Descriptive analysis of biomechanical and radiographic characteristics of the lower extremity of runners with Mortons foot syndrome

by Gloria Jean Ferrandino

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Physical Education
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Abstract:
A study was conducted to describe, compare and analyze twenty biomechanical, radiographic and weight-bearing characteristics of the lower extremity and the Morton's Foot syndrome found in eighty-eight runners of Bozeman, Montana who were known to exercise on a regular basis. All subjects were selected on the basis of the visible presence of a long second toe and the existence or non-existence of pain. The selected subjects were then classified into five groups: Group I (N=22), no outwardly appearing long second toe, no pain; Group II (N= 23), an outwardly appearing long second toe, no pain; Group IIIA (N= 17), an outwardly appearing long second toe, slight pain; Group IIIB (N=14), an outwardly appearing long second toe, moderate pain; and Group IIIC (N=12), an outwardly appearing long second toe, severe pain.

The data were treated by means of an analysis of variance and a step-wise regression analysis. Hand calculations were made to determine: the mean, mode and median differences in length of metatarsal I to metatarsal II acquired by Morton's, Schuster's and Sheer's methods; the group means for the parabolic weight-bearing curve angle; Ithe relationship incidence of the length difference of metatarsal I Ito metatarsal II acquired by Morton's, Schuster's and Sheer's methods to the metatarsus location of the greatest concentration of dynamic weight distribution; the mean incidence of the first ray ranges of motion; and the metatarsal location of greatest weight-bearing and calluses with and without first ray consideration.

No significant differences among the biomechanical, radiographic and weight-bearing measures were found to exist between the groups examined thereby making it impossible to independently describe any one of the groups.

The findings showed that either method by Morton, Schuster or Sheer could be used to determine the length difference of metatarsal I to metatarsal II as seen in the radiograph.

Pain related to Morton's Foot syndrome was found to be significantly predicted by: the percentage of length difference of metatar- sal I to metatarsal II; the ranges of internal and external rotation of the femur with the hip straight; the metatarsal location of the greatest concentration of dynamic body weight distribution; and eversion of the subtalor joint.

Those runners having an outwardly appearing long second toe with varying degrees of pain were found to have a shorter metatarsal I than did those runners having no outwardly appearing long second toe, and were found to bear the greatest dynamic weight on the heads of metatarsals II and III. Those runners having no outwardly appearing long second toe tended to bear the greatest weight on the heads of metatarsals I, II and III.

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Date 7 March 1978

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by

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ABSTRACT

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No significant differences among the biomechanical, radiographic and weight-bearing measures were found to exist between the groups examined thereby making it impossible to independently describe any one of the groups.

The findings showed that either method by Morton, Schuster or Sheer could be used to determine the length difference of metatarsal I to metatarsal II as seen in the radiograph.

Pain related to Morton's Foot syndrome was found to be significantly predicted by: the percentage of length difference of metatarsal I to metatarsal II; the ranges of internal and external rotation of the femur with the hip straight; the metatarsal location of the greatest concentration of dynamic body weight distribution; and eversion of the subtalor joint.

Those runners having an outwardly appearing long second toe with varying degrees of pain were found to have a shorter metatarsal I than did those runners having no outwardly appearing long second toe, and were found to bear the greatest dynamic weight on the heads of metatarsals II and III. Those runners having no outwardly appearing long second toe tended to bear the greatest weight on the heads of metatarsals I, II and III.

Chapter 1

INTRODUCTION

Research in exercise physiology supports jogging as a means of improving physical fitness. Accompanying this scientific basis was an increased interest of the individual to improve his health and physical fitness by means of jogging. Concomitant to the ever increasing masses of joggers were "runners' injuries", which are "... linked directly or indirectly to foot-plant" (i:vi).

Sheehan writes:

> "The human body is a marvelous instrument. When in perfect alignment and balance, there is almost no feat of endurance the body cannot handle even on a regular basis. However, structure imbalance of even minor degrees can result in incapacitating injuries and persistent disability. Prevention and treatment of muscoskeletal problems in the athlete, therefore rests on the establishment of the structural balance and architectural integrity of the body - and its re-establishment should injury occur." (24:106)

One such structural problem found in runners is diagnosed as Morton's Foot syndrome, also known as "Runner's Foot". The Morton's Foot syndrome is believed by Sheehan to be a prime cause of runner's complaints (30:10).

Sheehan suggests that the structural deformity characterizing this syndrome is the cause of such problems as chondromalacia of the knee, posterior tibial tendonitis and the heel spur syndrome. Such complaints are not traumatic in nature, but rather, of an "overuse" nature (8:23).

Overuse complaints result from repetitive stress exerted on a mechanically inefficient body part or tissue (8:23). Such mechanical inefficiency often occurs as a result of a structural imbalance which causes the neighboring structures, muscles and ligaments to be altered in order to compensate for the existing abnormality. A structural abnormality in the foot exhibits compensatory faults in the ankle, leg and knee (35:226). Since the foot is chiefly supported by the muscles during action patterns (35:226), it is likely that structural imbalances in the foot and leg would be of greater significance to the runner than they would be to the non-runner (19:67).

The following study was conducted to investigate common alignments of structural deformity of the foot with various symptom levels of severity in order to determine if correlations existed and whether inferences for treatment and/or prevention of such runner's complaints could be made.

Statement of the Problem

The general purpose of this study was to describe, compare and analyze biomechanical, radiographic and weight-bearing characteristics of the lower extremity of runners with an outwardly appearing long second toe.

Specifically, this study attempted:

1. to examine variances of biomechanical, radiographic and weight-bearing measures among those runners having no outwardly appearing long second toe who experienced no complaints, those runners having an outwardly appearing long second toe who experienced no complaints, those runners having an outwardly appearing long second toe who experienced complaints slight in nature, those runners having an outwardly appearing long second toe who experienced complaints moderate in nature and those runners having an outwardly appearing long second toe who experienced complaints severe in nature.
2. to determine correlations among the methods used by Morton (14), Schuster (21) and Sheer (26) to measure the ratio of difference of the length of metatarsal I with that of metatarsal II.
3. to examine differences among the following: the ratio of the length difference of metatarsals I and II; the existence or non-existence of an outwardly appearing long second toe; the parabolic weight bearing curve created by the heads of all metatarsals; and the metatarsus location of the greatest concentration of dynamic weight

distribution.

4. to determine if significant variances of the selected measures existed among the five groups investigated.

5. to determine which, if any, of the biomechanical, radiographic and weight-bearing measures could best describe the Morton's Foot syndrome.

The basis for such determinations were the selected biomechanical, radiographic and weight-bearing measures of: dorsiflexion and plantarflexion ranges of motion of the first ray; inversion and eversion of the subtalor joint; dorsiflexion of the ankle with the knee both flexed and extended; flexibility of the hamstring muscle groups; internal and external rotation of the femur with the hip flexed and extended; position of the forefoot with the rearfoot; calcaneal position to the floor with the subtalor joint neutral; calcaneal stance position in static angle of gait; frontal plane position of the tibia with the subtalor joint static; length of metatarsal I to metatarsal II; the angle of parabolic weight-bearing curve; and the metatarsus location of dynamic weight distribution.

Hypotheses

Null hypotheses. It was hypothesized that there would be no significant difference in the characteristics of the lower extremity as described by the selected biomechanical, radiographic and weight-bearing measures among those runners having no outwardly appearing long second toe who experienced no complaints, and those runners having an outwardly appearing long second toe who experienced no complaints, who experienced complaints slight in nature, who experienced complaints of moderate severity and who experienced complaints severe in nature.

Further, it was hypothesized that no significant differences would be found among the ratio of differences in length of metatarsals I and II, the existence or non-existence of an outwardly appearing long second toe, the parabolic weight-bearing curve, nor the evidence of metatarsus location of the greatest concentration of dynamic weight distribution.

Alternate Hypotheses. It was hypothesized that a significant difference would be found among the characteristics of the lower extremity as described by the selected biomechanical, radiographic and weight-bearing measures among those runners having no outwardly appearing long second toe who experienced no complaints, and those runners having an outwardly appearing long second toe who experienced no complaints, who experienced complaints slight in nature, who experienced complaints of moderate severity, and who experienced complaints severe in nature.

Further, it was hypothesized that significant differences would be found among the ratio of difference in length of metatarsals

I and II, the existence and non-existence of an outwardly appearing long second toe, the parabolic weight-bearing curve, and the evidence of metatarsus location of the greatest concentration of dynamic weight-bearing distribution. Thus, it would be possible to determine those biomechanical, radiographic and weight-bearing measures that best describe the Morton's Foot syndrome.

Definition of Terms

Abduction. Abduction is any motion during which the distal aspect of the foot, or any part of the foot, moves away from the mid-line of the body. This motion occurs in a transverse plane about a vertical axis lying in the frontal and sagittal planes (17:20).

Adduction. Adduction is any motion during which the distal aspect of the foot, or any part of the foot, moves in a transverse plane toward the midline of the body. This motion occurs about a vertical axis lying in the frontal and sagittal planes (17:20).

Ankle Equinus. Ankle Equinus is a structural condition which limits the ankle joint to less than 10° dorsiflexion from its neutral position (17:24).

Axis of Balance. The axis of balance is a functional division of the foot, running from the center of the heel forward between metatarsals II and III, which coincides with the center of weight exerted upon the talus, thus bisecting its structural stability into lateral directions (14:109-110).

Compensation. Compensation occurs when one or more neighboring body parts take over the action and/or support normally maintained by another body part that has ceased to function properly. Improper functioning may be due to structural deformity or biomechanical alterations.

Dorsiflexion. Dorsiflexion is any motion in which the distal aspect of the foot, or any part of the foot, moves in a sagittal plane toward the tibia. The axis of rotation is about the frontal and transverse axis (16:16).

Dorsiflexion of the First Ray. Dorsiflexion of the first ray exists when the dorsiflexion measurement exceeds that of plantar-flexion. Inversion accompanies this condition (17:84).

Eversion. Eversion is any motion occuring in the frontal and sagittal planes during which the plantar surface of the foot, or any part of the foot, tilts away from the body's midline (17:14).

First Ray. The first ray consists of the first cuneiform and first metatarsal which move about a common axis (17:76).

Hallux Abductus Valgus. Hallux abductus valgus is a deformity of the great toe in which the hallux rotates in the frontal plane causing its plantar surface to become prominent in the lateral direction. Further, the hallux deviates laterally in the transverse plane (5:17).

Hypermobility. Hypermobility is any motion occuring in a joint, in response to gravity, at a time when that joint should be stable under such force. Hypermobility of the first ray is either dorsiflexed or plantarflexed in nature (17:24).

Inversion. Inversion is any motion about the frontal and sagittal planes during which the plantar surface of the foot, or any part of the foot, tilts toward the body's midline (17:14).

Leverage Axis. The leverage axis is a functional line located directionally from the center of the heel forward between metatarsals I and II, the heads of which balance body-weight stresses as they act as the fulcrum during the propulsive phase of locomotion (14: 137-138).

Metatarsalgia. Metatarsalgia is a "wastebasket" term used to describe forefoot disorders (15).

Metatarsus. Metatarsus consist of the first through fifth metatarsals comprising the forefoot (17:26).

Morton's Foot Syndrome. Morton's Foot syndrome is a structural abnormality characterized by a short first metatarsal and a longer second metatarsal, a hypermobile first ray segment, and evidence of greater weight-bearing at the head of the second metatarsal (14).

Neutral Position of the Subtalor Joint. The neutral position of the subtalor joint is that alignment of the calcaneus and talus that allows the calcaneus to invert twice as many degrees as it everts (17:54).

Normal First Ray. A normal first ray exists when the range of motions of dorsiflexion equals that of plantarflexion (17:82).

Plantarflexion. Plantarflexion is any motion in which the distal aspect of the foot, or any part of the foot, is angulated in a sagittal plane away from the tibia. Rotation occurs about the frontal axis (17:16).

Plantarflexion of the First Ray. Plantarflexion of the first ray exists when the plantarflexion measurement exceeds that of dorsiflexion. Eversion accompanies this condition (17:86).

Postural Stability. Postural stability occurs when the structures located above the subtalor joint are maintained in a position perpendicular to those structures below the subtalor joint (14:117).

Pronation. Pronation occurs when the foot, or any part of the foot, is abducted, everted and dorsiflexed simultaneously (17:18).

Structural Stability. Structural stability occurs when the bones and ligaments located below the subtalor joint cause the foot to become a rigidly fixed base throughout which body-weight is supported in a definite ratio of distribution (14:115).

Subtalor Joint. The subtalor joint is the juxtaposition of three articulations of the talus and calcaneus (17:36).

Supination. Supination occurs when the foot acts simultaneously in the direction of inversion, adduction and plantarflexion (17:18).

Valgus. Valgus is an everted structural position of the foot, or any part of the foot, occurring solely in the frontal position (17:22).

Varus. Varus is a congenitally inverted structural position of the foot, or any part of the foot, occurring in the frontal plane (17:22).

Delimitations

The study was delimited to forty-six Bozeman, Montana runners who exercised regularly and ran a minimum of five miles each week and who had no history of orthopedic or surgical trauma to the hip, knee, leg, ankle or foot occurring within the past five years. The study was also delimited to the previously stated eighteen biomechanical measures, four radiographic and dynamic weight distribution measures.

Limitations

With the exception of controlling locations, instruments, methods, techniques and technicians employed in the examination of all subjects, no other controls were imposed. Therefore the following limitations existed.

Data collection occurred at various times of the day during the weeks of May 16 - June 8, 1977. Therefore, the time and type of activity, in addition to running, in which the subjects participated before or after the examination could not be controlled. In addition, neither the number of miles run per day, per week, the type of shoes worn, nor the type of surface on which all running took place were held constant.

The limited number of subjects per group did not provide a significant base for study.

Although Morton believed that Morton's Foot syndrome became symptomatic no earlier than the age of thirty, no attempt was made to delimit this study to only those subjects who were thirty years or older.

Further, no attempt was made to delimit the actual difference in length of the outwardly appearing long second toe to the first toe in the selection of subjects among those runners having an outwardly appearing long second toe who experienced no complaints, who experienced complaints slight in nature, who experienced complaints of moderate severity, and who experienced complaints severe in nature.

Chapter 2

REVIEW OF RELATED LITERATURE

Review of Research

Biomechanical examination of lower extremity alignment factors in athletes has become a fast growing area of research. Investigations were performed to determine the relationship of lower extremity alignment factors to overuse complaints experienced by athletes. Lillstvedt (11) found several of these factors to be significant in the prediction of pain related to the shin splint syndrome. Further, Courtney (2) found that lower extremity alignment factors served as contributing factors in the occurrence of achilles tendonitis.

Morton (14), using a Staticometer, determined the metatarsus distribution of weight in the normal foot to be of equal ratio on metatarsals II through V with metatarsal I taking on two times that of the others. In addition, he investigated the dynamic weight distribution of African men as they walked across a kinetograph. His findings indicated that the head of metatarsal II showed the greatest concentration of weight on feet having an outwardly appearing long second toe whereas greatest weight concentration occurred on metatarsal I in feet having a longer first toe.

Schuster (21) examined an extensive number of feet in an attempt to determine whether or not a short first metatarsal was a causative factor of orthopedic foot difficulties. Schuster found that the greatest incidence of a short metatarsal I, ranging from minus 2mm to minus 6mm, occurred in the patient group. Thus, he concluded that a short metatarsal I "must be one of the etiological factors in mechanical foot difficulties" (21:41).

To this investigator's knowledge, little or no research has been conducted with specific relevancy to pain associated with Morton's Foot syndrome and athletics.

Overuse Syndrome

Morton's Foot syndrome falls under the umbrella term, "overuse syndrome". Subotnick defines it as:

> "... a gradual accumulation of micro trauma resulting in, at first, minor injuries which become progressively more severe. The overuse syndrome is usually secondary to a combination of 3 factors: 1) conditioning, 2) training, 3) biomechanical structure of the lower extremity. Thus, overuse injuries may be a combination of overtraining plus feet and legs that have intrinsic or extrinsic imbalance problems. Intrinsic deformities are those which are in the foot structure itself. Extrinsic deformities occur where a bend in the legs places the foot at an improper angle to the running surface." (31:37)

In running, the feet support the entire body weight while in contact with the running surface. This impact occurs approximately 1000 times per mile (20:69). Since the biomechanical alignment of the lower extremity affects the runner's ability to accomodate this accumulative shock, even slight imbalances could result in overstress on these body parts (33). "Overstress leads to the overuse syndrome" (33:108), therefore, it is important that the runner maintain postural and structural stability.

Lower Extremity Postural and Structural Analysis

Postural stability relates to the structures found above the subtalor joint. With the foot providing a stable base of support and the body weight distributed throughout the plane of balance, the muscles of the leg maintain the leg's position in relation to the foot as a fixed base of support (14:117).

In order to maintain stability, the normal position of the leg must be such that its alignment will see the hip, thigh, distal 1/3 of the lower leg and calcaneus perpendicular to the supporting surface (30:7; 17:34). This allows external and internal rotation of the femur at the hip joint to be equal within an acceptable variance of 15° (23:154). Hip extension is affected by the soft tissues around the joint while hip flexion is affected by the length of the hamstring muscles. Therefore, it is necessary for the hamstring muscle group to have a minimum of 12° and a maximum of 20° flexion when measured with the subject supine and the hip flexed to 90° (15). Since such hip alignment and flexibility of the hamstring muscle group permit the knee to sufficiently extend during the stance phase of gait, the distal 1/3 of the tibia would then be made vertical within an acceptable varum or valgus variance of 2° (17:131).

Normalcy of the ankle joint has been discussed under postural stability since the talus moves according to the motion of the tibia and fibula and is, therefore, considered to be a part of the lower leg (22:38). During midstance and prior to toe-off in gait, the talus moves backward to allow the ankle joint to dorsiflex a minimum of 10° (17:130; 22:38). When ankle dorsiflexion is within normal limits at the contact phase, the heel is allowed to meet the ground first to permit shock absorption and foot position for proper support throughout the stance phase. If proper foot positioning is achieved in stance, the foot is then ready to function effectively during the propulsive phase (28:66-67).

In the normal lower extremity the subtalor joint lies in a neutral position with "the calcaneus perpendicular to the ground and parallel to the distal one-third (1/3) of the leg" (17:130).

When the range of motion of the subtalor joint is normal, the rearfoot functions properly at heel strike, thus allowing the lower leg to rotate internally causing the subtalor to evert (pronate). During the mid-support phase, the lower leg rotates externally to cause the subtalor joint to roll through its neutral position, and continue laterally to an inverted (supinated) position to allow the midtarsal joint to do its part in causing the foot to become a rigid lever for propulsion (22:86).

Structural stability relates to those bones and ligaments located below the subtalor joint which make the foot a rigidly fixed base of support. This rigidly arched contour is the means by which the body weight is supported in a definite ratio of distribution to areas of bone and ground contact (14:115).

The normal foot is found to be of three toe length structures: the Greek foot, in which the great toe is shorter than the second toe; the Egyptian foot, in which the great toe is longer than the second toe; and the squared foot, in which both the great toe and the second toe are of equal length. Any one of these structures may be found in combination with either of three metatarsal structures: the "index plus minus" type in which metatarsals I and II are equal in length; the "index minus" type in which metatarsal I is shorter than metatarsal II; and the "index plus" type in which metatarsal I is longer than metatarsal II (34:165-167). However, the ideal foot is believed to be of the Greek toe type (great toe is shorter than the second toe) with the "index plus" (metatarsal I is longer than metatarsal II) or the "index plus minus" (metatarsal I and metatarsal II are equal in length) metatarsal structure (34:165-167).

Balanced weight-bearing is achieved by the grasping action of the toes, parabolic weight-bearing angle created by the metatarsal alignment and the relative range of motion of the metatarsal-midtarsal joints.

The grasping action of all five toes provides firm and constant support of the metatarsal heads on the supporting surface (34:168). All metatarsal heads sustain weight when they lie in a transverse plane parallel to the supporting surface (34:168; 17:34). The ranking of lengths of the metatarsals exist in two specific combinations, 2>3>1>4>5 or 2>1>3>4>5 (7:105; 13:334). These metatarsal length patterns form a weight-bearing parabolic angle (Figure 1). Meschen cites the normal angle to be 136° (13:136). Gamble states that the normal parabolic angle of 142.5° in combination with the 2>1>3>4>5 metatarsal length pattern maintains a balanced weight transfer throughout the metatarsal-phalangeal joints, thus minimizing any pivotal action which would cause any one particular metatarsal head to bear excessive weight (6:126-127). Thus, a parabolic angle less than "normal", i.e. 136° or 142.5° creates less weight-bearing stability. It must be noted here that in the "normal" foot, as defined by Gamble, the lateral four metatarsals bear weight equally with the first metatarsal sustaining double that weight (6:123).

In the normal foot, equal weight distribution is achieved when the foot is stable. Stability is achieved when the subtalor joint is in a neutral position and the forefoot is perpendicular to the rearfoot. This allows the midtarsal joint to be fully pronated causing it to lock with the first ray. Such locking permits the first ray and hallux to become active as the prime propulsive