANG1=ATAN(AX1/AY1)*57.295
AX2=X(3)-X(1)
AY2=Y(1)-Y(3)
ANG2=ATAN(AX2/AY2)*57.295
QANG=ANG1+ANG2
WRITE(5,300)ANG1,ANG2,QANG
300 FORMAT(’ ANGLE1= ’,F10.8/’ ANGLE2= ’,F10.8/’ AVERAGE= ’,F10.8)
30 WRITE(5,400)
40 FORMAT(’ DO YOU WANT TO CALCULATE ANOTHER ANGLE?’
YES=1,NO=2’)
READ(5,500)S
500 FORMAT(1F)
IF(S .EQ. 1) GO TO 10
IF(S .EQ. 2) 40,30
40 STOP
END
### APPENDIX C

#### Average Angles for Determining Significant Differences for Pronation/Supination

<table>
<thead>
<tr>
<th>Heel Strike Shoe On</th>
<th>Heel Strike Shoe Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured</td>
<td>Non-Injured</td>
</tr>
<tr>
<td>(Degrees)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>10.3694</td>
<td>11.6370</td>
</tr>
<tr>
<td>14.9760</td>
<td>11.8385</td>
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<tr>
<td>13.0155</td>
<td>15.5730</td>
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<tr>
<td>Average=</td>
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<tr>
<td></td>
<td>3.95</td>
</tr>
<tr>
<td>Medial</td>
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</tr>
<tr>
<td>14.1955</td>
<td>03.9180</td>
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<tr>
<td>06.3785</td>
<td>05.3765</td>
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<td>08.4920</td>
<td>04.6370</td>
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<td>Average=</td>
<td>7.99</td>
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<tr>
<td></td>
<td>5.36</td>
</tr>
<tr>
<td>Lateral</td>
<td></td>
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<tr>
<td>17.7730</td>
<td>11.5570</td>
</tr>
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<td>13.3055</td>
<td>13.5900</td>
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<tr>
<td>09.8830</td>
<td>17.7770</td>
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<tr>
<td>Average=</td>
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<td>5.05</td>
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<table>
<thead>
<tr>
<th>Midstance Shoe On</th>
<th>Midstance Shoe Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured</td>
<td>Non-Injured</td>
</tr>
<tr>
<td>(Degrees)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>00.4200</td>
<td>00.9575</td>
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<tr>
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<td>05.5795</td>
</tr>
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<td>10.0995</td>
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<td>.91</td>
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<td>Medial</td>
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</tr>
<tr>
<td>13.9995</td>
<td>04.2465</td>
</tr>
<tr>
<td>-1.3645</td>
<td>01.5365</td>
</tr>
<tr>
<td>-0.5905</td>
<td>01.0195</td>
</tr>
<tr>
<td>Average=</td>
<td>3.74</td>
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<tr>
<td></td>
<td>1.63</td>
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<tr>
<td>Lateral</td>
<td></td>
</tr>
<tr>
<td>17.9625</td>
<td>06.9070</td>
</tr>
<tr>
<td>05.8565</td>
<td>09.9140</td>
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<td>06.2095</td>
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<tr>
<td>Average=</td>
<td>9.18</td>
</tr>
<tr>
<td></td>
<td>3.31</td>
</tr>
</tbody>
</table>
APPENDIX D

AVERAGE ANGLES FOR DETERMINING SIGNIFICANT DIFFERENCES
FOR Q ANGLES

<table>
<thead>
<tr>
<th></th>
<th>Heel Strike Shoe On</th>
<th>Heel Strike Shoe Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
<td>Non-Injured</td>
</tr>
<tr>
<td>Control</td>
<td>21.8000</td>
<td>24.2800</td>
</tr>
<tr>
<td></td>
<td>20.5000</td>
<td>22.4000</td>
</tr>
<tr>
<td></td>
<td>22.0500</td>
<td>22.6600</td>
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<tr>
<td>Average=</td>
<td>22.25</td>
<td>24.22</td>
</tr>
<tr>
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<td>25.3800</td>
<td>24.5100</td>
</tr>
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<td></td>
<td>21.5400</td>
<td>22.2600</td>
</tr>
<tr>
<td></td>
<td>29.1100</td>
<td>27.9200</td>
</tr>
<tr>
<td>Average=</td>
<td>25.12</td>
<td>24.95</td>
</tr>
<tr>
<td>Lateral</td>
<td>18.8500</td>
<td>20.7700</td>
</tr>
<tr>
<td></td>
<td>19.5200</td>
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</tr>
<tr>
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<td>21.9900</td>
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</table>

<table>
<thead>
<tr>
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<th>Midstance Shoe On</th>
<th>Midstance Shoe Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
<td>Non-Injured</td>
</tr>
<tr>
<td></td>
<td>21.3300</td>
<td>23.4800</td>
</tr>
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<td></td>
<td>23.8700</td>
<td>24.4500</td>
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<tr>
<td>Average=</td>
<td>24.01</td>
<td>24.29</td>
</tr>
<tr>
<td>Medial</td>
<td>26.6700</td>
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<td>26.9900</td>
</tr>
<tr>
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<td>26.01</td>
<td>26.96</td>
</tr>
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<td>Lateral</td>
<td>20.7200</td>
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<td></td>
<td>22.4300</td>
<td>19.4700</td>
</tr>
<tr>
<td>Average=</td>
<td>21.29</td>
<td>20.44</td>
</tr>
</tbody>
</table>
APPENDIX E

Instructions for the Investigation

Dear Subject,

Thank you for volunteering for the study. The test will involve you running on a treadmill for approximately 20 minutes. You will be familiarized to treadmill procedures at the time of testing.

All testing will be done in the Biomechanics Lab; third floor of the Student Health Center, Room 3220.

You will be filmed during the test. The film will be held strictly confidential and will be destroyed after all results are completed. You and your individual data will be held confidential. In the final paper, if necessary, you will be referred to as Subject 1, Subject 2, etc.

All test information will be forwarded to you after all the results are finalized.

I ask and hope that you show on time for your filming session. It is required that you wear running attire; shorts, proper shoes, etc. You will not be wearing a shirt during the test. Dressing and shower facilities will be available for your use.

I am investigating the characteristics of the running stride of subjects who have had a lateral meniscectomy (outside of the knee), a medial meniscectomy (inside of the knee), and subjects who have no history of knee problems.

I will contact you several days ahead of your filming session. If you have any questions, please contact me at 385-4075. Thank you for your time and cooperation.

Sincerely,

Richard R. Squires
APPENDIX F

Informed Consent Form

By signing this, I consent to the filming techniques used in the study. I understand the procedures and understand that all subject and film data will be kept strictly confidential. I understand that the film will be destroyed after all results are finalized. I have read the instruction sheet and agree to release all data and information for publication and/or presentation.

________________________________________
Signature

________________________________________
Date
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