Master's Thesis

THE EFFECTS OF LOW DYE TAPING

ON

FOOT PRESSURE IN SUBJECTS WITH PLANTAR FASCIITIS

A thesis presented to the School of Kinesiology

Lakehead University

In fulfilment of the degree of MSc

Paolo Sanzo ©

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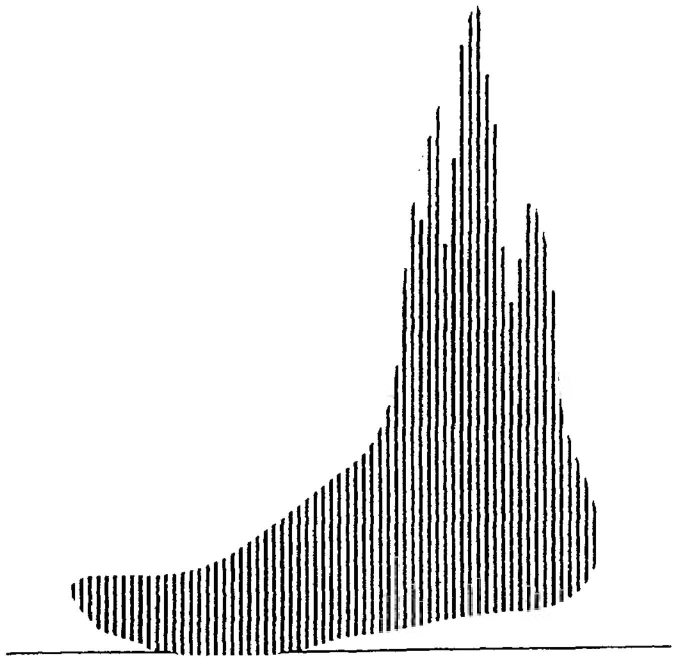

THE EFFECTS OF LOW DYE TAPING

ON

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ABSTRACT

The purpose of the investigation was to analyze the effect of low dye taping on the vertical foot pressure and the path of the centre of pressure (COP) in individuals with plantar fasciitis. Ten subjects (8 females and 2 males) meeting the specified diagnostic criteria were included in the study. The mean age of the subjects was 28.4 years. Each subject was tested under two conditions, walking with low dye taping and walking without. Vertical foot pressure and COP was measured using the F-Scan Gait Analysis System. Vertical foot pressure was significantly decreased in the rearfoot with the application of low dye taping during contact ($M = 0.29$, $SD = 0.37$, $t(9) = 2.46$, $p < 0.05$). Subjects did not demonstrate a significant change in pressure in the midfoot during midstance ($M = 0.18$, $SD = 0.51$, $t(9) = 1.12$, $p > 0.05$). Subjects also did not demonstrate a significant change in pressure in the forefoot during propulsion ($M = 0.08$, $SD = 0.59$, $t(9) = 0.46$, $p > 0.05$). Analysis of the COP curves revealed no consistent change. Throughout contact, midstance and propulsion there was no tendency towards medialization in the COP. The results of this study supports the research in that low dye taping decreases the amount of pressure transmitted through the foot during contact. However, there was no consistent change in the COP curves with the application of low dye taping failing to support the inferences reported by some researchers. Based upon the results of this investigation low dye taping decreases the foot pressure under the rearfoot during contact. Low dye taping has no consistent effect on the COP, and does not produce any medialization of the COP thereby increasing tension on the plantar fascia. Further study should be pursued analyzing the effects of low dye taping.

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CHAPTER 1:

Introduction:

The rising interest in physical activity has led to the development of a wide array of overuse injuries. With the increased number of individuals participating in physical activity, healthcare professionals are faced with the challenge of treating many overuse injuries. Plantar fasciitis, inflammation of the plantar fascia, is an example of this type of injury (McKenzie, Clement & Taunton, 1985; Neale & Adams, 1989). It is the most common cause of heel pain today (Gould, 1988; Goulet, 1984; Jahss, 1991; Klenerman, 1991; McBryde, 1984; Schepsis, Leach & Gorzyca, 1991; Taunton, Clement & McNicol, 1982).

Heel pain has often been a diagnostic and therapeutic challenge to practitioners. It can arise from several anatomical structures including soft tissues, bones, neurological tissues, or referred sources (Gould, 1988). Alleviation of such injuries depends upon making an accurate diagnosis and then providing the appropriate treatment (Gould, 1988). It is important to understand the anatomy and mechanics of the plantar fascia in order to correctly diagnose and treat the problem.

The plantar fascia is a thick band of longitudinally arranged collagen fibres (Appendix A). It extends from the tuberosity of the calcaneus to the flexor tendon sheaths of each digit (Hicks, 1954; Riegger, 1988). The plantar fascia is made up of three components. The central component originates from the posteromedial calcaneal tuberosity; the lateral component originates from the lateral margin of the medial calcaneal tubercle and is connected with the origin of the abductor digiti minimi muscle;

the medial component originates distally and medially and is continuous with the abductor hallucis muscle (Donatelli & Wolf, 1990). Because of its predominant medial attachment, the plantar fascia promotes inversion of the calcaneus and supination of the foot at the subtalar joint (Donatelli & Wolf, 1990).

The skin and subcutaneous tissue are thicker in the heel than anywhere else in the body (Riegger, 1988; Harbison, 1987). The subcutaneous tissue is divided into lobules by fibrous septa causing the tissue to resemble that of a sponge. Several bursae and capillary vessels are also present in this area (Riegger, 1988; Kwong, Kay, Voner & White, 1988).

The plantar fascia has several functions in the foot. It plays a role in maintaining the medial longitudinal arch and decreasing the force transmitted during weight bearing (Hicks, 1953; Hicks, 1954; Donatelli, 1985). It has been reported that in the static stance position the plantar fascia takes up as much as 60% of the stress of weight bearing (Brown & Yavorsky, 1987; Cailliet, 1983; Donatelli, Hurlbert, Conaway & St. Pierre, 1988; Donatelli, 1987). The plantar fascia also affects the movements that occur at the subtalar joint during gait (DeMaio, Paine, Mangine & Drez Jr., 1993; Urban, 1990; Kwong et al., 1988; Kosmahl & Kosmahl, 1987; Brown & Yavorsky, 1987; Cailliet, 1983; Donatelli, 1985; Donatelli, 1987; Donatelli et al., 1988).

Plantar fasciitis has often been used as a generic term for describing all types of heel pain. The overuse of this term has led to confusion regarding the understanding of this problem (Jahss, 1991). It should be clarified that plantar fasciitis denotes a clinical condition in which the main feature is pain on the plantar aspect of the heel.

Pain is often localized anteromedial to the tubercle of the calcaneus (Cailliet, 1983; DeMaio et al., 1993; Gould, 1988; Kosmahl & Kosmahl, 1987; Lemelle, Kisilewicz & Janis, 1990; Tanner & Harvey, 1988; Urban, 1990).

Plantar fasciitis is usually characterized by a gradual, insidious onset of pain but may also be associated with a history of trauma or overuse (Chandler & Kibler, 1993; Harbison, 1987). Overuse results in microtears in the plantar fascia and resultant signs and symptoms (Chandler & Kibler, 1993). Tenderness is evident on palpation of the plantar fascia. The location of the point tenderness is dependant upon the temporal stage of the inflammation (Kwong et al., 1988). In the acute phase, pain is localized to the medial tuberosity of the calcaneus. In the chronic phase, pain may extend to the distal part of the fascia (Kwong et al., 1988). It is common to see calloused skin on the medial side of the heel pad in patients complaining of heel pain (Harbison, 1987). Calloused skin in this area suggests that altered biomechanics may be occurring during walking resulting in excessive pressure on the medial side of the foot. Passive dorsiflexion of the metatarsophalangeal joints of the foot causes an increase in the tension on the plantar fascia and may reproduce pain (Brown & Yavorsky, 1987; DeMaio et al., 1993; Giallonardo, 1988; Harbison, 1987; Klenerman, 1991).

Another symptom of plantar fasciitis is pain with the first few steps in the morning, and after prolonged sitting. The pain improves with walking but becomes worse by the end of the day (Cailliet, 1983; Chandler & Kibler, 1993; DeMaio et al., 1993; Harbison, 1987; Kosmahl & Kosmahl, 1987; Schepsis et al., 1991).

Plantar fasciitis is usually unilateral, but bilateral involvement may occur

(Harbison, 1987; Kosmahl & Kosmahl, 1987). Involvement bilaterally may be associated with a systemic inflammatory disease such as Rheumatoid Arthritis, Gout, Ankylosing Spondylitis or Reiter's Syndrome (Kosmahl & Kosmahl, 1987; Kwong et al., 1988). The clinician needs be aware of other painful joints or other signs and symptoms compatible with these systemic disorders.

Plantar fasciitis is most common in middle-aged adults with the incidence increasing steadily during the fifth and sixth decade of life (Neale & Adams, 1989). This problem is common in obese individuals and may be explained by the increased mechanical stress and direct microtrauma of the added weight. It may also be explained by an increase in the level of physical activity of the individual (Gould, 1988; Harbison, 1987; Kosmahl & Kosmahl, 1987).

In athletes, plantar fasciitis is more common in sports that involve running (Chandler & Kibler, 1993; DeMaio et al., 1993). It is also common in dancers, tennis players, and basketball players (DeMaio et al., 1993). Plantar fasciitis occurs in non-athletes in roughly the same percentage as athletes (DeMaio et al., 1993). Those working in occupations that require prolonged weight bearing, such as labourers or cooks, have also been associated with this condition (DeMaio et al., 1993).

Lateral x-rays of the calcaneus may or may not reveal the presence of a bone spur (DeMaio et al., 1993; Harbison, 1987; Klenerman, 1991; McBryde, 1984). Epidemiological studies have found that as much as 11% of the adult population in the United States has a calcaneal spur on x-ray without the presence of heel pain (Kosmahl & Kosmahl, 1987). Most studies have shown no consistent radiological changes with plantar fasciitis. Presently, abnormal biomechanics has wide support as the prime etiological factor for heel pain and not the calcaneal spur (Chandler & Kibler, 1993; Gould, 1988; Harbison, 1987; Kosmahl & Kosmahl, 1987; Klenerman, 1991; Kwong et al., 1988; McBryde, 1984).

There is no consistent pattern of leg, ankle and foot malalignment associated with plantar fasciitis (Chandler & Kibler, 1993; Brown & Yavorsky, 1987; Donatelli, 1985; Gould, 1988; Harbison, 1987; Kosmahl & Kosmahl, 1987; Klenerman, 1991; Kwong et al., 1988). Similarly, there is no consistent relationship between plantar fasciitis and footwear (McKenzie, 1985; Rodgers, 1988).

The signs and symptoms and clinical presentation of plantar fasciitis can be quite variable. There are no criteria for a definitive diagnosis; the diagnosis is based solely upon clinical findings (Giallonardo, 1988). The presence of the previously mentioned signs and symptoms is a good indication that the plantar fascia is the painful structure. A thorough subjective and objective assessment, is the only way to diagnose this problem (Giallonardo, 1988).

The treatment of plantar fasciitis ranges from the conservative use of ice and heat, to the more aggressive surgical intervention and resection of the plantar fascia or neural structures. Most patients with plantar fasciitis are managed conservatively and respond well to nonoperative management (DeMaio et al., 1993; Kosmahl & Kosmahl, 1987). Treatment is directed at both short and long term goals. It is designed to resolve the inflammation, decrease tension and pressure on the fascia and associated structures, and correct any biomechanical abnormalities such as calcaneal or forefoot valgus or varus deformities (DeMaio et al., 1993; Gould, 1988; Jahss, 1991; Klenerman, 1991).

Treatment involves the use of whirlpool baths, ultrasound, ice, deep friction massage, low dye taping, heel pads and cushions, or custom made orthoses. These modalities are used to decrease the inflammation in the area and relieve the pressure and force transmitted through the plantar fascia (Chandler & Kibler, 1993; DeMaio et al., 1993; Kosmahl & Kosmahl, 1987; Neale & Adams, 1989; Riddle & Freeman, 1988; Schepsis et al., 1991; Tanner & Harvey, 1988).

Anti-inflammatory medications, local cortisone injections, progressive stretching and strengthening programs, modification of training errors and surgical interventions are also methods of treatment (Chandler & Kibler, 1993; DeMaio et al., 1993; Gould, 1988; Jahss, 1991; Kosmahl & Kosmahl, 1987; Neale & Adams, 1989; Schepsis et al., 1991; Tanner & Harvey, 1988).

Plantar fasciitis is a common overuse injury today. Patients present with a variety of signs and symptoms often complaining of pain in the heel or throughout the plantar fascia. Treatment for this overuse injury ranges from conservative measures such as the use of heat and ice, to more aggressive treatments such as surgery or local cortisone injections. Low dye taping is one of the conservative methods of treating plantar fasciitis. Due to the lack of research assessing the effects of this technique, the present study attempts to evaluate the effects of low dye taping on foot pressure in subjects with plantar fasciitis.

Purpose:

The purpose of this investigation is to measure the effects of low dye taping on foot pressure in subjects experiencing plantar fasciitis.

Definitions:

Low Dye Taping: Low dye taping is defined as a technique using one inch adhesive tape in which circumferential and figure-8 straps are applied to the plantar aspect of the foot. This is done in a systematic order as illustrated in Appendix H and explained in the methodology.

Pressure: Pressure is defined as the force per unit area, where the force is acting perpendicular to the surface area of the foot ($P=F/A$, where P=pressure, F=force and A=area).

Centre of Pressure: Centre of pressure (COP) is defined as the geometric centroid of the applied force distribution. The path of the COP is recorded by plotting the instantaneous COP at regular intervals during the entire stance phase of gait.

Contact Phase: The contact phase of the stance phase of gait is the period of time from initial heel strike to the point to which the forefoot becomes fully weight borne with the entire foot flat on the ground. Contact accounts for 27% of the total stance phase.

Midstance Phase: Midstance follows contact and is characterized by single limb support. Midstance accounts for 40% of the total stance phase.

Propulsion Phase: The propulsion phase is the period during the stance phase which begins with heel lift and ends with toe off. Propulsion accounts for 33% of the total stance phase.

Pronation: Pronation is the combination of eversion, abduction and dorsiflexion at the talo-crural and subtalar joints resulting in lowering of the medial margin of the rearfoot and the medial longitudinal arch (Appendix B).

Supination: Supination is the combination of inversion, adduction and plantarflexion of the foot, resulting in raising of the medial margin of the foot and the medial longitudinal arch (Appendix B).

F-scan: The F-scan system is a computerized in-shoe sensor and gait analysis system detecting, displaying and recording vertical plantar forces and pressures during the gait cycle.

Limitations:

There are some limitations to consider when evaluating the inferences made from the findings of this study. This research will be conducted recognizing the following limitations:

1. The effectiveness of the tape was compromised over the period of application due to loosening of the tape caused by perspiration, weightbearing and movement.
2. Measurement error in test protocols or analyzing techniques employed:
    a. Possible effects of movement between the foot and the foot sensors used
    b. Subjects were limited to walking in an area covered by the length of the cable possibly altering their gait
    c. Possible alteration of normal gait pattern due to the application of measuring device onto the foot

CHAPTER 2:

Review of the Literature:

Existing literature dealing specifically with the gait pattern of individuals with plantar fasciitis and the effectiveness of low dye taping is limited. Therefore, a broader approach to reviewing the related literature was necessary. The following is a review of the literature highlighting the historical developments in gait analysis. The use of the F-scan system and associated research will be reviewed, as will normal and pathomechanics of gait.

History of Gait Analysis:

Scientists of the Victorian era were not the first to hypothesize about the study of gait and human movement. Credit must also be given to other distinguished names such as Aristotle, DaVinci and Borelli who had hypothesized about human movement and gait, years earlier (Cavanagh & Henley, 1993; Esquenazi & Keenan, 1993). Aristotle, who wrote several books on the study of gait, DaVinci, who believed that the human eye was inadequate to record motion, and Borelli, who was the first to apply Newtonian principles of mechanics to the movement of the human body, need to be recognized for their contribution to this field of study (Cavanagh & Henley, 1993; Esquenazi & Keenan, 1993).

The area of gait analysis as we know it today, started to expand in the early 19th century. The works of Marey in Paris, Muybridge in Stanford, and Braune and Fischer in Leipzig, aided in the modernization and advancement of gait analysis techniques

(Cavanagh & Henley, 1993; Esquenazi & Keenan, 1993). Together, they helped produce a variety of equipment for early day gait analysis. This equipment ranged from instrumented shoes fitted with mounted ink pens, to early day cine cameras and force platforms.

Scientists have been trying for over a century to perfect a way to measure joint motion, force and pressure in the foot (Frederick-Pell & Cardi, 1993). The molds, ink pads, lead plates, and rubber mats used in the early days, provided only qualitative force and pressure measures (Frederick-Pell & Cardi, 1993). The technical limitations of these measurement systems led to the development of improved measuring devices.

The methods of gait analysis can be placed into four categories: direct print techniques, direct visualization techniques, force plate and load cell systems, and insole pressure pad techniques (Frederick-Pell & Cardi, 1993; Podoloff & Benjamin, 1991).

Direct print techniques use a deformable mat with a flat upper surface and a raised lower surface to measure force and pressure (Frederick & Hartner, 1993). The rigid lower surface flattens in proportion to the pressure applied to the upper surface. An imprint is made as the subject's foot contacts the upper surface.

Direct print techniques register only the peak pressure applied during foot to ground contact and the results are only quantifiable with optical scanning. Because this technique allows only one sample per testing trial, dynamic gait analysis cannot be done. Morton, introduced the first device of this type in 1930 (Frederick & Hartner, 1993). Since then, others have used similar devices, but improved methods of gait analysis have made this an outdated mode of measurement.

Direct visualization techniques are another method of analyzing gait. Elftman's Barograph, and Rosemeyer's use of cinematography are examples of this technique (Frederick & Hartner, 1993). Direct visualiation can be used to measure pressure under the foot while standing, or during a single step in the gait cycle (Frederick & Hartner, 1993). Cinematography is not used as often in the analysis of gait due to the advancements in technology. High speed videography has now replaced cine in gait analysis laboratories. Video and film are unique in their capacity to record without the application of instrumentation to the subject (ie. passive systems) (Esquenazi & Keenan, 1993). Conversion into quantitative data often requires manual digitization of the data which can be prone to error and is time consuming. Marker identification also requires manual intervention and may also be prone to error. Other problems include the limited sampling rate with video and the need for enhanced lighting with cine and high-speed video cameras (Esquenazi & Keenan, 1993).

Force plate and load cell systems are commonly used today to measure force. These systems use strain gauges and piezoelectric crystals to measure force. The measurement of force is obtained through the deformation of a conducting material (Rodgers, 1988). As the material is deformed, the resistance of the system changes proportionally to the force applied (Frederick & Hartner, 1993). This type of system usually consists of a force plate and several pressure sensors (Frederick & Hartner, 1993; Rodgers, 1988). When a load is applied to the plate's surface, ground reaction forces are measured.

Ground reaction forces are one of the most commonly measured biomechanical variables (Rodgers, 1988). Ground reaction forces show the amount and direction of loading applied to the foot and ankle during locomotion (Rodgers, 1988). Studies have shown that the magnitude of this vertical force may range from 1.1 to 1.3 times the body weight (Rodgers, 1988) (Appendix C-Figure 1A). Force platforms provide one instantaneous measure of this ground reaction force. This measure is called the centre of pressure(COP) distribution.

The path of the COP is created by plotting the instantaneous COP at regular intervals during the entire stance phase of gait. It is the change in position of the center of mass in the X-Y plane within the base of support, in this case the base of support is the foot. A normal progression of the distribution is from just lateral to the midline at heel strike, to a more medial migration by toe off. By the time toe off occurs, the COP lies directly under the first or second toe (Rodgers, 1988) (Appendix C-Figure 1B). By examining the COP we can analyze the timing and location of pronation or supination during the gait cycle (Rodgers, 1988). COP measured by force platforms are limited because the measures may not be specific to the anatomical locations in which they are occurring (Rodgers, 1988). For example, if the forces recorded under the forefoot and rearfoot were equal and occurred simultaneously, the COP would be recorded as an intermediate point between these two. This COP may not be the correct point where the loading is occurring.

Force plate data collection has now improved to the stage that information can be quantified over a series of continuous steps (Rodgers, 1988). This is done by linking a group of force platforms in series. Improved methods using other gait analysis techniques, for example insole pressure pad techniques, have been developed (Ferguson-Pell & Cardi, 1993; Frederick & Hartner, 1993; Payne-Herbold, 1992; Podoloff & Benjamin, 1991; Young, 1993).

The fourth method of gait analysis can be placed into the category of insole pressure pad techniques. The F-Scan Gait Analysis System is one method of gait analysis that fits into this classification (Ferguson-Pell & Cardi, 1993; Frederick & Hartner, 1993; Payne-Herbold, 1992; Podoloff & Benjamin, 1991; Young, 1993).

The T-scan, the predecessor to the F-scan, was originally developed in 1989 for analyzing dental occlusion (Podoloff & Benjamin, 1991). Before the development of the T-scan, dentists used qualitative methods of assessing occlusion such as marking papers or impression materials, such as waxes and plaster models (Podoloff & Benjamin, 1991). The T-scan sensor allowed dentists to detect the location and relative amount of tooth contact. The success of this system led to the expansion into other medical and industrial areas.

With the advances in the area of orthopaedic medicine and the ability to replace degenerative joints, there developed a need to quantitatively measure the contact between the articulating surfaces. The development of the K-scan allowed orthopaedic surgeons to quantitatively measure the contact between the femoral and tibial condyles in artificial knee joint replacements (Podoloff & Benjamin, 1991).

The development of the F-scan sensor that followed, allowed improved quantitative analysis of gait. The F-scan system consists of flexible, paper thin insoles, each containing 960 sensors, 4 sensors per square centimetre (Appendix D-Figure 3). The pressure sensitive sensors are characterized by a gridwork of rows and columns (Podoloff & Benjamin, 1991). Each sensing trace is coated with a silver based pressure sensitive, resistive ink. As force is applied, the conductive particles are brought closer together and a proportional decrease in the electrical resistance takes place. By scanning the grid, and measuring the resistance at each point, the pressure distribution and force can be measured. The scanning rate across the grid is 100Hz. Schaff (1993) has noted that for dynamic gait analysis sampling rates of 50Hz or greater should be used. Because changes in pressure occur very rapidly, anything lower than 50Hz will result in a loss of information. Generally, the rule is that the best digital representation occurs when the sampling frequency is greater than twice the highest frequency of the event (Schaff, 1993). The faster the sampling frequency, the better the digital representation.

Each insole is flexible and can be easily trimmed to fit any foot size and shape. The system is capable of recording bipedal forces and pressures as they occur sequentially during the gait cycle (Ferguson-Pell & Cardi, 1993; Frederick & Hartner, 1993; Payne-Herbold, 1992; Podoloff & Benjamin, 1991; Young 1993). The ankle cuff of the system controls the sensor grid scanning, and the conversion of the measured resistance values (Podoloff & Benjamin, 1991). The receiver in the ankle cuff converts the data and arranges it into a serial stream of information. This information is transmitted over a light weight cable to the computer (Appendix D-Figures 1 and 2). The software in the system is designed to store, display, print and compare data from the sensors.

The F-scan system operates in real time mode or play back mode. In real time mode, information appears on the screen as the subject walks. In the play back mode, prerecorded information can be examined. The F-scan can display both 2-D and 3-D pictures of weight transfer throughout the gait cycle; allows one to view the peak pressure distribution with both qualitative and quantitative capabilities; provides graphic representation of the centre of force progression curve and total force versus time curve; and can display comparative feet on the same screen (Young, 1993). The F-scan, however, should be used in a supportive role to provide additional information and not necessarily as a sole indicator of abnormality (Young, 1993). To fully benefit from the information gained, the user requires a thorough understanding of the normal biomechanics of gait.

Clinically, the advancements in the biomechanical technology have enabled more quantitative and accurate documentation of human movement (Cavanaugh & Henley, 1993). The clinician may have different requirements in selecting a pressure measurement system than the researcher. Schaff (1993) suggested that the resolution (more than 1000 measuring points per mat), the flexibility and durability of the sensors, the reproducibility and accuracy, the price and availability of different sized insoles, all must be examined to determine which pressure measurement system is most suitable.

High resolution of the measuring system is an important requirement (Schaff, 1993). The higher the spatial resolution of the measuring sensor, the better the spatial recording of different pressure values (Schaff, 1993). If the resolution is higher, the pressure can be localized to a specific area. According to Schaff (1993), this is an important requirement for barefoot walking.

Another characteristic that must be assessed is the flexibility and durability of the sensors (Schaff, 1993). The F-scan system has the characteristics of being thin, flexible and durable thereby meeting these requirements. The reproducibility and accuracy of the measurement system are critical (Schaff, 1993). This is based upon the measurement principles used in measuring the pressure under the foot. Modern day pressure measurement systems are based on 5 different principles for pressure measurement. These principles include the resistive principle used by the F-scan system, the capacity principle and capacity principle with microchips used by the EMED and PAROTEC systems, the piezoresistive principle used by the ERNST system and the piezoceramic principle. Each measurement technique has several advantages and disadvantages.

The F-scan system uses material properties that change its resistance under pressure (Podoloff & Benjamin, 1991). One disadvantage is that after prolonged loading the sensor changes its properties. As a result, the insole may change behaviour so that one may get different pressure readings for the same patient (Schaff, 1993). Reproducibility of pressure measurements is not as high for resistive sensors as compared to other methods of pressure measurement such as force platform measures (Schaff, 1993). Improvement in the development of the sensor has been made and a number of researchers have performed reliability studies and found the F-scan to be reliable (Feiwell, Rose & Cracchiolo, 1991; Baumann, Krabbe & Farkas, 1992; Agins, Ghizzone & Kessler, 1992).

Although other measurement systems have many advantages, there are several disadvantages that may also be taken into consideration. For example, one disadvantage of the capacitance principle is that measuring frequency is limited to 200Hz (Schaff, 1993). The capacitance and piezoelectric chips are good at high frequency but are less durable. The piezoceramic sensor is only suitable for dynamic measurements and is fragile and temperature sensitive (Schaff, 1993).

There are many advantages and disadvantages with each system. The user must consider these in the clinical application and in the design of the research study.

Normal Biomechanics of Gait:

To assess the pathomechanics of an individual's gait, one must understand the mechanics of normal gait. The stance phase of gait comprises approximately 60% of the gait cycle, while the swing phase makes up the other 40% (Brown & Yavorsky, 1987). Since one gait cycle is approximately 1 second in length, the stance phase of gait lasts approximately 0.6 seconds (Brown & Yavorsky, 1987). Contact begins with heel strike and ends at propulsion when the great toe leaves contact with the ground (Brown & Yavorsky, 1987).

At heel strike, the femur, tibia and lower leg are in an externally rotated position with the subtalar joint and the forefoot supinated (Brown & Yavorsky, 1987). As the foot contacts the ground, the femur and tibia rotate internally, the talus plantarflexes and adducts, and the calcaneus simultaneously rolls into eversion. This movement of the talus and calcaneus is called **closed kinetic chain pronation** (Donatelli & Wolf, 1990).

This sequence of events is controlled eccentrically by tibialis anterior and extensor digitorum longus, and by the tensile strength of the ligaments of the lower extremity (Donatelli & Wolf, 1990).

Following heel contact on the lateral border of the supinated foot, controlled pronation occurs to aid with shock absorption of the force (Brown & Yavorsky, 1987). A normal foot does not pronate beyond the contact period, and reaches its maximally pronated position at the end of contact (Brown & Yavorsky, 1987).

In the normal foot, the calcaneus everts from the neutral position a total of 4-6 degrees (Brown & Yavorsky, 1987). Hyper or hypomobility in the subtalar joint reduces the ability of the foot to act as a shock absorber, and the ability to convert the torque of the lower extremity (Evans, 1990; Donatelli, 1987). Changes in subtalar joint mobility may result in pathological conditions such as plantar fasciitis (Evans, 1990; Donatelli, 1987).

Midstance follows the contact phase of gait. During this period the foot is converted from a mobile adaptor to a rigid lever for propulsion (Brown & Yavorsky, 1987; Donatelli & Wolf, 1990). During midstance the trunk and lower leg move forward, the femur and tibia externally rotate, the ankle dorsiflexes to approximately 10 degrees, and the talus abducts and dorsiflexes (Brown & Yavorsky, 1987; Donatelli & Wolf, 1990). The subtalar joint supinates moving the rearfoot from a maximally pronated position back towards neutral.

When the neutral subtalar joint position is reached, the cuboid and the navicular are perpendicular to one another causing the midtarsal joint to lock against the rearfoot (Donatelli, 1987). A fixed cuboid now acts as a rigid lever for a more efficient pull of the peroneus longus and tibialis posterior muscles producing flexion of the first ray. A rigid forefoot is produced in preparation for propulsion (Donatelli, 1987). Abnormal pronation at this stage of the gait cycle decreases the stability of the foot affecting propulsion (Donatelli, 1987).

Propulsion also requires stabilization of the first metatarsophalangeal joint (Donatelli, 1987; Donatelli & Wolf, 1990). Stabilization of this joint is achieved by contraction of the peroneus longus muscle, the locking mechanism of the navicular and cuboid, and the **windlass effect** of the plantar fascia (Sarrafian, 1987; Donatelli & Wolf, 1990; Donatelli, 1985). The windlass effect is illustrated in Figure 1.

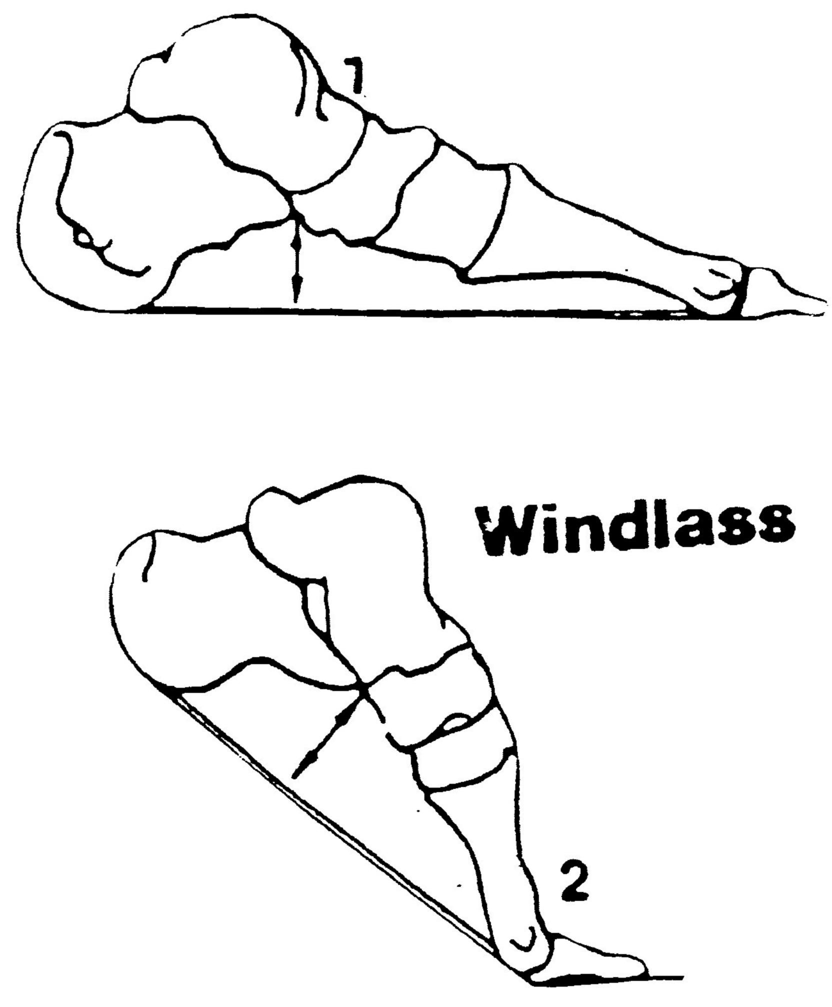

Figure 1. 1 Plantar fascia in a lax position with the foot in neutral.
2. Increased tension in the plantar fascia as the toes extend raising the medial longitudinal arch and facilitating supination of the foot.

NOTE: Adapted from "Normal Biomechanics of the Foot and Ankle" by R. Donatelli, 1985, Journal of Orthopaedic and Sports Physical Therapy, 1, p. 92.

As the weight is transferred from the first metatarsal to the phalanges, extension of the first metatarsophalangeal joint occurs. As the toes extend, tension in the plantar fascia increases and the medial longitudinal arch is raised (Donatelli, 1985). Because the plantar fascia is made up of inelastic, collagen fibres, and has a fixed length, it is often associated with a hinged truss (Urban, 1990; Sarrafian, 1987; Riegger, 1988). This truss is made up of an inelastic cable attached between two struts. The plantar fascia parallels this cable. The cable is attached to a fixed point on one end and to a rotating drum on the other. For the plantar fascia, these two points are equivalent to the origin of the aponeurosis on the medial tubercle of the calcaneus, and the distal attachment onto the first metatarsophalangeal joint. As the drum of the hinged truss is rotated, the length of the cable is shortened, drawing the two struts together and raising the height of the truss (Hicks, 1953; Hicks, 1954; Sarrafian, 1987; Urban, 1990; Kwong et al., 1988; Reigger, 1988). Similarly, the plantar fascia draws the calcaneus towards the digits during gait. Due to the medial attachment of the plantar fascia onto the calcaneus, the medial longitudinal arch is raised, the calcaneus inverted and the foot supinated (Urban, 1990; Kwong et al., 1988; Reigger, 1988).

Hicks (1954) demonstrated that when the plantar fascia's attachments were cut and the toes were extended in cadavers, the arch raising action almost disappeared. The toes become extended while walking by the action of the body weight, and the arch is raised by this ligamentous mechanism without the direct action of any muscles. No muscle is directly concerned with the elevation of the arch. This action is entirely boney and ligamentous, however, this must not be taken to imply that muscles never have an effect upon the arch (Hicks, 1954). The plantar fascia becomes taut when the metatarsophalangeal joints dorsiflex during push off. Abnormal pronation at this stage would decrease the stability of the first ray and increase the stress on the plantar fascia.

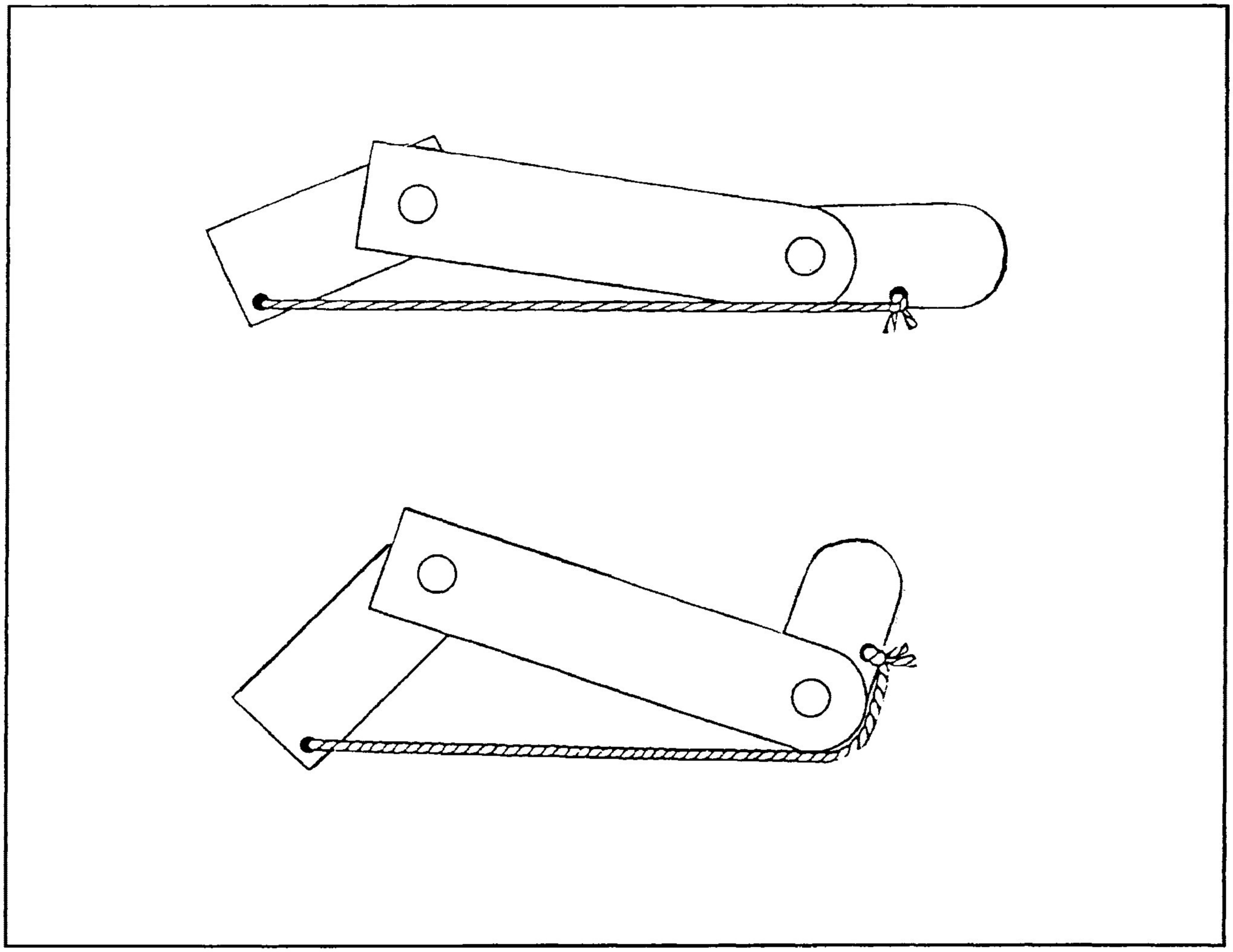

Figure 2. The illustration presents a hinged truss with an inelastic cable attached to one strut on one end and to a fixed point on a drum attached to the other end. As the drum is rotated, the length of the cable is shortened, drawing the two struts closer together and raising the height of the truss. This parallels the function of the plantar fascia during gait.

NOTE: Adapted from "Anatomy of the Ankle and Foot" by C. L. Reigger, 1988, Physical Therapy, 68, p. 1803.

A thorough understanding of normal gait is required to comprehend the pathomechanics of gait that alter the length tension relationship of the plantar fascia, resulting in the development of this common overuse injury.

Pathomechanics of Gait:

Pathomechanics has been defined by Brown and Yavorsky (p.34, 1987) as the mechanics of motion resulting in, or leading to, dysfunction or injury. Compensation occurs to counterbalance abnormal mechanics, or pathomechanics, during motion (Brown & Yavorsky, 1987). Compensation is the change in a structure, position, or function of one part of the body in an attempt to adjust to a deviation of structure, position, or function of another body part (Root, Orien & Weed, 1971).

There may be both normal and abnormal compensations. In the foot, compensation occurs due to pronation and supination of the subtalar and midtarsal joints (Brown & Yavorsky, 1987). An example of normal compensation is the adjustment made by the foot to variations in the surface or terrain. Normal compensation maintains balance and produces no abnormality or pathology (Brown & Yavorsky, 1987).

Abnormal compensations, on the other hand, are adjustments that lead to pathology and injury (Brown & Yavorsky, 1987). Pronation is considered abnormal when it exceeds the amount required, or when it occurs when supination should be occurring (Brown & Yavorsky, 1987). During normal gait, maximum pronation is achieved by footflat (Donatelli, 1987). Abnormal pronation can then be defined as pronation that occurs beyond 25% of the stance phase (Donatelli, 1987). Since the stance phase of gait is approximately 60% of the gait cycle and one gait cycle takes approximately one second to complete, it can be assumed that normal pronation should be completed by approximately 0.15 seconds into the stance phase (Brown &

Yavorsky, 1987). Supination is considered abnormal when it exceeds the amount that is required or when it occurs when pronation should be occurring during the gait cycle (Brown & Yavorsky, 1987).

Excessive pronation has been implicated as a prime etiology for the development of plantar fasciitis (DeMaio et al., 1993; Kwong et al., 1988; Kosmahl & Kosmahl, 1987). It is the most commonly reported factor leading to plantar fasciitis. Excessive pronation of the subtalar joint during the stance phase everts the calcaneus and pulls the tuberosity away from the distal attachment of the plantar fascia (Kosmahl & Kosmahl, 1987). The net effect is an increase in the tension on the plantar fascia and its attachment on the calcaneal tuberosity (Kosmahl & Kosmahl, 1987). As a result of the implications of being an overpronator, the subject sample will consist of subjects that overpronate during walking.

Pronation and supination are integral components of normal foot function because loading forces are adapted to by specific anatomical structures sequentially (Urban, 1990; Kwong et al., 1988). However, if either component is prolonged or occurs out of sequence, it then becomes abnormal and may produce pathology. Consequently, excessive or restrictive motion decreases the ability of the foot to act as a shock absorber, torque convertor, mobile adaptor to the terrain, and a rigid lever for push off (Donatelli, 1987). Normal loading forces during gait are, therefore, not supported by the primary structures, muscles and bones; instead, they are imposed on the secondary structures, the joint capsule and ligaments. Any situation that increases the tension within these secondary structures beyond the point they can physiologically withstand may hasten the onset of overuse injuries (Urban, 1990). One such injury is plantar fasciitis.

A review of the literature has shown that particular anatomic foot configurations can sometimes be associated with plantar fasciitis. The pronated foot has already been discussed. The cavus foot, the planus foot, or the internally or externally rotated lower extremity may also be associated with the onset of plantar fasciitis (DeMaio et al., 1993; Evans, 1990; Urban, 1990; Kwong et al., 1988; Sarrafian, 1987; Brown & Yavorsky, 1987).

The cavus foot may result in the onset of plantar fasciitis because the hindfoot is placed in an inverted and supinated position while the forefoot is pronated (Kwong et al., 1988; Franco, 1987). Because of this position, the foot is unable to absorb shock from heel strike to midstance. It is during this period of the gait cycle that pronation is necessary to aid in shock attenuation. If the foot remains in this supinated position, then the ability of the foot to absorb shock is compromised because the navicular and cuboid remain in a parallel orientation. The result is an increased load on the plantar fascia (DeMaio et al., 1993; Franco, 1987; Kwong et al., 1988).

The pes planus foot may also be associated with the onset of plantar fasciitis. Another name for pes planus is "flat feet" (Franco, 1987; Evans, 1990). Flattened feet result in lowering of the medial longitudinal arch, pronation of the subtalar joint, and forefoot valgus (Franco, 1987; Evans, 1990). Because of this, the medial portion of the plantar fascia is put on a stretch at its insertion on the medial calcaneal tubercle. Hence, the plantar fascia becomes overstretched and inflamed resulting in plantar fasciitis (Franco, 1987; Evans, 1990).

An internally or externally rotated lower leg may be due to excessive tibial or femoral torsion. If the lower leg were to remain internally rotated, the subtalar and midtarsal joints would remain pronated and the forefoot would remain supinated (Sarrafian, 1987). Internal rotation and vertical loading of the tibiotalar column would result in lowering of the medial longitudinal arch and increased tension in the plantar fascia (Sarrafian, 1987). The ability of the stance foot to supinate and the timing of this motion at heelstrike and propulsion would also be compromised. Conversely, if the lower leg were to remain externally rotated, the subtalar and midtarsal joints would remain supinated and the forefoot pronated (Sarrafian, 1987). This would create a rigid foot at heel strike as the navicular and cuboid would assume a perpendicular orientation. At heelstrike, where controlled pronation is required, the externally rotated lower leg and supinated position of the foot would create a foot that was not able to adjust to the changes in the terrain. As a result, an increased strain on the plantar fascia would develop (Donatelli, 1987).

Another biomechanical factor that must be considered when examining the pathomechanics associated with plantar fasciitis is the amount of tightness in the gastrocnemius and soleus muscle (Chandler & Kibler, 1993; DeMaio et al., 1993). During heel strike, foot flat and toe off, the plantar flexors normally play a role in absorbing and dissipating the applied forces. Tight posterior structures decrease the ability of the gastrocnemius and soleus muscle to adequately fulfil their roles. Also, because of the anatomical attachment of the Achilles tendon onto the calcaneus, a tight tendon pulls the foot into excessive valgus, increasing pronation. Tightness of the gastrocnemius and soleus muscles decreases the ability of the calcaneus to invert. The decreased ability of the calcaneus to invert suggests that the foot remains pronated and the cuboid and navicular parallel. This position adds to the excessive pressure transmitted through the plantar fascia (Chandler & Kibler, 1993; DeMaio, 1993).

Weakness of the plantar flexors has also been identified as another possible mechanism contributing to the development of plantar fasciitis (Chandler & Kibler, 1993). Weak plantar flexors fail to provide enough force during the push off phase of gait. As a result, there is an increased tensile load placed on the plantar fascia (Chandler & Kibler, 1993).

Decreased strength and range of motion of the gastrocnemius and soleus muscle complex creates an alteration in the normal biomechanics of the foot and decreases the ability of the foot to both absorb forces and generate forces to propel the body forward (Chandler & Kibler, 1993).

As can be seen it is important that pronation and supination occur during gait but that they also occur at the appropriate time and for the correct length of time. The inability of the foot to correct for such abnormalities predisposes an individual to develop problems such as plantar fasciitis. Gait analysis can be used to objectively evaluate the effects of various interventions in correcting the above mentioned pathological patterns.

Research Using the F-Scan Gait Analysis System:

According to Young (1993), recognizable patterns are displayed in the output generated by the F-scan for various abnormalities such as excessive pronation or supination, heel pain such as plantar fasciitis, or hallux rigidus deformities.
Young (1993) concluded that the F-scan allowed practitioners to quantify the pressure exerted in specific areas. This allowed the clinician a parameter on which to measure his or her therapeutic success. Young (1993) suggested the benefits in evaluating excessive plantar pressure in the diabetic or neuropathic foot. He also suggested uses for the orthopaedic surgeon in assessing foot function before and after surgery.

Feiwell, Rose, & Cracchiolo (1991), used the F-scan to measure the effects of heel wedges on the plantar foot pressures. They first attempted to determine the reproducibility, durability and variability of the system. They found that the F-scan provided accurate and reproducible plantar pressure measurements, consistent pressure recordings between subsequent steps, and accurate maximum plantar pressure recordings. It was noted, however, that each subject required their own individual sensors, and that the recordings were influenced by the type of shoe worn and the floor surface. Overall, Feiwell et al. (1991) concluded that the F-scan system was useful in accurately and reliably measuring static and dynamic plantar foot pressures.

One advantage in using the F-Scan Gait Analysis System noted by Baumann, Krabbe and Farkas (1992) is that the sensors were thin enough to provide little interference with movement and with the mechanical properties of the shoe's insole.

Several studies have been conducted using the F-scan to examine ulcerations in the diabetic foot. Baumann et al. (1992), attempted to measure the pathological mechanical stresses under the feet of diabetic patients using the F-Scan Gait Analysis System. They first assessed the reliability and accuracy of the F-Scan Gait Analysis System using normal subjects during level walking. The total sum of the forces transmitted through the foot during a gait cycle was calculated by summing the force readings of all single sensors. This was then compared to the vertical ground reaction forces measured with a stationary Kistler force platform. The resultant difference between the two measures was less than +/-10% as illustrated in Figure 3. Baumann et al. (1992), concluded from their findings that the critical pressure areas under the patient's foot could be identified exactly. Despite not knowing the absolute pressure values, any reduction in pressure in an endangered area of the foot was considered positive. They concluded that the F-Scan Gait Analysis System was a useful tool in monitoring foot pressure in the diabetic patient.

Agins, Ghizzone, and Kessler (1992) examined the pressure pattern of 22 subjects walking with and without shoes. Twenty of the subjects had diabetes, one had spina bifida and one had a previous stroke. The F-scan was used to assess the subjects' walking pattern to make modifications to existing orthotics in hope of decreasing plantar pressures. For five of the subjects who did not have orthotics, recommendations were made based on the plantar pressures recorded with the F-scan. Agins et al. (1992), found the F-scan to be reliable and beneficial in the treatment and prevention of these ulcerations.

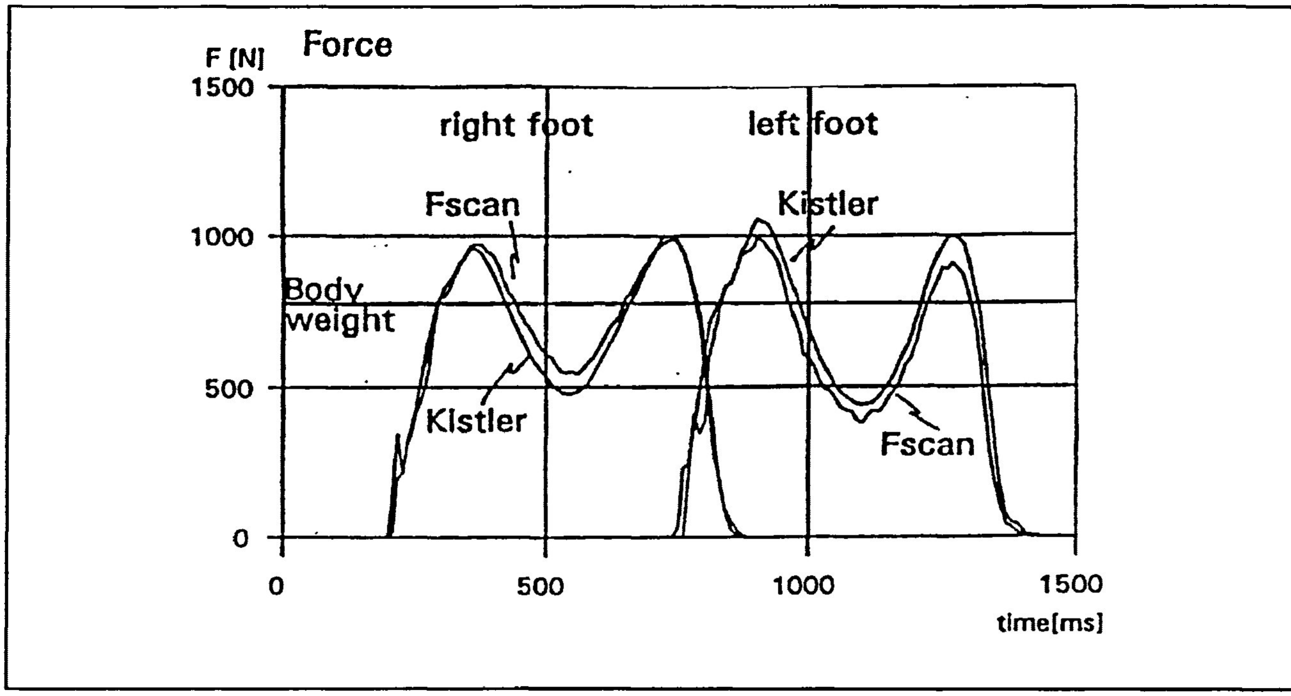

Figure 3. Total reaction force recorded during the gait cycle using the Kistler force platform and the F-scan sensor.

NOTE: Adapted from "The Application of In-shoe Pressure Distribution Measurements in the Controlled Therapy of Diabetes Patients" by W. Baumann et al., 1992, VDI Berichte, p. 1825.

Veves, Lyons, and Habershaw (1994) measured the effect of a combination of specially designed Thorlo socks and extra depth shoes on the peak force and pressure in 21 diabetic subjects at risk of foot ulceration. Foot pressure measurements showed that the specially designed footwear provided satisfactory foot pressure relief in at risk diabetic patients who were using the recommended footwear.

Stewart and Berezowski (1994) also used the F-scan on a single diabetic subject with a foot ulceration. The F-scan was used to determine the degree to which the orthotics and shoes decreased the plantar pressures. This is another example that shows the increasing use of the F-scan in determining the effectiveness of various treatments.

Mueller (1992) reviewed the literature on the evaluation and treatment of the neuropathic foot. He stressed the importance of the advances made in the technology and the benefits of these advancements. Mueller discussed the ability of various systems to measure the pressure and impulse at various anatomical locations highlighting the use and benefit of the F-scan in this area (Mueller, 1992).

Sarnow, Veves, Giurini, Rosenblum, Chrzan and Habershaw (1994ab) measured plantar pressures in 109 subjects (65 control subjects, 44 diabetic patients) under three conditions. Plantar pressure was measured using the F-Scan Gait Analysis System. Pressure was measured between the shoes and socks, between the sock and the foot inside the shoes, and between the sock and the foot without shoes.

Sarnow et al. (1994ab), concluded that the in-shoe pressure measurements were significantly lower than when walking without shoes in both the control group and in the diabetic patients. This finding suggested that shoes were able to redistribute the pressures experienced and had a cushioning effect in both groups. There was a higher reduction in plantar pressure measurements for in-shoe measurements for the diabetic group of patients as well.

The F-scan was also used by Lord and Hosein (1992) to demonstrate the effectiveness of moulded inserts in pressure redistribution for diabetic patients at risk of plantar ulceration. The F-scan was used to obtain the pressure distribution during gait for the subject walking with moulded inserts and with flat PPT inserts. Analysis of the peak pressures obtained by the F-scan helped to assess the effectiveness of the alternative flat PPT inserts.

Albert and Christensen (1994) used the F-scan to compare in-shoe plantar pressures in patient-selected shoe wear versus clinician-selected shoe wear. 24 diabetic patients were tested. Each subject first walked in their own shoe wear and then with the clinician-selected shoe wear. Plantar pressure was measured under the metatarsal heads using a box 10 by 5 centimetres. Rearfoot pressure was measured using a box 7.5 by 7.5 centimetres. The area in the boxes under the metatarsal heads and in the rearfoot was specified by the researcher in the recording parameters of the F-scan software. Analysis of the plantar pressures revealed an increase in pressure with the clinician-selected shoe wear as compared to the patient-selected shoe wear. A's a result of their findings, Albert and Christensen recommended that extra depth shoes be prescribed for diabetic patients but pressure dispersing insoles should also be added. The use of the F-scan measurements aided in modifying recommendations to better control plantar pressures.

Foti, Derrick and Hamill (1992), attempted to evaluate plantar pressures during the initial portion of the stance phase of walking using the F-Scan Gait Analysis System. The sensor was attached to the bottom of the athletic shoe insole and forces were sampled at 100Hz. Subjects were asked to ambulate with just the insole attached to their feet and then with specially constructed hard and soft polyurethane midsoles. They reported that pressures were greater near the COP and decreased away from the COP during walking on just the insole. While walking in shoes, pressures were lower and more evenly distributed over the plantar surface of the foot. Slightly greater pressures were observed for the hard shoes as compared to the soft shoes.

Majid and Bader (1993) investigated the biomechanical characteristics and the pressure distribution at the interface between the soccer shoe and the playing surface in a variety of shoes. They examined the pressure distribution within several soccer shoes using the F-Scan Gait Analysis System for a subject walking across a grass surface.

The results obtained showed a significant difference between the in-shoe pressure distribution over the first metatarsal area of the foot in the selected shoe designs (Majid & Bader, 1993). Majid and Bader (1993) reported that the F-scan could be an invaluable tool for measuring the distribution of pressure at the plantar surface of the foot during gait. The constraints that they encountered were due to the short length and weight of the transmission cable as this limited the assessment to walking (Majid & Bader, 1993).

Wilson (1992) used the F-Scan Gait Analysis System to generate baseline reference data for static barefoot pressure patterns in 120 women. Subjects ranged in age and weight, with no subjects having any significant foot problems. Barefoot standing plantar pressures were recorded bilaterally. Through visual analysis of the pressure distributions, it was possible to classify them into six different groups as illustrated in Figure 4. These groups correspond to those defined by Hughes, Jagoe, Clark and Klenerman (1989) in their study of pressure patterns in barefoot walking using the pedobarograph.

Hughes et al. (1989), assessed the mean peak pressures under the metatarsal heads of 160 asymptomatic subjects. Each subject was required to walk over the pedobarograph. Three trials were recorded in total for each subject. The resulting pressure patterns were recorded. Subjective assessment, objective rule based method and cluster analysis of the pressure patterns resulted in the formulation of the above mentioned classifications. Hughes et al. (1989), stressed that further research into this area was required to refine and clarify the classifications.

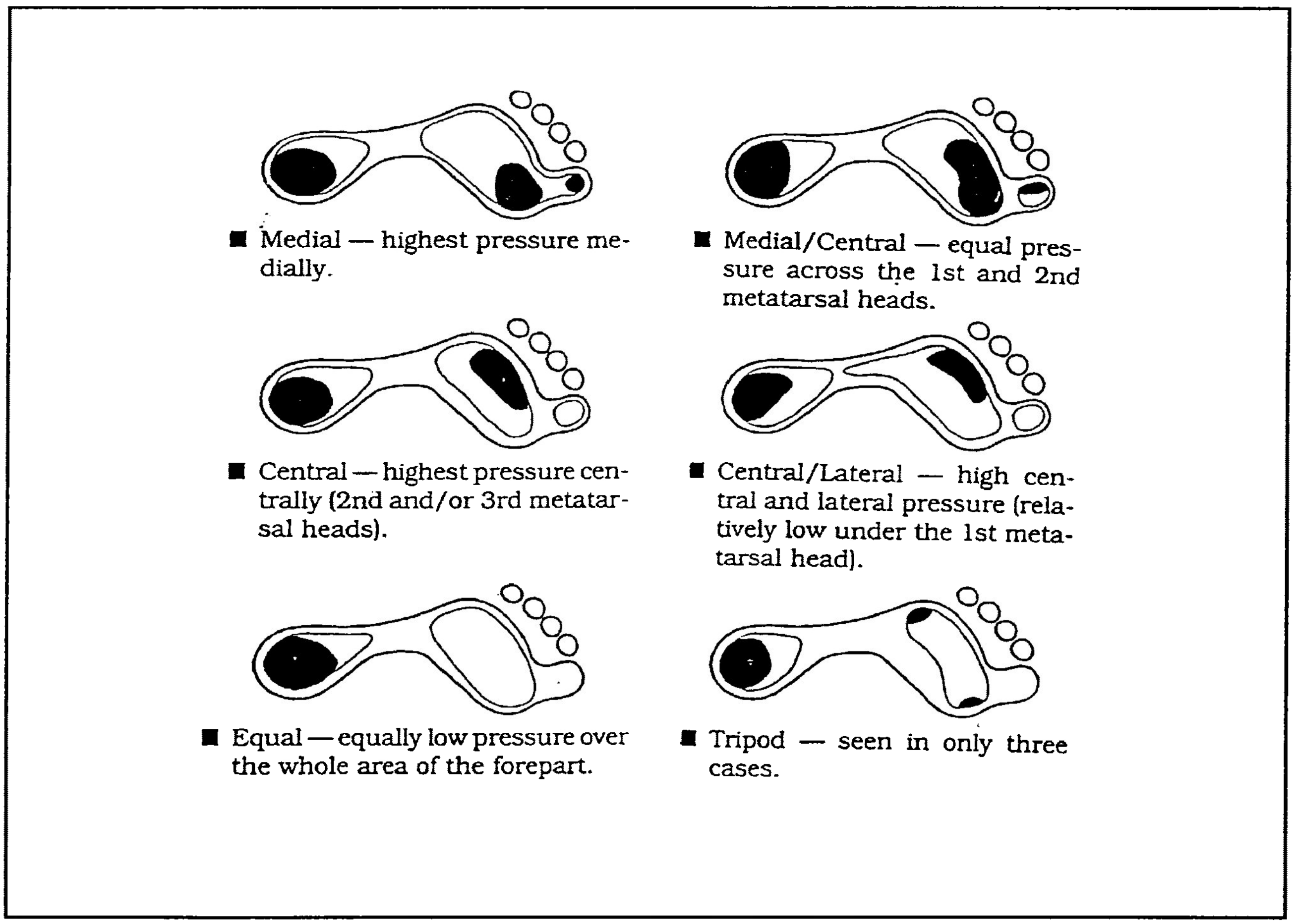

Figure 4. Plantar pressure distribution classifications.

NOTE: Adapted from "Measuring In-shoe Pressures to Help Predict Underfoot Comfort" by M. Wilson, 1992, SATRA Bulletin, p. 8.

Novick, Stone, Birke, Brasseaux, Broussard, Hoard and Hawkins (1993) used the F-scan and the Hercules pressure transducer systems to measure pressure at the first metatarsal head, third metatarsal head, midfoot and heel in three orthotics. Both measurement systems recorded significant reductions in pressure at the first metatarsal head with the rigid relief orthosis (Novick et al., 1993). A difference was observed in the data as the pressure values for the Hercules device were often greater than the F-scan values recorded at the same anatomical sites (Novick et al., 1993). This discrepancy can be explained by several factors. First, because the Hercules transducer was thicker it may have resulted in a greater concentration of forces over its surface area producing higher pressure readings (Novick et al., 1993). Second, the graphics box used by the F-scan software to identify the desired anatomical site on the plantar aspect of the foot, may have corresponded to a larger area onto which the force was dissipated. This resulted in a lower pressure reading (Novick et al., 1993). These discrepancies illustrate some difficulties in comparing data generated from two different systems. It must be reiterated, though, that both systems generally produced the same findings.

The F-Scan Gait Analysis System has also been used in several single subject designs to examine various overuse injuries. Cibulka, Sinacore, and Mueller (1994) used the system to analyze the running style of a subject who complained of unilateral posteromedial shin pain. In-shoe pressure analysis of the patient's running style showed that he habitually ran on his toes with an absence of heelstrike (forefoot contact running). Because of this observation during the assessment, the subject's running style was modified. Treatment focused on retraining the subject's running style to insure he ran with a heel to toe pattern. The subject's running style was reevaluated using the F-scan. Significant changes were noted in the subject's running style. After approximately three weeks of treatment focusing on modifying the running style, the subject had no shin pain (Cibulka et al., 1994). This is one example of how the F-scan can be used to assess the effectiveness of treatment. In this example, effectiveness was based on pain relief and upon changes in a patient's gait or running pattern.

Sutherland (1992), used the F-scan system to assess the gait pattern of an eight year old boy diagnosed with left mild hemiparesis secondary to a porencephalic cyst. Dynamic pressure distribution was recorded for both feet. This information was combined with EMG data to decide the most effective treatment for the child.

Tremaine, Banco, Hayda, Rayman, Teed and Tremaine (1993), quantitatively measured the effects of metatarsal pads under the metatarsal heads and on the clinical efficacy of using the F-scan system. Plantar pressure measurements were recorded for 10 asymptomatic subjects. Tremaine et al. (1993), concluded that metatarsal pads did in fact decrease plantar pressure. Pressure changes were dependant on the size of the pad used, the type of material and the placement of the pad. Tremaine et al. (1993), also supported the use of in-shoe pressure measurement systems to assess the clinical efficacy of metatarsal pad placement.

Barefoot walking and the vertical force under specific anatomical sites was assessed in a study by Saltzman, Johnson, Goldstein and Donnelly (1992). Saltzman et al. (1992), used the F-scan to assess the effects of shoe wear, custom made inserts, patellar tendon bearing braces and extra padded patellar tendon braces on load transmission to neuroarthropathic feet of 6 diabetic patients. Four distinct anatomical sites were marked. Vertical force was measured under the first distal phalanx, the first metatarsal head, the third metatarsal head, the fifth metatarsal head, the medial midfoot, the lateral midfoot, the medial hindfoot and the lateral hindfoot. Three complete gait cycles were assessed under five different circumstances including barefoot walking. The F-scan sensor was attached to the dorsum of the feet using a surgical shoe cover.

Corbett, Abramowitz, Coleman, Fowble, Rask and Whitelaw (1993) measured in-shoe plantar pressure under the first metatarsophalangeal joint in 20 asymptomatic patients using the F-Scan Gait Analysis System. Corbett et al. (1993) measured in-shoe plantar pressure under the first metatarsophalangeal joint in subjects while they were wearing their normal footwear, a wooden postoperative shoe, a fibreglass short leg walking cast and a postoperative shoe with a first metatarsophalangeal joint cutout orthotic device. From the data collected from the F-scan, Corbett et al. (1993) concluded that the most effective method in reducing first metatarsophalangeal pressure was with the use of either a postoperative shoe with a cutout orthotic device, or a short leg walking cast. Because certain foot surgeries benefit from a reduction in the loading forces, it was concluded from this study that this method of reducing first metatarsophalangeal pressure can also be applied in the postoperative patient. This is another example where data collected by the F-scan can be used to determine the most beneficial treatment.

The F-scan has also been used in other areas of research. Johnson and Schiffman (1992) used the F-scan to analyze plantar pressure during the golf swing of professional golfer Tom Purtzer. The analysis of plantar pressure under the feet with the F-Scan Gait Analysis System was used as an educational tool in improving the golf swings of other professional and amateur golfers as well. Lange, Derrick and Hamill, also used the F-scan to analyze in-shoe pressure for mediolateral stability during the golf swing in a variety of shoes.

Research Analyzing The Effectiveness of Low Dye Taping:

A review of the literature has shown that there is very little research examining the effectiveness of low dye taping. Scranton et al. (1982) compared plantar forces in a single subject walking barefoot, with heel cups, medial arch supports and low dye taping. Cholesterol crystal force plate analysis and a computerized Kistler force platform were used in the study. Scranton et al. (1982) found that the low dye taping and heel cups significantly diminished the duration of forces under the midfoot and medialized the instant centre of forces. The authors also found that the medial arch supports shifted the instantaneous centre of forces laterally but did not alter the duration of the forces under the arch. On the basis of these findings, Scranton et al. (1982) concluded that low dye taping, heel cups and arch supports altered the force under the foot and could be used as effective treatments in preventing common overuse injuries such as plantar fasciitis, shin splints and metatarsalgia. A number of limitations were presented by Chapman in a letter to the authors following the published article (Scranton et al., 1982). The small sample size, the lack of a control group, the use of only patients with "flexible flat feet" and the fact that only one trial was performed was highlighted. Chapman also questioned whether the medialization of the forces were desired, and the methods taken in collecting and analyzing the force measures were reliable. Based on these limitations the strength of the conclusions that were drawn by the authors were questioned.

CHAPTER 3:

Methods & Procedures:

The purpose of this investigation was to measure the effects of low dye taping on foot pressure in the feet of subjects experiencing plantar fasciitis. All of the testing procedures took place at Thunder Bay Orthopaedics Incorporated, Thunder Bay, Ontario. All testing was conducted during the same time frame to control for diurnal effects. Prior to testing, all subjects were well informed of testing methods and procedures. An informed written consent (Appendix E) was obtained as required by the Ethics Advisory Committee of Lakehead University. Upon completion of the experiment, the subjects were debriefed and given a copy of the F-scan printout.

A pilot study was conducted to standardize the technique of taping, collection of data, and data analyses by the tester. The F-Scan Gait Analysis System was used to compare the pressure and COP distribution in one subject. The subject had no history of foot problems and nc other medical conditions that may have contraindicated involvement into the study. The protocol explained in the Testing Procedures was followed. The plantar pressure recordings were analyzed as described in the Pressure Time Graphical Analysis section (see Appendix H for raw data).

Subjects:

The clinical signs and symptoms of plantar fasciitis are numerous. Patients diagnosed with this problem may present with one or all of the signs presented in the Introduction. There is no definitive test that can be done to specifically diagnose this condition. A thorough history and careful objective clinical assessment to rule out other pathologies are the only methods of diagnosing plantar fasciitis. Another difficulty in defining the patient population is that there is currently no objective grading system for the varying degrees of plantar fasciitis and heel pain. Specific criteria were developed by the researcher to formulate a homogeneous population representative of patients presenting with plantar fasciitis. These criteria were based upon common signs and symptoms found in a review of the literature.

Subjects met the following criteria for inclusion into the study:

1. Heel pain in the morning with the first few steps.
2. Heel pain with the first few steps after prolonged sitting.
3. Pain localized to the anteromedial tubercle of the calcaneus and/or throughout the plantar fascia.
4. Not currently being treated for plantar fasciitis.
5. No previous cortisone injections into the plantar fascia.
6. Heel pain has been present for less than 1 year.
7. Patient has greater than 5 degrees of forefoot varus.
8. No other medical conditions or problems.

Ten subjects who met the inclusion criteria were included in the study. Subjects were referred into the study from the Northwestern Ontario Sports and Orthopaedic Clinic and the Thunder Bay Physiotherapy Centre Foot Clinic. Screening of the patients was done at both facilities to insure all criteria were met. Forefoot varus was measured as described by Donatelli (1990). Patients who did not meet all of the inclusion criteria listed on the inclusion criteria questionnaire (Appendix F) were excluded from the study. The subject's age, standing height (measured in cm) and total body mass (measured in kg) was also taken at this time. Mean subject characteristics are reported in Table 1.

Table 1

Subject Characteristics

Variables	Mean	Std. Dev. (+/-)	Range	Minimum	Maximum
Age (yr)	28.40	9.24	30	16	46
Height (cm)	165.40	9.73	28	150	178
Body Mass(kgs)	69.50	3.96	36	50	86
Forefoot varus (degrees)	6.30	0.67	2	6	8

N of cases: 10

Testing Procedures:

Apparatus:

Low dye taping was applied using 1-inch adhesive tape and skin adhesive spray. Pressure and COP distribution data were measured and recorded using the F-Scan Gait Analysis System. The F-scan system consisted of a 386 IBM-compatible computer with F-scan software, a VGA colour monitor and graphics card, 640 KB of random access memory, hard disc, mouse and two free full size expansion ports. A Hewlett-Packard Paintjet colour printer was also required for colour printout of the data.

The peripheral support gear consisted of one velcro ankle cuff unit with accompanying cable, one waist belt, and ten sensor insoles. Ten consent forms, one ten foot measuring tape, weigh scale, ten white sheets of tracing paper and one pair of exercise shorts were also required for testing.

Subject Preparation:

Tracings of the subject's affected foot were taken and the appropriate sized F-scan sensor was trimmed. The sensor was strapped to the plantar aspect of the foot using a tight fitting elastic sock to prevent movement between the foot and the insole. Movement between the insole and the foot can create problems in the measurement of pressure and in the reproducibility of the pressure readings. Because of the critical nature of the reproducibility of the pressure measurements, a tight fitting sock was used to reduce movement between the insole and the surface of the foot.

Once the sensors were securely fastened to the affected foot, the velcro ankle cuff unit was attached to the superior to the ankle joint. The unit was strapped to the distal end of the tibia and fibula, superior to the medial and lateral malleolus (Appendix D-Figure 1). The waist belt was then fastened around the subject's belt area. The connection pad (Appendix D-Figure 3) was carefully inserted into the inferior port holes of the velcro ankle cuff units. Upon completion of the initial preparation steps, the subject's name, height, weight and age were entered. Calibration of the system was performed. The computer guided the investigator through these steps.

Prior to data collection, the subject was instructed to walk for a few minutes to get used to walking with the apparatus. Subjects were limited to walking in an area covered by the length of the cable and some found that their gait pattern was altered slightly by this cable. Any adjustments required were done so at this time to improve comfort.

Walking Foot Pressures Without Low Dye Taping:

Once the subject was comfortable with the apparatus, data collection proceeded. Subjects were instructed to walk a total distance of 50 feet at a self-selected speed. The subject's gait pattern without the application of tape was recorded. Data collection was initiated by hitting the space bar to begin and end the collection of the data. Three trials were completed and recorded in total. Data was recorded for a period of 6 seconds for each trial. Approximately 6 steps were recorded for each of the three trials. The first and last steps were not analyzed because a portion of the step may have been missed in the recording due to the subject reaching the end of the F-scan cable or the end of the 50 foot runway. Therefore, a total of 4 steps were analyzed for each trial. Once the three trials without tape were completed, the stocking, velcro ankle cuff unit, and sensor were carefully removed from the foot.

Low Dye Taping Technique:

The low dye taping technique was then applied as described by Kosmahl and Kosmahl (1987) and illustrated in Appendix G. The following steps were taken:

1. Skin Preparation: Any hair from the ankle down to the level of the metatarsal heads was shaved. Because of the short period of time that the subject had the low dye taping on, the loosening effect was minimal. To combat any loosening of the tape, an adhesive skin preparation spray was used to enhance the contact of the tape and the effectiveness of the technique. The adhesive spray was applied to the entire dorsal and plantar aspect of the foot. One minute was allowed to let the skin adhesive time to dry.

2. Taping technique: Low dye taping was applied directly to the skin in the following manner:
    1. An anchor strap was placed across the plantar aspect of the foot at the level of the metatarsal heads (Appendix G-Figure 2).
    2. With the ankle joint kept in a neutral position, the first toe was mildly plantarflexed. The first longitudinal strap was applied to the anchor strap on the plantar aspect of the foot over the first metatarsal head. This strap followed the medial border of the foot, around the heel, and along the lateral border to the fifth metatarsal head (Appendix G-Figure 3).
    3. A second anchor strap was placed around the metatarsal heads to hold the first longitudinal strap in place.
    4. The second longitudinal strap was begun over the plantar aspect of the first metatarsal. This coursed around the heel in the same manner as the first

longitudinal strap. The strap slightly overlapped the first longitudinal strap (Appendix G-Figure 4).

5. Subsequent straps were started in the same manner, coursing medially as they turned around the heel to the metatarsal heads. These longitudinal straps were stopped when the end of the strap overlapped its beginning at the plantar aspect of the first metatarsal head (Appendix G-Figure 5).
6. Closing straps were next used to complete the low dye taping technique. Each closing strap began on the lateral border of the foot and coursed across the plantar aspect of the foot medially. The first closing strap began on the lateral aspect of the foot. The strap was then drawn across the plantar aspect of the foot finishing medially over the navicular tubercle (Appendix G-Figure 6).
7. The closing straps were applied so that each strap overlapped the previous strap by one half. The final strap began on the dorsolateral aspect of the fifth metatarsal and ended at the base of the first metatarsophalangeal joint (Appendix G-Figure 7).

Walking Foot Pressures With Low Dye Taping:

Once the low dye taping technique was completed, the sensor was again reapplied as described in the initial preparation section. The testing procedures for walking with tape followed the same steps as described previously for walking without tape. Three trials were recorded walking with low dye taping. The F-scan and tape was then removed from the subject's foot and the skin was washed and dried.

Pressure Time Graphical Analysis:

The following steps were followed to analyze the plantar pressure recordings:

1. Pressure versus time graphs were analyzed by calculating the total length of the stance phase for each trial. The total length of the stance phase was calculated as the difference in time between the first and last recording for each of the trials in the pressure versus time graphs.
2. The stance phase graphs were then divided into a contact, midstance and propulsion phase. According to Brown and Yavorsky (1987) the contact phase of gait is 27% of the total stance phase, midstance 40% and the propulsion phase 33% of the total stance phase. The total length of the stance phase was divided into the appropriate time frames for contact (27% of total stance phase time), midstance (40% of total stance phase time) and propulsion (33% of total stance phase time).
3. Once the pressure versus time graphs were divided into a contact, midstance and propulsion phases, the mouse was used to move a vertical line along the points on the graph. Every two one hundredths of a second the pressure value on the graph (measured in pounds per square inch) that corresponded with the location of the vertical line was recorded. The value for each point on the pressure versus time graph was displayed on the screen once the vertical line was placed over that point in time on the graph.
4. The range and mean pressure of the contact, midstance and propulsion phase were calculated for the trials with and without low dye taping. Trial mean pressure was calculated for the contact period for each of the four steps of trials 1, 2 and 3 without

tape for each of the 10 subjects. Trial mean pressure was calculated by summing the pressure values for the contact phase of steps 1, 2, 3 and 4, respectively. The total sum of the pressure values for each step was then divided by the number of pressure values taken for that step to calculate the mean pressure for each of the four steps. The mean step pressures were used to calculate a trial mean contact pressure. The mean contact pressure was then calculated by adding the three trial mean contact pressures and dividing by three (three trials without tape). Mean contact pressure without tape was calculated and recorded for each of the 10 subjects in this way. This same procedure was used to calculate a mean trial pressure without tape for midstance and propulsion. Mean trial pressures without tape were then used to calculate mean midstance and mean propulsion pressures without tape for each subject. This process was repeated to calculate mean pressures with tape for the contact, midstance and propulsion phases for each of the ten subjects.

Descriptive Analysis of COP Curves:

For each of the four steps recorded in the three trials, both with and without tape, tracings of the COP curve were made. An example of the COP path is illustrated in Appendix C. Tracings for the steps in trial 1, 2 and 3 (walking without tape) were compared to the steps in trial 1, 2 and 3 (walking with tape). The COP path for walking without tape was compared to COP path for walking with tape for each subject. The COP lines were contrasted and compared for each subject when walking with and without low dye taping. COP lines for walking without tape were described relative to the COP lines for walking with tape and according to their location to the midline of the foot. If the line was located medial to the COP line being compared and medial to the midline then a medialization effect occurred. If the COP line was located lateral to the COP line being compared and lateral to the midline then a lateralization effect occurred. If the COP line overlapped the COP line being compared then no change was noted. Change in the mean pressure in the rearfoot, midfoot and forefoot areas was also noted. A summary of the general trends of the COP curve for each subject was recorded. A comparison was made between each trial for each subject to see if any consistent deviations in the COP curve occurred with the application of low dye taping. The frequency of the medialization, lateralization or no change was recorded.

Experimental Design:

A within-subjects (repeated measures) design was used in which subjects were exposed to one independent variable (taping) with two levels (no tape versus tape). Two dependent variables (pressure and COP) were measured using the F-Scan Gait Analysis System. The dependent variable pressure had three levels, pressure during contact, pressure during midstance, and pressure during propulsion.

Statistical Analysis:

A within-subjects t-test was used to detect significant relationships between the dependent variable pressure measured in pounds per square inch (PSI) for the contact, midstance and propulsion phases and the independent variable taping. Level of significance was set at $p < 0.05$. Statistical techniques were not used to analyze the COP curves. The COP curves were analyzed as described in Descriptive Analysis of COP Curves.

CHAPTER 4:

Results:

Pressure measures taken from the F-Scan Gait Analysis System under the two testing conditions, walking with and without tape, were contrasted and compared. The level of significance was set at $p < .05$. Means, standard deviations, and range values for all pressure measures were generated to enhance the descriptive analysis. COP curves were also contrasted and compared for each trial. Table 2 presents the mean, standard deviation, minimum, maximum and range values for foot pressure for the ten subjects during contact, midstance and propulsion measured under the two testing conditions, walking with and without tape.

Table 2

Summary of Foot Pressure Measures(PSI)

Phase of Stance	Mean	Std. Dev. (+/-)	Range	Minimum	Maximum
CONTACT					
Without tape	1.64	0.51	1.47	0.94	2.41
With tape	1.35	0.40	1.32	0.79	2.11
MIDSTANCE					
Without tape	2.33	0.84	2.74	1.31	4.05
With tape	2.15	0.52	1.38	1.35	2.73
PROPULSION					
Without tape	2.10	0.68	2.23	1.26	3.49
With tape	2.02	0.47	1.37	1.44	2.81

N of cases: 10

A complete list of all mean foot pressure measures for each trial is presented in Appendix J. A repeated measures t-test ($p < .05$) was performed comparing foot pressure at contact with and without low dye taping, during midstance with and without low dye taping and during propulsion with and without low dye taping (see Appendix J for details).

Subjects demonstrated a significant decrease in pressure in the rearfoot during contact:

$$M = 0.29,\ SD = 0.37,\ t(9) = 2.46,\ p < .05$$

Subjects did not demonstrate a significant change in pressure in the midfoot during midstance:

$$M = 0.18,\ SD = 0.51,\ t(9) = 1.12,\ p > .05$$

Subjects did not demonstrate a significant change in pressure in the forefoot during propulsion:

$$M = 0.08,\ SD = 0.59,\ t(9) = 0.46,\ p > .05$$

The COP lines were contrasted and compared for each subject when walking with and without low dye taping. COP lines were described according to the location. If the COP line was located medial to the COP line being compared then a medialization effect occurred. If the COP line was located lateral to the COP line being compared then a lateralization effect occurred. If the COP line overlapped the COP line being compared then no change was noted. Analysis of the COP lines for each subject revealed that there was no consistent change in the COP when low dye taping was applied. A lateralization in the COP line occurred at times but was not a consistent finding in this study. It must be highlighted that the lateralization noted was extremely minimal. The changes in the COP are summarized in Table 3.

COP Changes During Contact:

During the contact phase of gait, 5 subjects displayed no change in the COP line while 5 subjects displayed a lateralization when low dye taping was applied. No subjects displayed a medialization in the COP line when low dye taping was applied. Analysis of the COP curves and the location of the pressure as displayed on the colour printouts produced by the F-scan during the contact phase showed that there was no consistent alteration in the COP. During the contact phase of gait 5 out of the 10 subjects displayed either no change in the COP curve or a lateralization with the application of low dye taping. With the application of tape, only 4 subjects made contact with the ground with the foot in a pronated position while 6 made contact with the foot in a more supinated position. Although contact was made with the foot in a pronated position in 4 subjects when walking with low dye taping, the location of the COP curve was slightly more lateral than without the use of low dye taping.

COP Changes During Midstance:

During midstance, 4 subjects displayed no change in the COP line while 6 subjects displayed a lateralization in the COP with the application of low dye taping. As in the contact phase of gait, no subjects displayed a medialization in the COP line when low dye taping was applied. Analysis of the COP curves during midstance showed that there was no consistent and significant alteration in the COP. During midstance 4 out of 10 subjects tested presented with no change in the COP curve, while 6 subjects presented with a lateralization of the COP curve with the application of low dye taping.

Our results showed that during midstance when ambulating without tape 4 out of 10 subjects presented with the COP line in a pronated position and 6 out of 10 in a supinated position. With the application of tape, only 2 subjects presented with the COP line in a pronated position while the 8 other subject's COP line was in a supinated position. The tape appeared to produce a lateralization of the COP in the subjects tested.

COP Changes During Propulsion:

During propulsion, 7 subjects displayed no significant change in the COP while 3 subjects displayed a lateralization when low dye taping was applied. No subjects displayed a medialization in the COP when low dye taping was applied. Analysis of the COP curves during this portion of the stance phase show that all subjects ambulated with the same pattern both with and without the application of low dye taping. The COP pattern coursed from a slightly lateral position to the medial aspect of the foot so that by toe off the COP was located under the first and second toes. The COP pattern for each subject followed a normal pattern for all trials with and without tape. The low dye taping did not produce any consistent or significant changes in the COP line during propulsion. A summary of the COP changes is illustrated in Table 3.

Table 3

Summary of COP Changes

Phase of Stance	# of Subjects	Findings
Contact	5 out of 10 5 out of 10	-lateralization of COP line -no change in COP line
Midstance	6 out of 10 4 out of 10	-lateralization of COP line -no change in COP line
Propulsion	3 out of 10 7 out of 10	-lateralization of COP line -no change in COP line

N of Cases: 10

See Figure 5 displaying two common COP curves showing the pressure changes under the foot and the unchanged COP curves when tape was applied to the under surface of the foot. See Appendix K for inidividual pressure readouts.

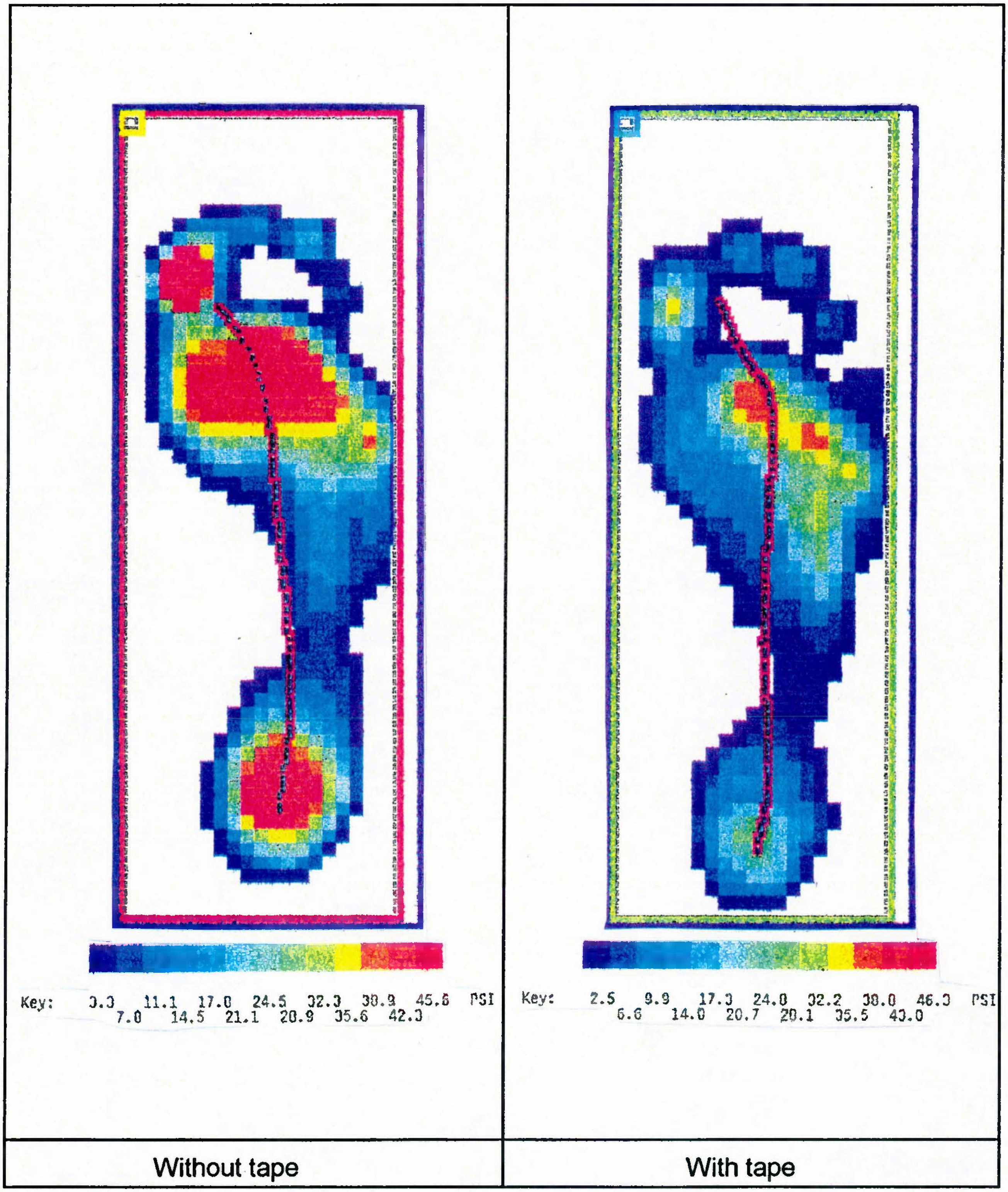

Figure 5. Example of F-scan pressure readout without tape versus with tape illustrating common pressure and COP changes.

CHAPTER 5:

Discussion:

The purpose of this investigation was to measure the effects of low dye taping on foot pressure in the feet of subjects experiencing plantar fasciitis. Vertical foot pressure and COP measures were taken from the F-Scan Gait Analysis System under two conditions. Subjects were asked to walk without and with the application of low dye taping. Based upon a review of the current literature only one study was found that examined the effects of low dye taping. Although several studies indicated that low dye taping was widely used as a method of treating this condition, only one study examined what the effects of low dye taping were. Therefore, the primary objective of this study was to objectively measure the effect of low dye taping on vertical foot pressure in the rearfoot, midfoot and forefoot during contact, midstance and propulsion and to critically evaluate the effect on the COP during each of these phases.

The results presented will be discussed in more detail under the following three headings:

1. Pressure and COP Changes Under the Rearfoot During Contact
2. Pressure and COP Changes Under the Midfoot During Midstance
3. Pressure and COP Changes Under the Forefoot During Propulsion

Pressure and COP Changes Under the Rearfoot During Contact:

With the application of low dye taping there was a statistically significant decrease in the pressure during the contact ($t(9) = 2.46$, $p < .05$). The mean foot pressure under the rearfoot without tape was 1.64 PSI and 1.35 PSI with tape. The low dye taping technique appeared to successfully decrease the force transmitted under the foot at heel contact. These findings correspond with the findings of Scranton et al. (1982) who also found that low dye taping decreased the force under the foot.

A review of the literature shows that several authors have also made similar inferences. DeMaio et al. (1993), Gould (1988), Jahss (1991) and Klenerman (1991) have all stressed the importance of decreasing the pressure transmitted in the plantar fascia as one of the goals of treating this condition and that low dye taping is one of the treatments used in this painful foot disorder. Although this study is not assessing the effectiveness of low dye taping, rather assessing the effects of taping on foot pressure, our findings indicate that pressure under the rearfoot decreased during contact.

Kosmahl and Kosmahl (1987) have also suggested that low dye taping modified the forces on the medial longitudinal arch. The findings in this study cannot specifically state that there was a decrease in the force in this particular anatomical structure but we can generalize that during contact there was a decrease in the amount of pressure with the application of low dye taping and this may have also produced a decrease in the force transmitted through this and other soft tissue structures in the area.

A question that must be asked is what caused this decrease in force? There are a number of possibilities that must be considered and can be applied to the pressure decreases noted in midstance and propulsion as well. One hypothesis is that the decrease in pressure can be attributed to the dissipation of force by the fat pad in the heel of the foot. It has been suggested that the skin and subcutaneous tissue in the heel resemble that of a sponge and it may be this sponge-like property that absorbs the force at contact (Riegger, 1988; Kwong, Kay, Voner & White, 1988). It can also be suggested that the elastic properties of the tape absorb some of the force thereby decreasing the pressure at contact. If the fat pad of the heel was responsible for the change in pressure, the pressure under the foot should be equal in both the trial without and with tape. As can be seen from our results, this was not the case. There was a greater decrease in pressure with the application of low dye taping. It may in fact then be the elastic properties of the tape that caused the decrease in the pressure, or a combination of the absorption of pressure by the fat pad in the heel and the elastic properties of the tape that produced this effect.

A review of other related literature shows that Schepsis et al. (1991) suggested that low dye taping controlled heel valgus and altered the position of the foot during foot strike. Neale and Adams (1989) also suggested that low dye taping caused inversion of the calcaneus during ambulation. Similarly, Kosmahl and Kosmahl (1987) suggested that low dye taping controlled pronation of the foot during ambulation. Analysis of the COP curves and the location of the pressure as displayed on the colour printouts produced by the F-scan during the contact phase showed that there was no consistent alteration in the COP. During the contact phase of gait 6 out of the 10 subjects displayed no change in the COP curve while 4 out of the 10 subjects had a lateralization with the application of low dye taping. The COP was essentially unchanged though.

At heel strike when the foot makes contact with the ground, contact is normally made on the lateral border of a supinated foot. Controlled pronation then must occur to aid in the absorption of the force (Brown & Yavorsky, 1987). The navicular and cuboid bones remain in a parallel orientation allowing the foot to absorb shock, adjust to ground terrain changes and control equilibrium (Donatelli, 1985). Our results showed that at when ambulating without tape, 8 out of 10 subjects made contact with the ground at heel strike with the foot in a pronated position and 2 in a supinated position. As was discussed in the review of the literature, pronation is considered abnormal when it exceeds the amount required, or when it occurs when supination should be occurring (Brown & Yavorsky, 1987). Pronation at heel strike results in the lowering of the medial longitudinal arch and increased tension on the plantar fascia (Sarrafian, 1987). Pronation at this point in the stance phase would also compromise the ability of the foot to adjust to uneven terrain, changes in equilibrium and absorb pressure.

With the application of tape, only 4 subjects made contact with the ground with the foot in a pronated position while 6 made contact with the foot in a more supinated position. Although contact was made with the foot in a pronated position in 4 subjects when walking with low dye taping, the location of the COP curve was slightly more lateral than without the use of low dye taping. The application of the tape improved the position of the foot at heel strike in some subjects compared to the pronated position of the heel at heel strike without the application of tape. The lateralization of the position of the COP at this point in gait is important as it results in supination of the heel at contact thereby raising of the medial longitudinal arch and decreasing the stretch on the plantar fascia.

Scranton et al.(1987) found that in their analysis of the effects of low dye taping, heel cups and medial arch supports, low dye taping shifted the instantaneous centre of forces medially. Scranton et al. (1987) concluded that this and the decrease of the forces under the feet were desirable effects and that low dye taping could be used as an effective treatment in plantar fasciitis. Once again it must be reiterated that although the current study is not examining the effectiveness of low dye taping as a treatment rather it is examining the effects of the taping technique on the foot pressure and COP curve, based upon the current literature and the negative effects of abnormal pronation one would question whether a medialization in the COP would be desirable? One would assume that a medialization in the COP, as described by Scranton et al. (1987), would result in an increase in pronation of the foot. Based upon a review of the current literature this is not a desired effect in this patient population, rather a decrease in the amount of pronation or a control in the timing of the pronation is essential to correct the pathomechanics of the gait pattern in individuals with plantar fasciitis. Therefore, based upon the literature, it appears that a lateralization of the COP curve is more desirable than a medialization. In all of the trials conducted with the application of low dye taping, there was no medialization of the COP curves for all subjects during contact, midstance and propulsion. Our study failed to produce this negative effect of medialization for the sample of subjects tested.

Pressure and COP Changes Under the Midfoot During Midstance:

The application of low dye taping did not produce a statistically significant decrease in the average foot pressure during midstance ($t(9) = 1.12$, $p > 0.05$). If we relate the pressure decreases to the elastic properties of the tape, it could be possible that as a function of time the tape becomes stretched and the elasticity is compromised. As a result of this there is an inability to support the plantar fascia due to loosening of the tape. Another hypothesis could be that due to the supination that occurs during this phase of the gait cycle there is not as much tension placed on the tape and as a result the tape has a less significant effect on pressure change in the foot. Supination of the foot occurs at this point and may result in a raising of the medial longitudinal arch and a decrease in tension on the tape. Therefore, it may be possible that the role of the tape in effecting pressure change in the foot may be related to when pronation and supination is occurring during the gait cycle? Since pronation occurs mainly during the contact phase of the gait cycle as the calcaneous makes contact with the ground, low dye taping may only have an effect during this portion of the gait cycle. This is an area that can be investigated further in future studies.

Analysis of the COP curves during midstance showed that there was no consistent alteration in the COP. During midstance 8 out of 10 subjects tested presented with no change in the COP curve while 2 subjects presented with a lateralization of the COP curve with the application of low dye taping.

During the midstance phase of gait the foot is converted from a mobile adaptor to a rigid lever in preparation for propulsion (Brown & Yavorsky, 1987; Donatelli & Wolf, 1990). Subtalar joint supination occurs at this point in the gait cycle, resulting in locking of the midtarsal joints as the navicular and cuboid take on a perpendicular orientation (Donatelli, 1987). A rigid forefoot is produced in preparation for propulsion. Abnormal pronation at this stage results in instability of the first ray during propulsion and increased tension on the plantar fascia (Donatelli, 1987). Once again we see the importance of controlling abnormal pronation at this stage to prevent increased tension on the plantar fascia.

Our results showed that during midstance when ambulating without tape, 4 out of 10 subjects presented with the COP line in a pronated position and 6 out of 10 in a supinated position. With the application of tape, only 2 subjects presented with the COP line in a pronated position while the 8 other subject's COP line was in a supinated position. The tape appeared to produce a lateralization of the COP in only 2 subjects while 8 subjects remained unchanged. This lateralization of the COP would aid in the locking mechanism of the midtarsal bones to produce a rigid forefoot in preparation for propulsion and reduce undue stress on the fascia resulting from over pronation.

Pressure and COP Changes Under the Forefoot During Propulsion:

The application of low dye taping did not produce a statistically significant change in the mean foot pressure under the forefoot during propulsion ($t(9) = 0.46$, $p > 0.05$). A question that can be asked is why was there no significant change in foot pressure at this stage of gait? If we relate the previous pressure decreases to the elastic properties of the tape, it could be possible that as a function of time the tape continues to become stretched and the elasticity is further compromised. Since the tape would likely have the greatest amount of stretch with the first metatarsophalangeal joint in this weight bearing and extended position, the tape may lose its ability to sustain its role in decreasing the pressure of weightbearing.

During propulsion, the locking mechanism of the navicular and the cuboid, and the windlass effect of the plantar fascia aid in the stabilization of the first metatarsophalangeal joint (Sarrafian, 1987; Donatelli & Wolf, 1990; Donatelli, 1985). During this portion of stance, the calcaneus is drawn towards the digits, the medial longitudinal arch raised, the calcaneus inverted and the foot supinated (Urban, 1990; Kwong et al, 1988; Reigger, 1988). As was explained for midstance, the effects of low dye taping may only have an effect on pressure changes in the foot when pronation occurs. Because supination occurs at this point in gait, the effects of taping may not be significant. If abnormal pronation occurred at this stage in the gait cycle, however, it would cause instability of the first ray and increase the stress on the plantar fascia. If this were the case then we may have seen low dye taping play a more significant role in pressure change in the forefoot. This is also an area where further study is needed.

Analysis of the COP curves during this portion of the stance phase show that all subjects ambulated with the same pattern both with and without the application of low dye taping. The COP pattern coursed from a slightly lateral position to the medial aspect of the foot so that by toe off the COP was located under the first and second toes. The COP pattern for each subject followed an essentially normal pattern for all trials with and without tape. The low dye taping did not produce any significant changes in the COP line during propulsion.

CHAPTER 6:

Conclusions:

Recent trends in exercise and the rise in the participation level in physical activity has led to an increase in the development of a wide array of overuse injuries. Plantar fasciitis is an example of this type of overuse injury. It is characterized mainly by inflammation of the plantar fascia and heel pain localized to the anteromedial calcaneal tubercle that is greatest with the first steps in the morning or after prolonged sitting (Cailliet, 1983; Chandler & Kibler, 1993; DeMaio et al., 1993; Harbison, 1987; Kosmahl & Kosmahl, 1987; Schepsis et al., 1991). The signs and symptoms are numerous and quite variable for this condition with treatment ranging from conservative to more aggressive measures. The treatment of plantar fasciitis aims to decrease the inflammatory process in the heel, decrease tension and pressure on the fascia and associated structures and correct any biomechanical abnormalities (DeMaio et al., 1993; Gould, 1988; Jahss, 1991; Klenerman, 1991). Low dye taping is one of the modalities used by health care professionals to achieve the desired goals mentioned above.

Research specifically examining the effects of the low dye taping technique are minimal. There have been a number of hypotheses as the what the proposed effects of the tape are but little research to back up these inferences. It is suggested that low dye taping modifies the forces on the medial longitudinal arch decreasing stress on the plantar fascia and aids in controlling pronation of the foot during walking (Kosmahl & Kosmahl, 1987; Neale & Adams, 1989; Schepsis et al., 1991). Riddle and Freeman

(1988) have also suggested that the tape adds compression to the foot thereby decreasing the inflammation in the area. Scranton et al. (1982) was the only study found in the published literature that specifically looked at the effects of low dye taping. Scranton et al. (1982) found that low dye taping decreased the forces under the foot and medialized the centre of force line. Because of the lack of research looking at the effects of low dye taping, the purpose of the present study was to assess the effects of low dye taping on foot pressure in individuals suffering from plantar fasciitis. Foot pressure measures were taken using the F-Scan Gait Analysis System. Foot pressure and COP were compared and analyzed.

Based upon the results of this investigation, the application of low dye taping was effective in significantly decreasing foot pressure under the rearfoot during contact. We can conclude then that low dye taping may be effectively used in patients suffering from plantar fasciitis to decrease foot pressure. Low dye taping may also be effective in decreasing the pressure in the foot in other foot problems where excessive pressure is a possible cause or aggravating factor. We cannot conclusively state that this technique would be effective for other patient populations.

Low dye taping did not produce a consistent change in the COP lines. Low dye taping produced a lateralization of the COP line during contact and midstance under the rearfoot and midfoot, but this change was only minimal. The results of this investigation also showed that the application of low dye taping does not produce a medialization of the COP line and an increase in pronation. We can conclude from this that low dye taping did not produce any consistent changes in the COP line. We can also conclude that the application of low dye taping does not produce any medialization of the COP line and thereby increase the amount of pronation in the foot and increase the amount of stress and tension on the plantar fascia.

To further validate the effects of the low dye taping technique on patients suffering from plantar fasciitis, it is recommended that:

(i) a larger sample size be used in order to attempt to generalize findings
(ii) two more control groups be used, one which does not receive any intervention and another group which only receives the low dye taping
(iii) the use of a 3D gait analysis system be employed in combination with the F-scan Gait Analysis System to more accurately assess the lower extremity kinematics, more specifically foot kinematics, during gait.

Recommendations for further study include addressing the following questions:

1. What is the effect of low dye taping on the foot while running?
2. What are the effects of orthotics versus heel pads versus low dye taping on foot pressure?
3. What is the effect of low dye taping on foot pressure in normal, asymptomatic subjects with no foot abnormalities or pain?
4. What is the effect of low dye taping on patients suffering from metatarsalgia and/or other related foot problems?

There are a number of areas related to this study that require further investigation. The methodology used and results from this study can be incorporated into future investigations analyzing the effects of various other modalities on pathological gait, or on the effect of low dye taping on different patient populations suffering from other common overuse injuries.

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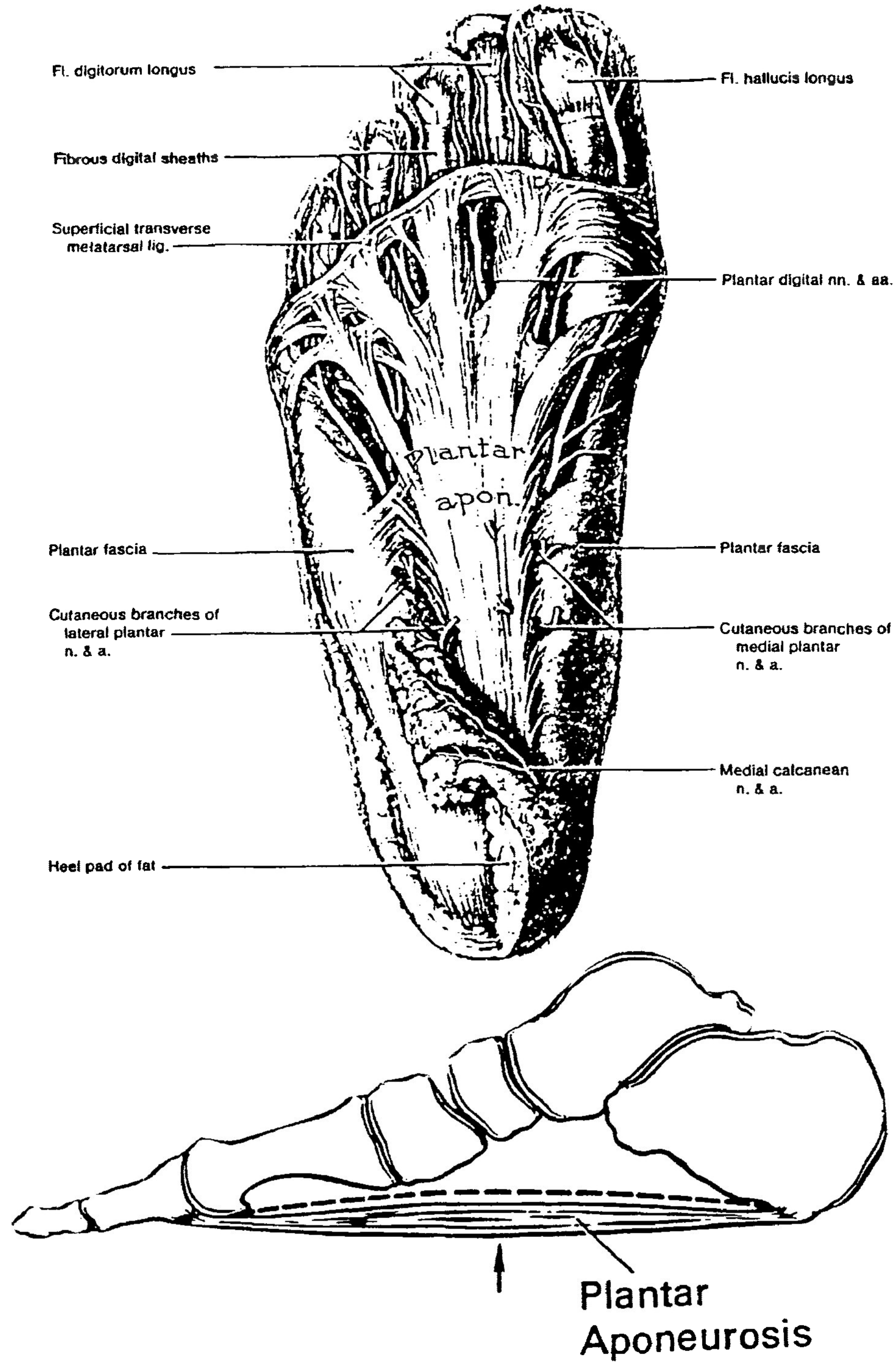
APPENDIX A:

Diagrammatic Representation of the Plantar Fascia



NOTE: Adapted from Clinically Oriented Anatomy by K. L. Moore, p. 507.

APPENDIX B:

Closed Kinetic Chain Pronation, Neutral Position and Supination

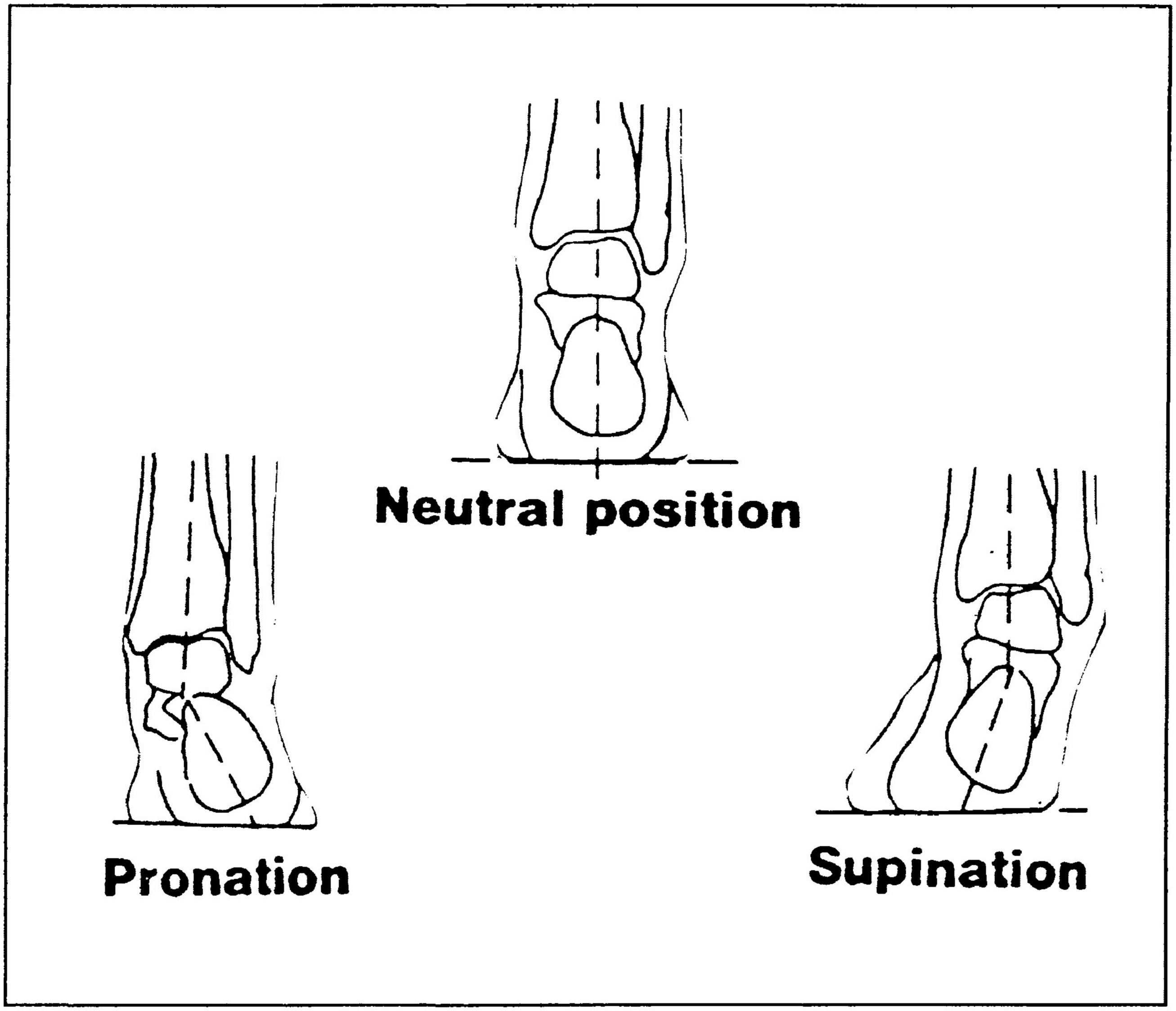


Figure 1. Closed kinetic chain pronation, neutral and supination.

NOTE: Adapted from "Normal Biomechanics of the Foot and Ankle" by R. Donatelli, 1985, Journal of Orthopaedic and Sports Physical Therapy, 7, p. 93-95.

APPENDIX C:

Ground Reaction Forces and Path of the Centre of Pressure During the Stance Phase of Gait

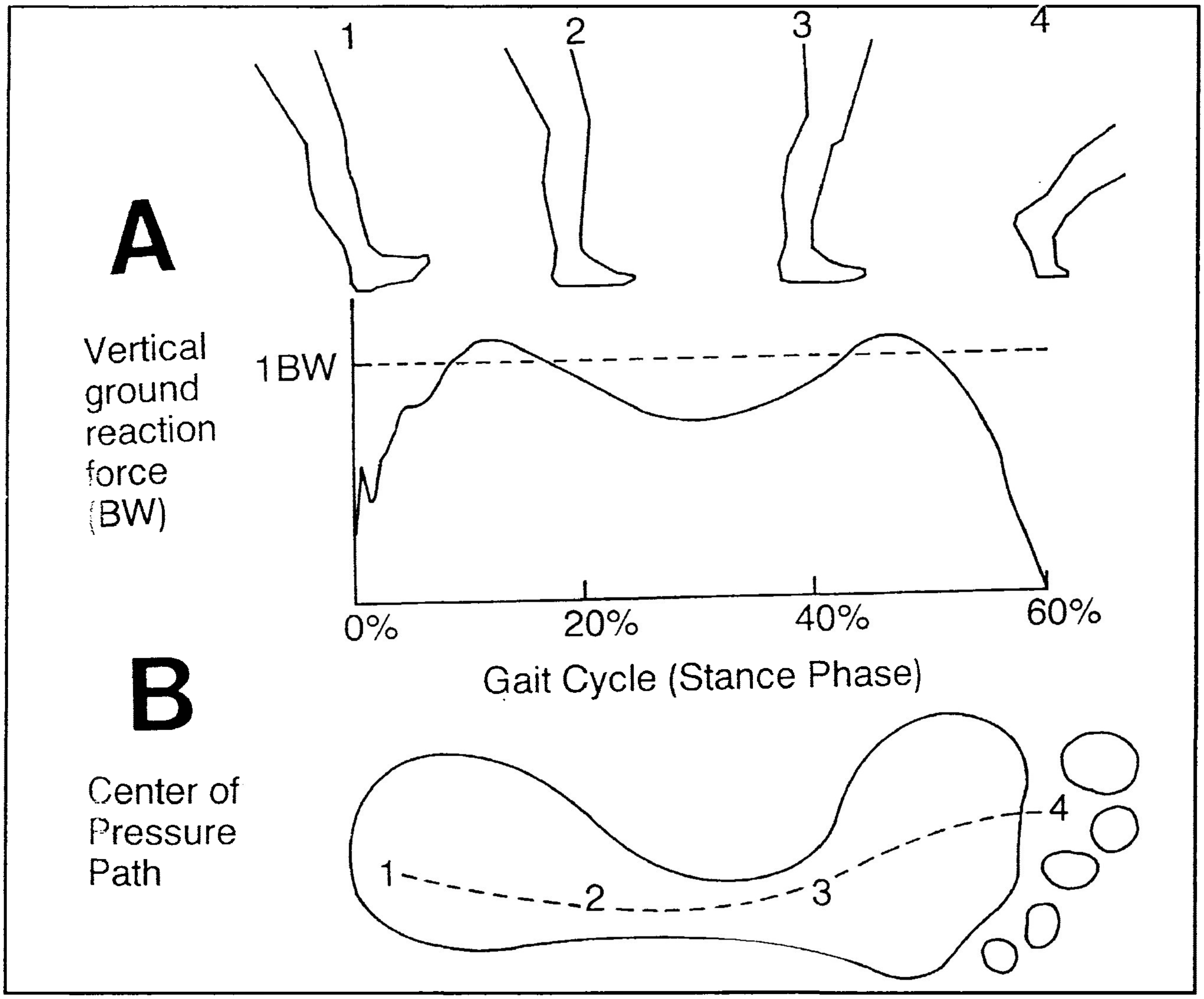


Figure 1. A. Ground reaction forces beneath the foot during the stance phase of the gait cycle (BW = body weight, 1 = heel strike, 2 = foot flat, 3 = midstance, 4 = toe off).

B. Path of the COP during the gait cycle.

NOTE: Adapted from "Dynamic Biomechanics of the Normal Foot and Ankle During Walking and Running" by M. Rodgers, 1988, Physical Therapy, 68, p. 1825.

APPENDIX D:

Primary Components of the F-Scan Gait Analysis System

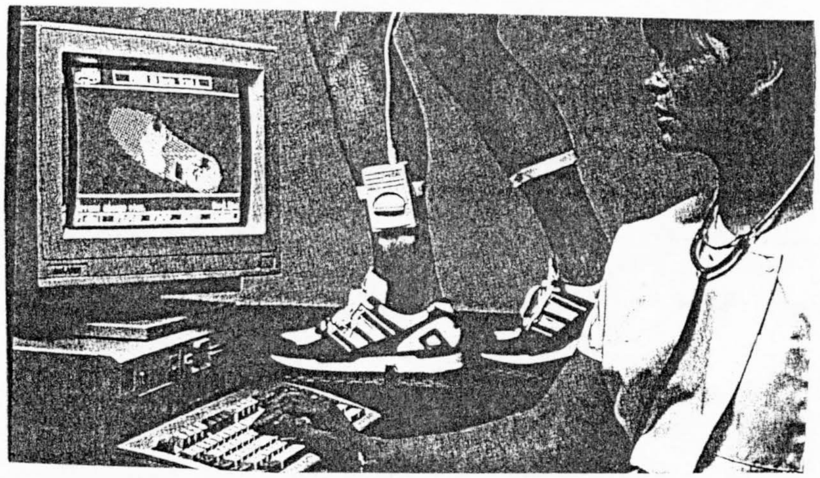


Figure 1. Pictorial representation of the F-Scan System.

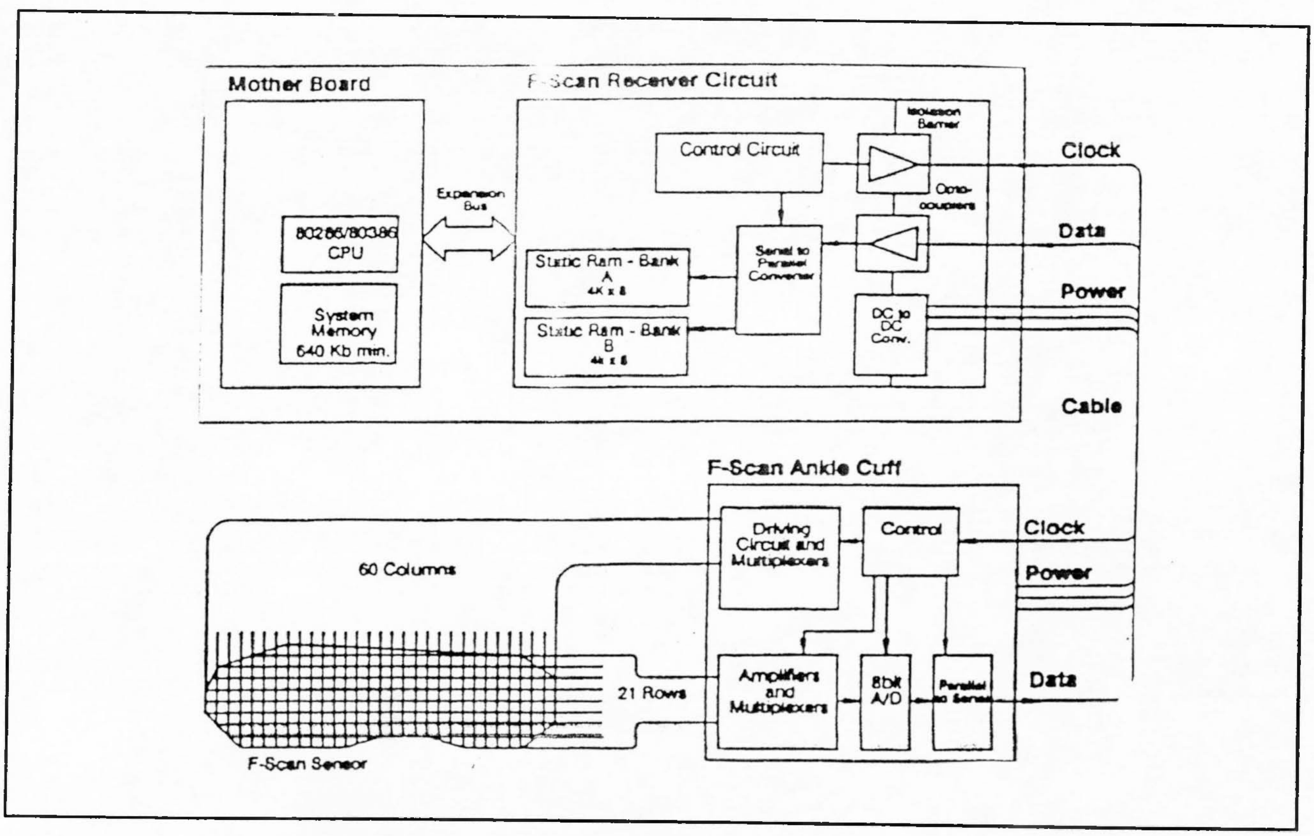


Figure 2. The F-Scan system's primary components are the sensors, data collection electronics and software.

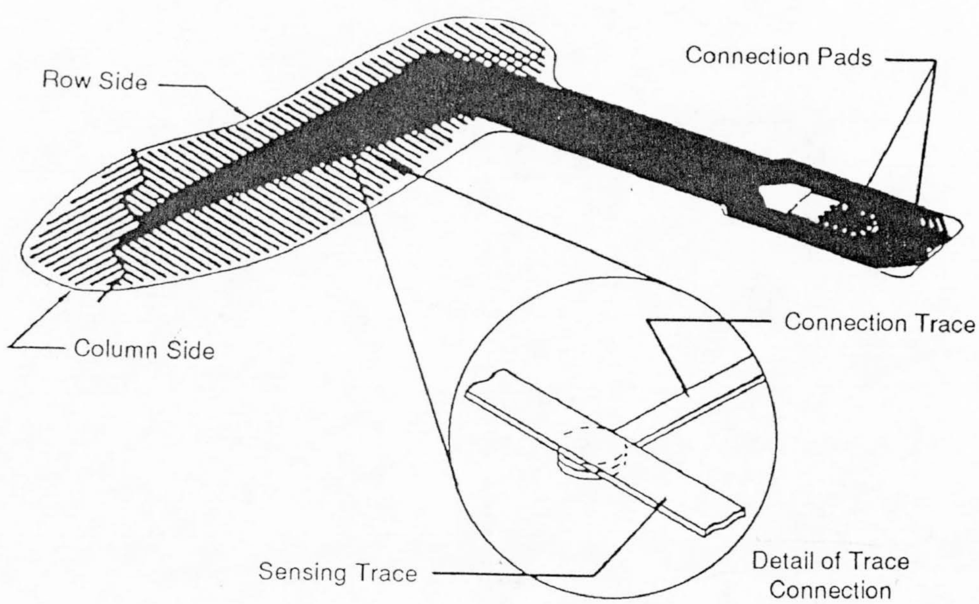


Figure 3. The F-Scan sensor uses a combination of conductive, dielectric, and resistive inks. Each sensing cell, located at a grid crossing point, has a resistance inversely proportional to the applied surface pressure. The pressure distribution on the sensor's surface can be determined by scanning the grid and measuring the resistance at each intersection.

NOTE: Adapted from "A Pressure Mapping System for Gait Analysis" by R. M. Podoloff & M. H. Benjamin, 1991, Sensors, p. 22.

APPENDIX E:

Consent Form

The Effects of Low Dye Taping on Foot Pressure in Subjects With Plantar Fasciitis

I, ____________ consent to take part in a study that will examine the effects of low dye taping on the vertical pressure and COP transmitted through my foot as I walk. The purpose of this investigation is to learn how low dye taping, a method of treating patients with plantar fasciitis, affects the above mentioned measures.

Paolo Sanzo, the principal investigator, has explained to me that I will be required to attend a one hour session at Thunder Bay Orthopaedics for testing. During testing I will be required to walk fifty feet with the F-scan sensor attached to the sole of my foot both with and without the low dye taping.

I understand that my involvement in this investigation will be of benefit to the advancement of science and aid in determining the effects of this technique. If the technique proves to be effective there will be an increase in the support of my foot aiding in my ability to walk normally and painfree. I also understand that there will be no adverse effects from involvement in this study.

I understand that all records will be kept confidential and that only Paolo Sanzo, the principal investigator, and his supervising professor, Dr. Tony Bauer, will have access to this information. If the results of this investigation are published, I will not be identified in any way. I understand that I am free to withdraw from this study at any time even after signing this form, and this will in no way affect my present or future association with Lakehead University.

____

Signature of Participant　　　　　　Date

____

Signature of Witness　　　　　　Date

____

Signature of Researcher　　　　　　Date

APPENDIX F:

Inclusion Criteria Questionnaire

NAME:____________ HEIGHT:___________

AGE:____________ WEIGHT:___________

1. Heel pain in the morning with the first few steps. [ ]
2. Heel pain with first few steps after prolonged sitting. [ ]
3. Pain localized to the anteromedial tubercle of the calcaneus and/or throughout the plantar fascia. [ ]
4. Not currently being treated for plantar fasciitis. [ ]
5. No previous cortisone injections into the plantar fascia. [ ]
6. Heel pain has been present for less than 1 year. [ ]
7. Forefoot varus ______ degrees (greater than 5 degrees required for inclusion) [ ]
8. No other medical conditions or problems. [ ]

APPENDIX G:

Materials and Methods of Low Dye Taping

Figure 1. Materials for low dye taping include 1-inch adhesive tape, skin adhesive and a razor.

Figure 2. First anchor strap.

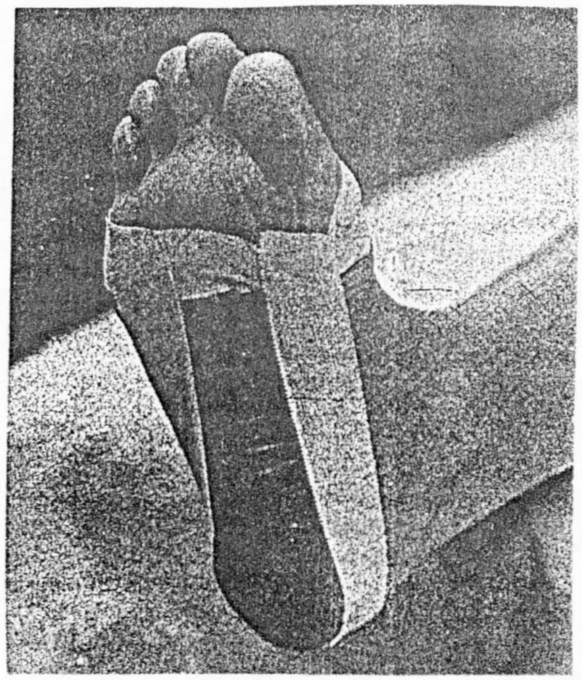


Figure 3. First longitudinal strap.

Figure 4. Second longitudinal strap.

Figure 7. Completed low dye taping technique.

NOTE: Adapted from "Painful Plantar Heel, Plantar Fasciitis, and Calcaneal Spur: Etiology and Treatment" by E. M. Kosmahl and H. E. Kosmahl, 1987, Journal of Orthopaedic and Sports Physical Therapy, 9, p. 20-22.

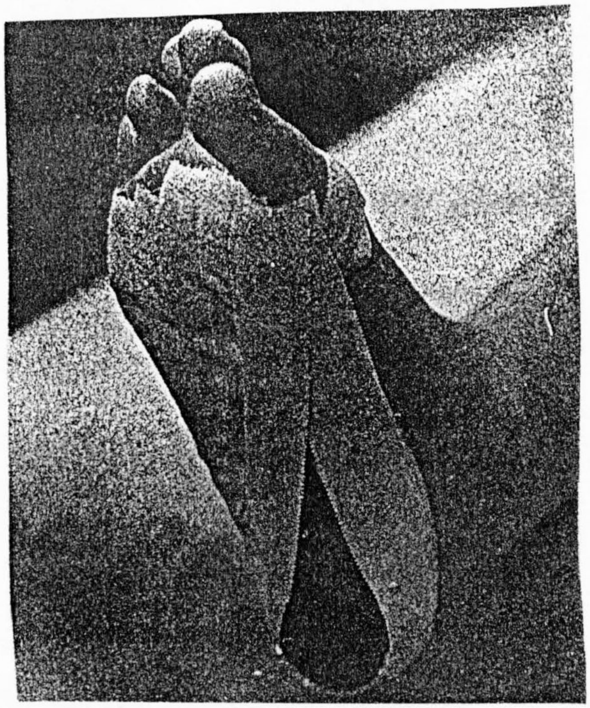


Figure 5. Last longitudinal strap.

Figure 6. First closing strap.

APPENDIX H: Pilot Study Raw Data

TRIAL #	STEP #	TREATMENT TYPE	MEAN PRESSURE VALUES FOR EACH TRIAL (PSI) CONTACT	MIDSTANCE	PROPULSION
1 VML1TPS.FSX	1 of 5	NO TAPE	2.48	3.18	2.75
	2 of 5	NO TAPE	2.13	3.05	2.63
	3 of 5	NO TAPE	2.31	3.00	2.77
	4 of 5	NO TAPE	2.21	2.96	2.88
2 VM3TPS.FSX	2 of 6	NO TAPE	1.70	2.49	2.36
	3 of 6	NO TAPE	2.03	2.49	2.19
	4 of 6	NO TAPE	1.98	2.52	2.58
	5 of 6	NO TAPE	2.12	2.61	2.39
3 VML4TPS.FSX	1 of 5	NO TAPE	1.83	2.54	2.28
	2 of 5	NO TAPE	1.71	2.48	2.41
	3 of 5	NO TAPE	2.08	2.61	2.48
	4 of 5	NO TAPE	1.76	2.57	2.28
4 VML5TPS.FSX	1 of 5	NO TAPE	1.52	2.43	2.32
	2 of 5	NO TAPE	1.78	2.37	2.31
	3 of 5	NO TAPE	1.99	2.49	2.36
	4 of 5	NO TAPE	1.94	2.43	2.28
5 VML2TPS.FSX	2 of 6	WITH TAPE	1.23	2.48	2.44
	3 of 6	WITH TAPE	1.46	2.55	2.58
	4 of 6	WITH TAPE	1.34	2.53	2.47
	5 of 6	WITH TAPE	1.44	2.49	2.43
6 VML6TPS.FSX	2 of 6	WITH TAPE	1.19	2.16	2.39
	3 of 6	WITH TAPE	1.24	2.18	2.33
	4 of 6	WITH TAPE	1.30	2.20	2.44
	5 of 6	WITH TAPE	1.50	2.21	2.31
7 VML7TPS.FSX	2 of 6	WITH TAPE	1.20	2.03	2.05
	3 of 6	WITH TAPE	1.25	2.13	2.33
	4 of 6	WITH TAPE	1.28	2.16	2.21
	5 of 6	WITH TAPE	1.30	2.16	2.27
8 VML8TPS.FSX	2 of 6	WITH TAPE	1.28	2.01	2.05
	3 of 6	WITH TAPE	1.20	1.81	2.07
	4 of 6	WITH TAPE	1.14	1.97	2.17
	5 of 6	WITH TAPE	1.11	1.84	2.09

TRIAL #	STEP #	TREATMENT TYPE	MEAN LENGTH OF PHASES FOR EACH TRIAL (sec) CONTACT	MIDSTANCE	PROPULSION
1 VML1TPS.FSX	1 of 5	NO TAPE	0.18	0.27	0.23
	2 of 5	NO TAPE	0.18	0.26	0.22
	3 of 5	NO TAPE	0.17	0.26	0.21
	4 of 5	NO TAPE	0.17	0.26	0.21
2 VM3TPS.FSX	2 of 6	NO TAPE	0.17	0.26	0.21
	3 of 6	NO TAPE	0.17	0.25	0.21
	4 of 6	NO TAPE	0.16	0.24	0.20
	5 of 6	NO TAPE	0.17	0.25	0.21
3 VML4TPS.FSX	1 of 5	NO TAPE	0.16	0.24	0.20
	2 of 5	NO TAPE	0.16	0.23	0.19
	3 of 5	NO TAPE	0.16	0.23	0.19
	4 of 5	NO TAPE	0.17	0.25	0.20
4 VML5TPS.FSX	1 of 5	NO TAPE	0.16	0.24	0.20
	2 of 5	NO TAPE	0.15	0.22	0.19
	3 of 5	NO TAPE	0.16	0.23	0.19
	4 of 5	NO TAPE	0.16	0.23	0.19
5 VML2TPS.FSX	2 of 6	WITH TAPE	0.17	0.26	0.21
	3 of 6	WITH TAPE	0.16	0.24	0.20
	4 of 6	WITH TAPE	0.16	0.24	0.20
	5 of 6	WITH TAPE	0.17	0.25	0.21
6 VML6TPS.FSX	2 of 6	WITH TAPE	0.16	0.23	0.19
	3 of 6	WITH TAPE	0.16	0.23	0.19
	4 of 6	WITH TAPE	0.16	0.23	0.19
	5 of 6	WITH TAPE	0.16	0.23	0.19
7 VML7TPS.FSX	2 of 6	WITH TAPE	0.16	0.24	0.20
	3 of 6	WITH TAPE	0.16	0.23	0.19
	4 of 6	WITH TAPE	0.16	0.23	0.19
	5 of 6	WITH TAPE	0.16	0.23	0.19
8 VML8TPS.FSX	2 of 6	WITH TAPE	0.16	0.23	0.19
	3 of 6	WITH TAPE	0.15	0.22	0.19
	4 of 6	WITH TAPE	0.16	0.23	0.19
	5 of 6	WITH TAPE	0.15	0.22	0.19

APPENDIX I: Mean Foot Pressure Measures(PSI)

TRIAL #	STEP #	MEAN FOOT PRESSURE MEASURE (PSI)		
		CONTACT	MIDSTANCE	PROPULSION
NO TAPE:				
1	1	1.76	2.57	2.18
1	2	1.76	2.52	2.15
1	3	1.85	2.50	2.24
1	4	1.80	2.53	2.22
2	1	1.44	2.22	2.04
2	2	1.51	2.25	2.11
2	3	1.50	2.29	2.11
2	4	1.51	2.29	2.11
3	1	1.51	2.17	2.00
3	2	1.62	2.21	2.02
3	3	1.67	2.18	1.99
3	4	1.64	2.22	2.09
WITH TAPE:				
1	1	1.38	1.96	2.28
1	2	1.36	2.08	2.41
1	3	1.42	2.06	2.48
1	4	1.40	2.03	2.28
2	1	1.28	2.04	2.32
2	2	1.43	2.04	2.31
2	3	1.38	2.04	2.36
2	4	1.40	2.05	2.28
3	1	1.33	1.95	2.39
3	2	1.24	1.99	2.33
3	3	1.30	2.01	2.44
3	4	1.30	2.00	2.31

APPENDIX J:

T-test Values Average Foot Pressure at Contact

VARIABLE	MEAN	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Average of mean foot pressures without tape	1.64	0.51	0.16
Average of mean foot pressures with tape	1.35	0.40	0.13

PAIRED DIFFERENCES		
MEAN	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
0.29	0.37	0.12

t-value	degrees of freedom	2-tail significance
2.46	9	0.36
95% confidence interval	0.02, 0.55	

T-test Values Average Foot Pressure Midstance

VARIABLE	MEAN	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Average of mean foot pressures without tape	2.33	0.84	0.27
Average of mean foot pressures with tape	2.15	0.52	0.17

PAIRED DIFFERENCES		
MEAN	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
0.18	0.51	0.16

t-value	degrees of freedom	2-tail significance
1.12	9	0.294
95% confidence interval	-0.19, 0.55	

T-test Values Average Foot Pressure Propulsion

VARIABLE	MEAN	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
Average of mean foot pressures without tape	2.10	0.68	0.22
Average of mean foot pressures with tape	2.02	0.47	0.15

PAIRED DIFFERENCES		
MEAN	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN
0.08	0.59	0.19

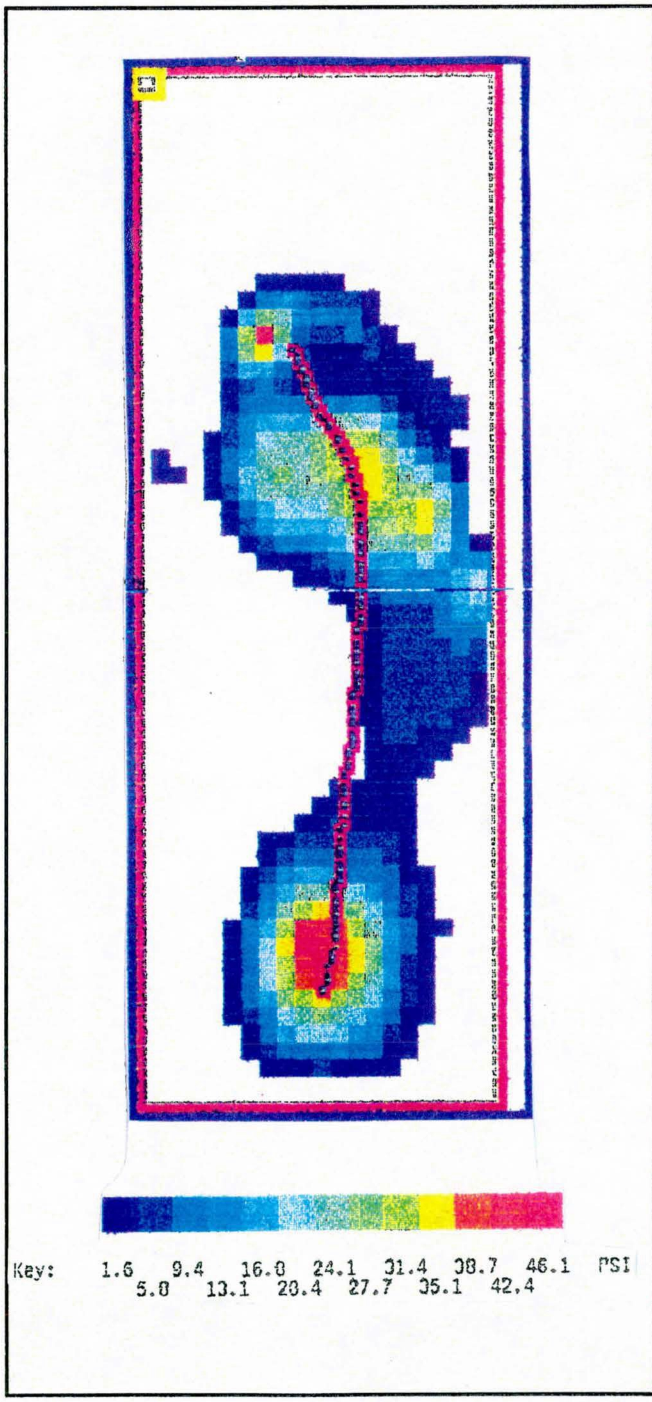
t-value	degrees of freedom	2-tail significance
0.46	9	0.656
95% confidence interval	-0.33, 0.50	

APPENDIX K:

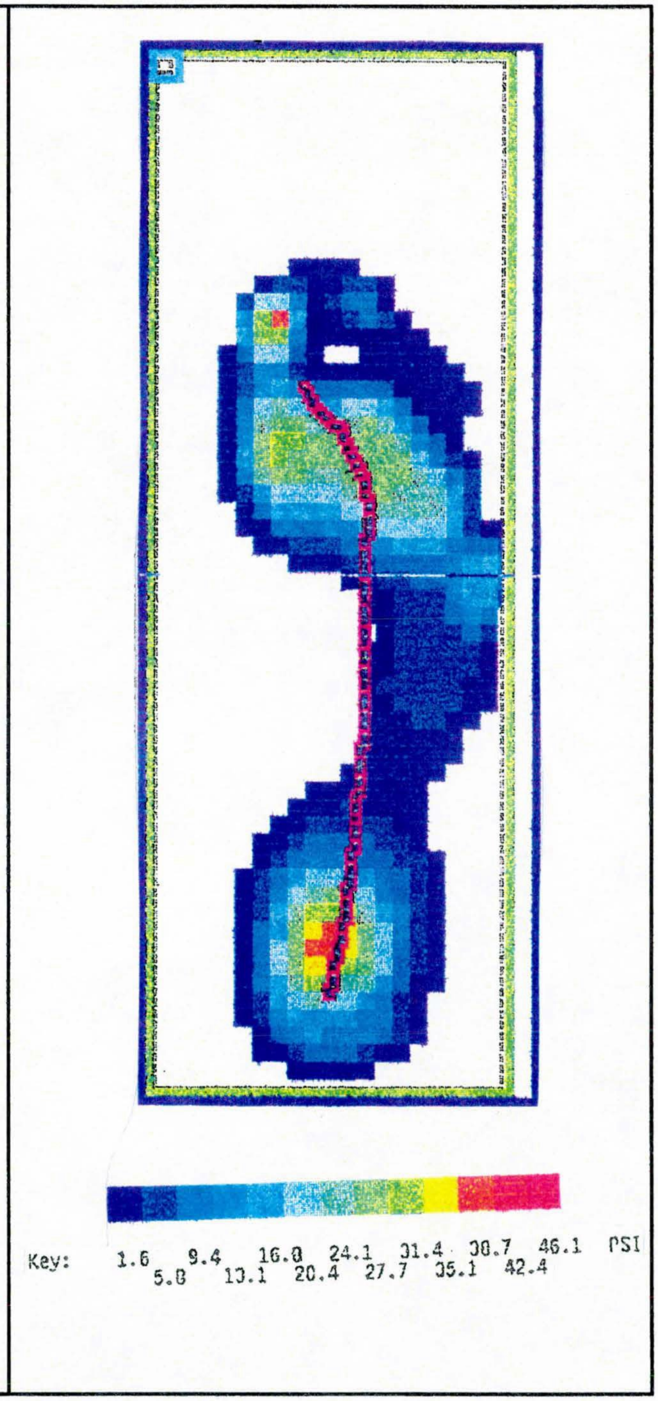
Individual F-scan Readings for Best Trial

SUBJECT #1:

Without tape

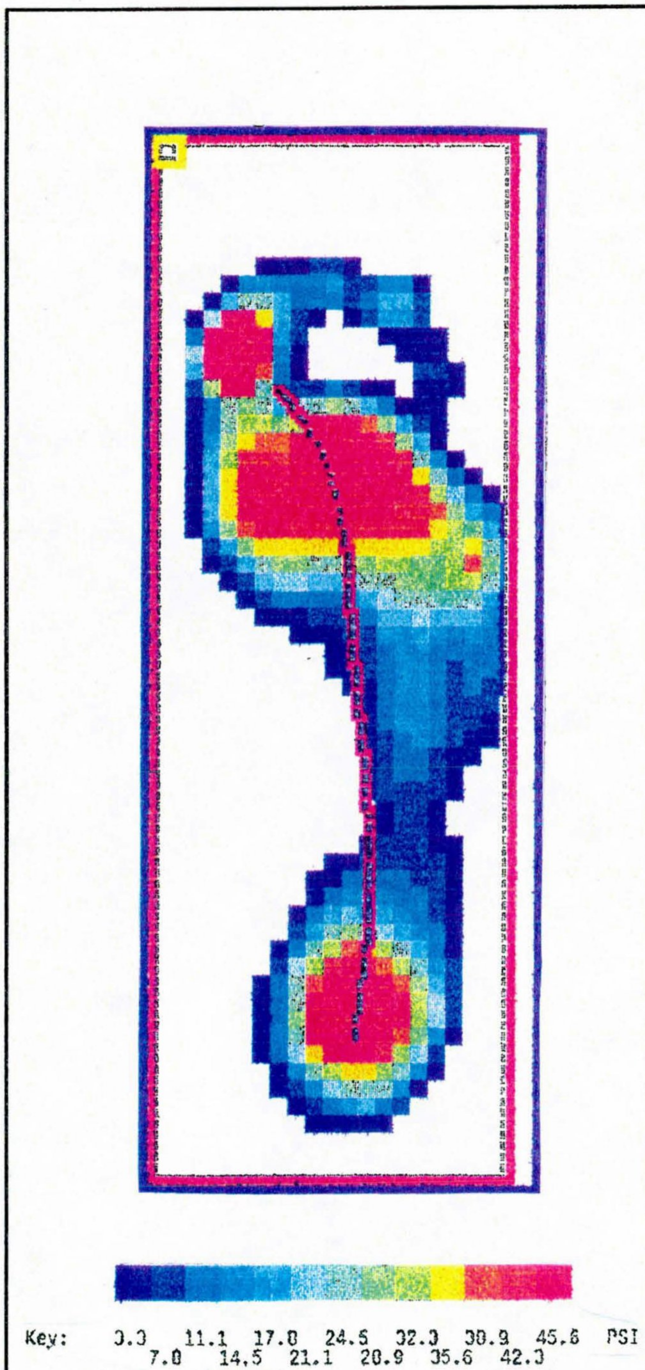


With tape



SUBJECT #2:

Without tape



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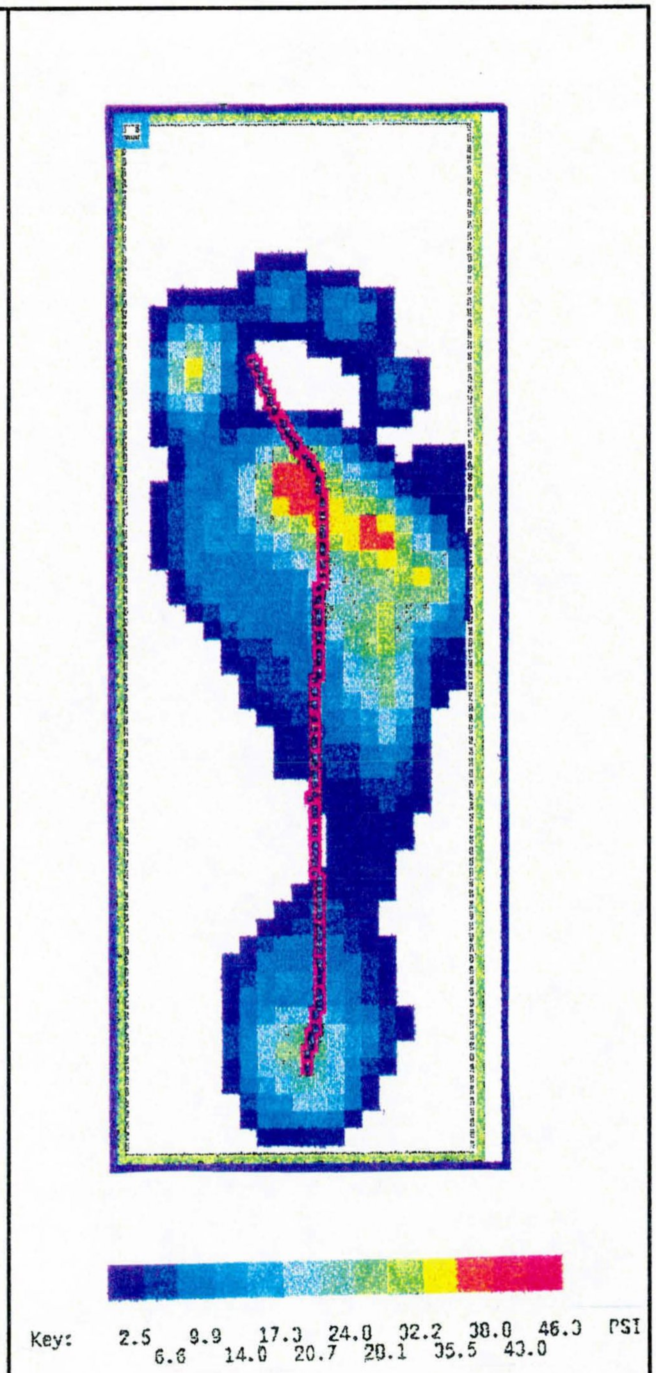

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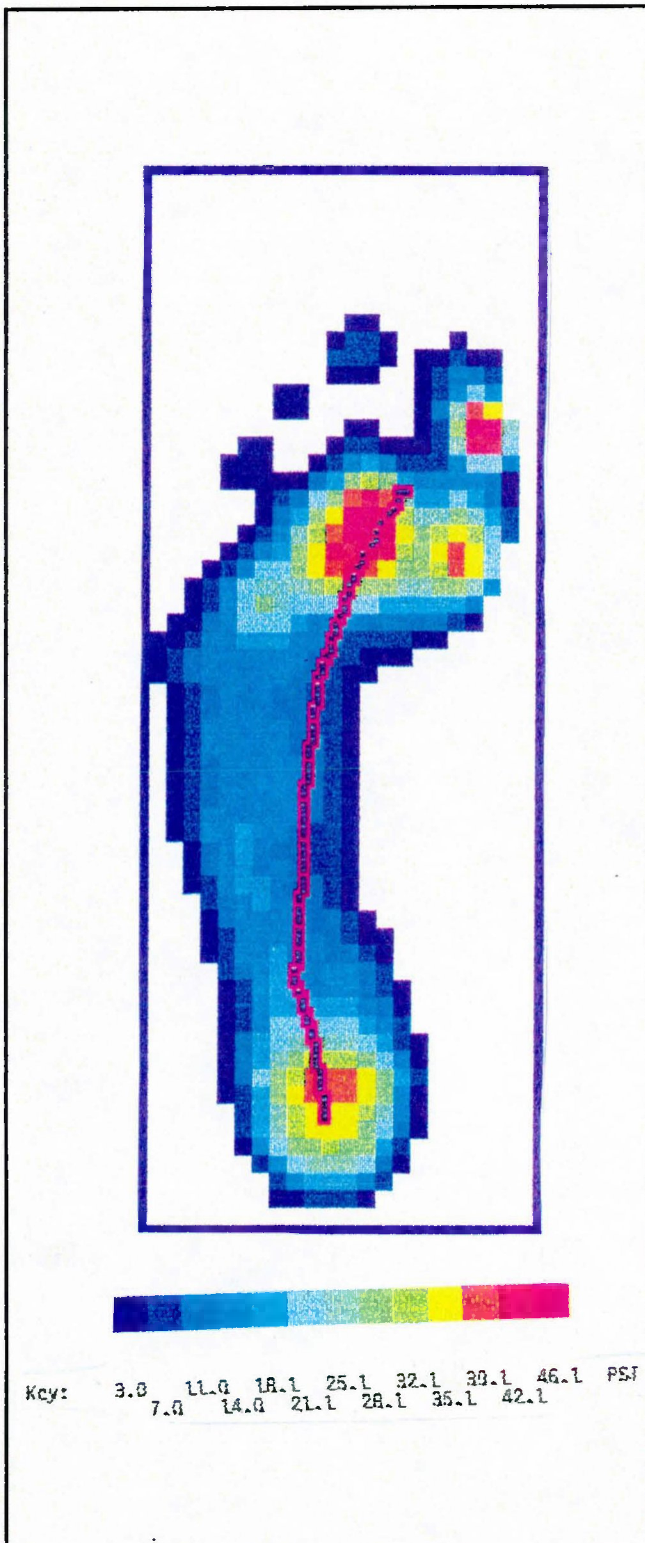

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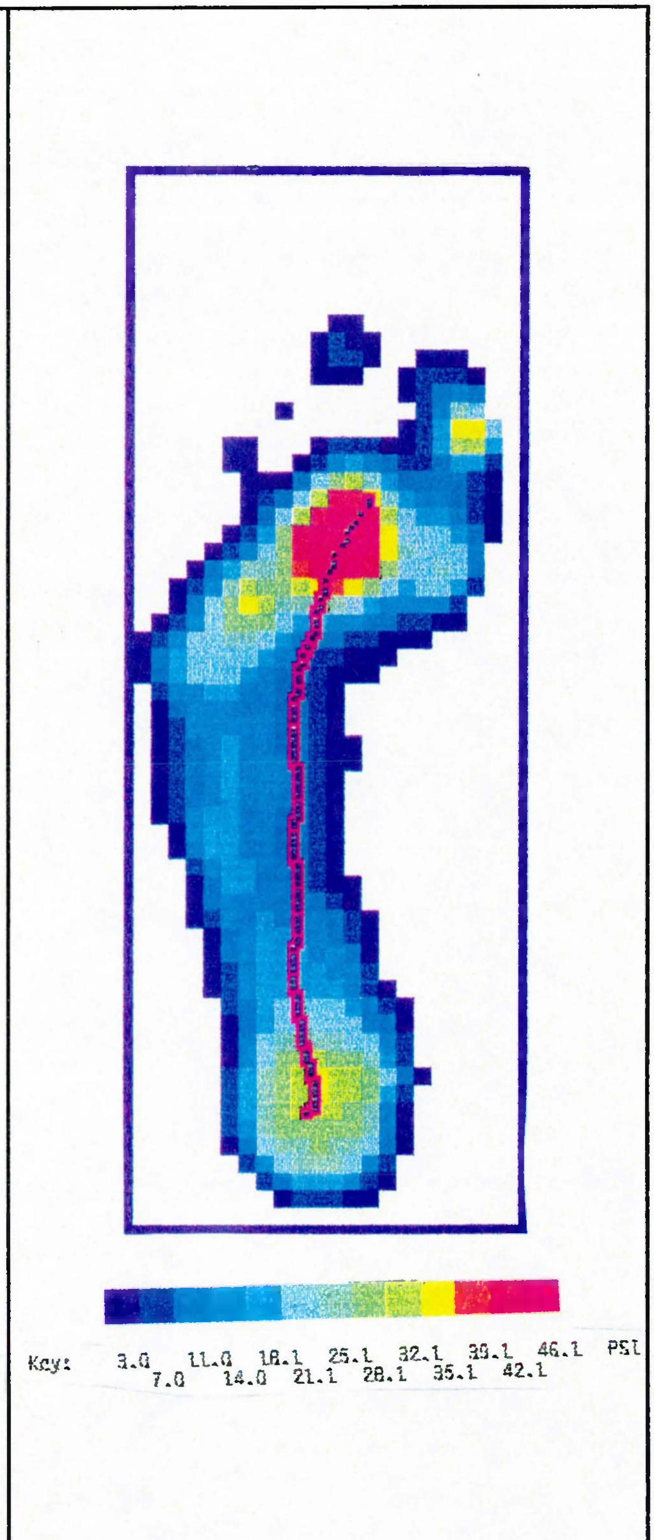

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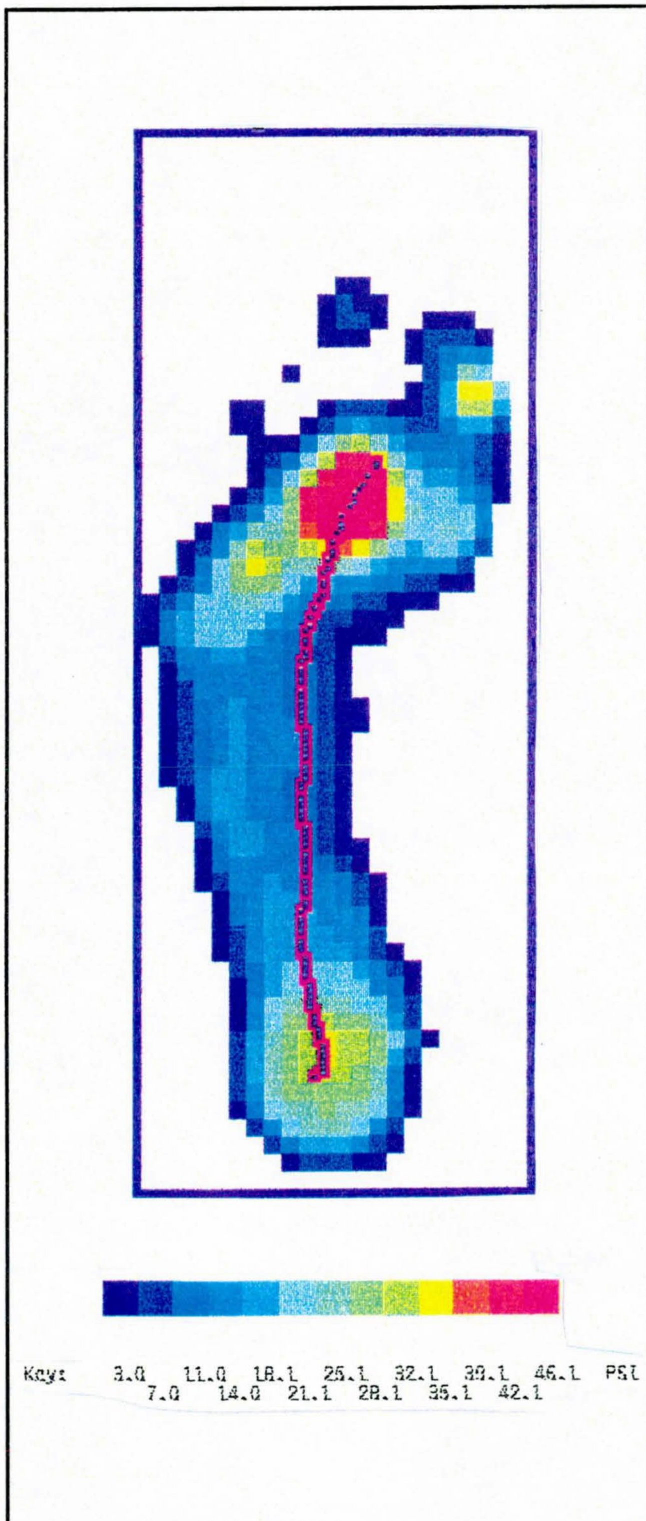

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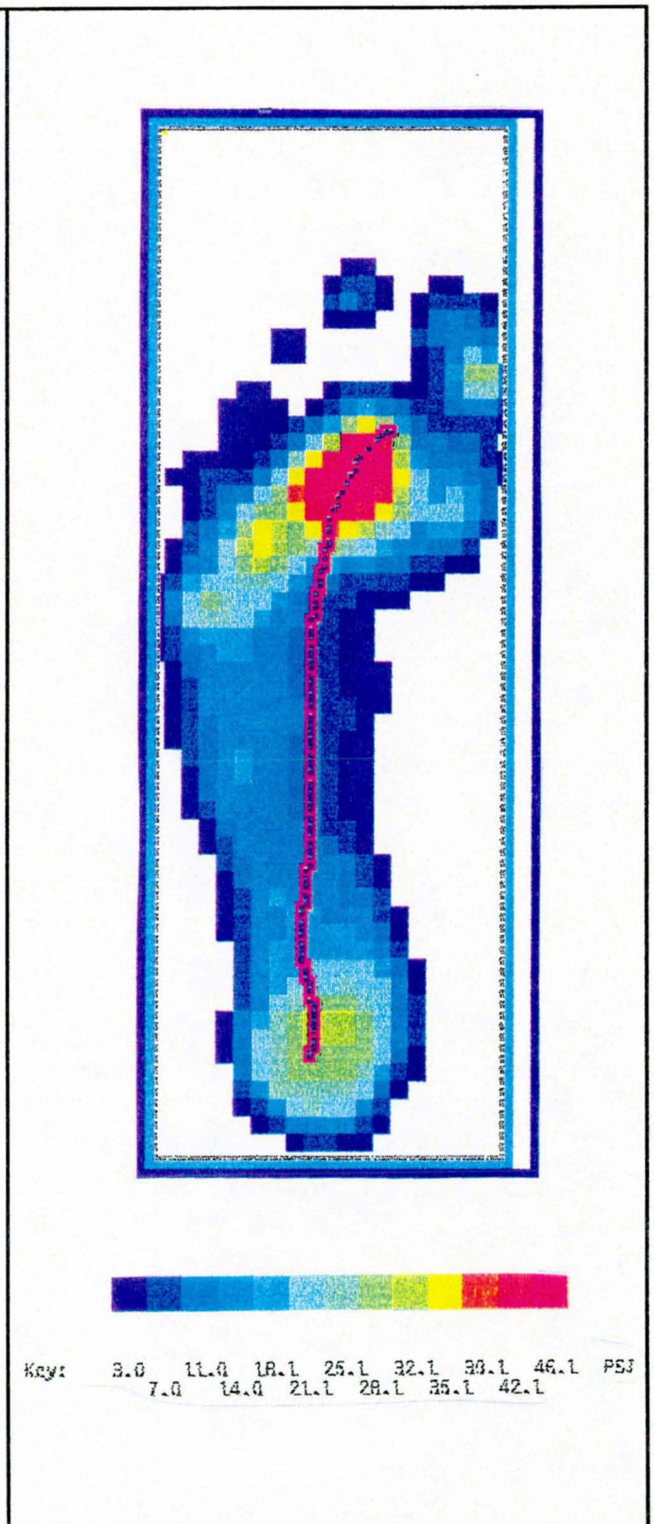

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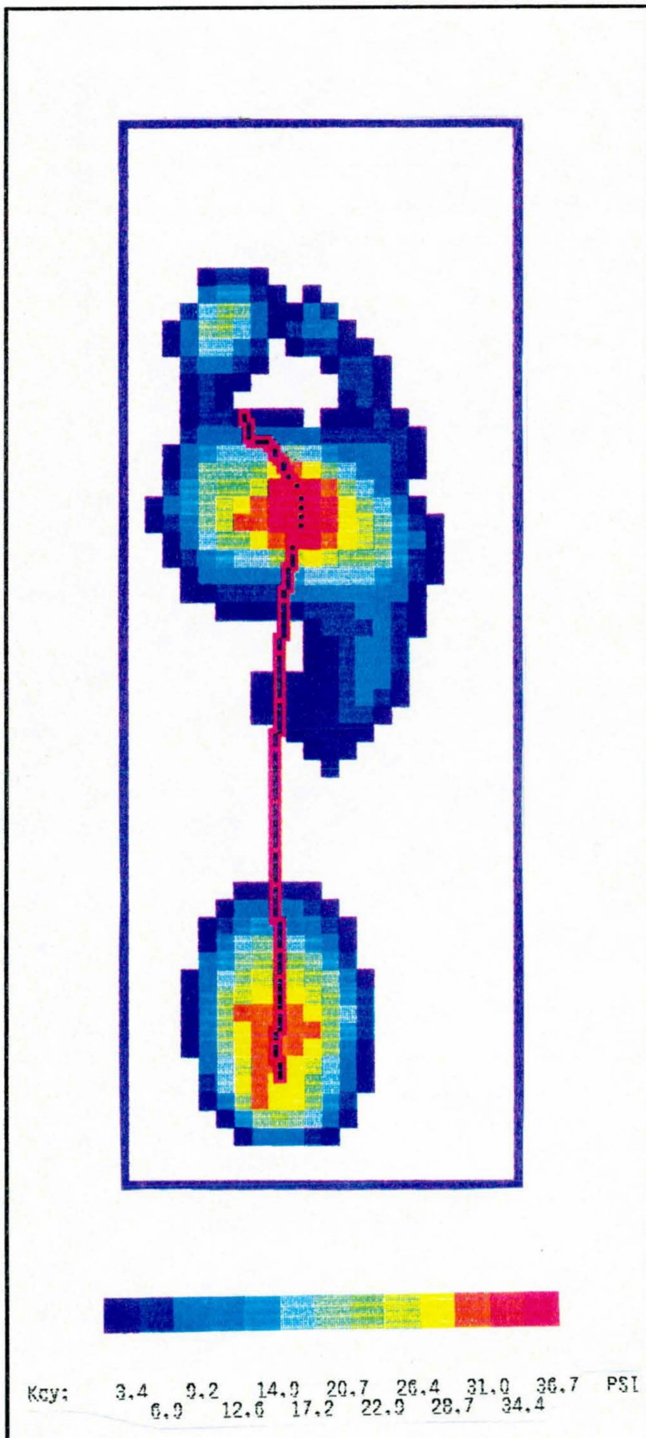

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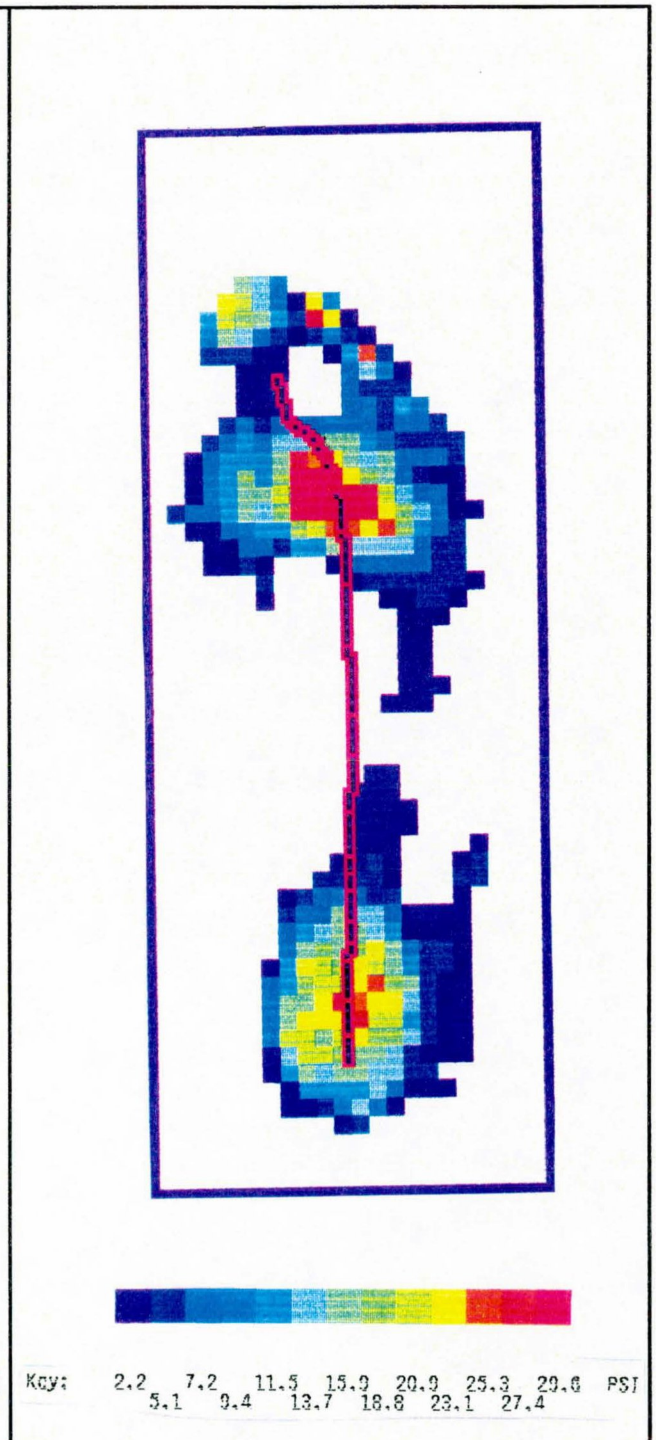

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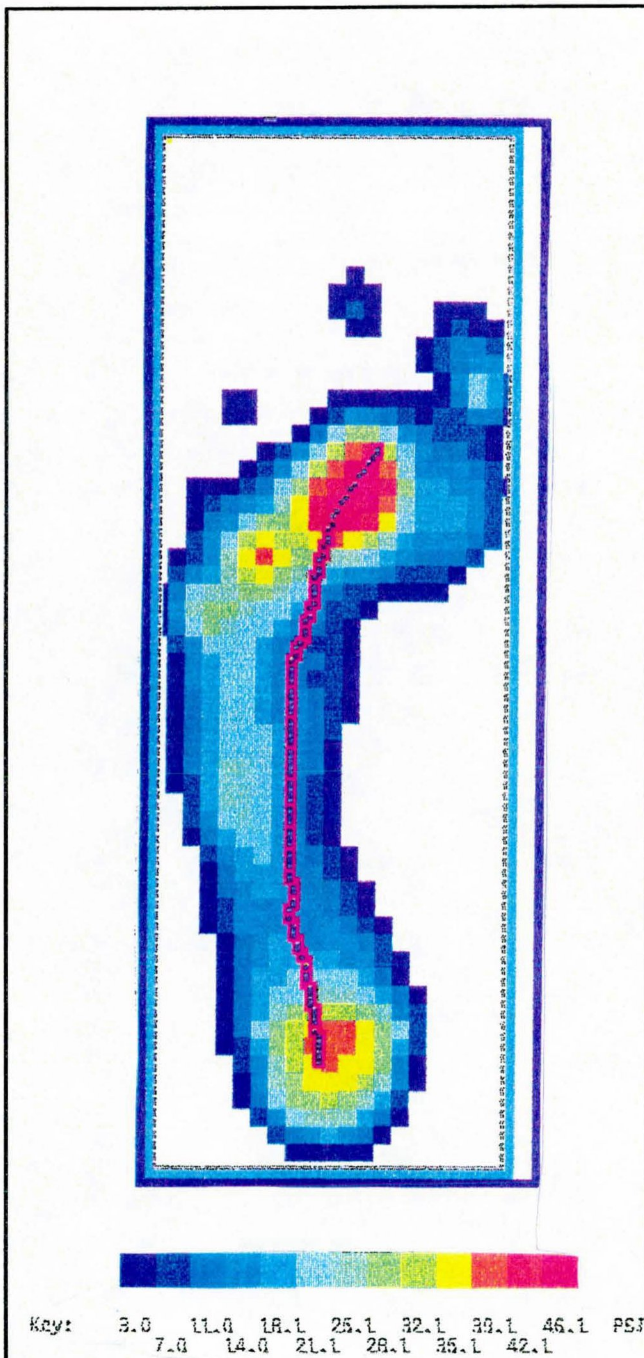

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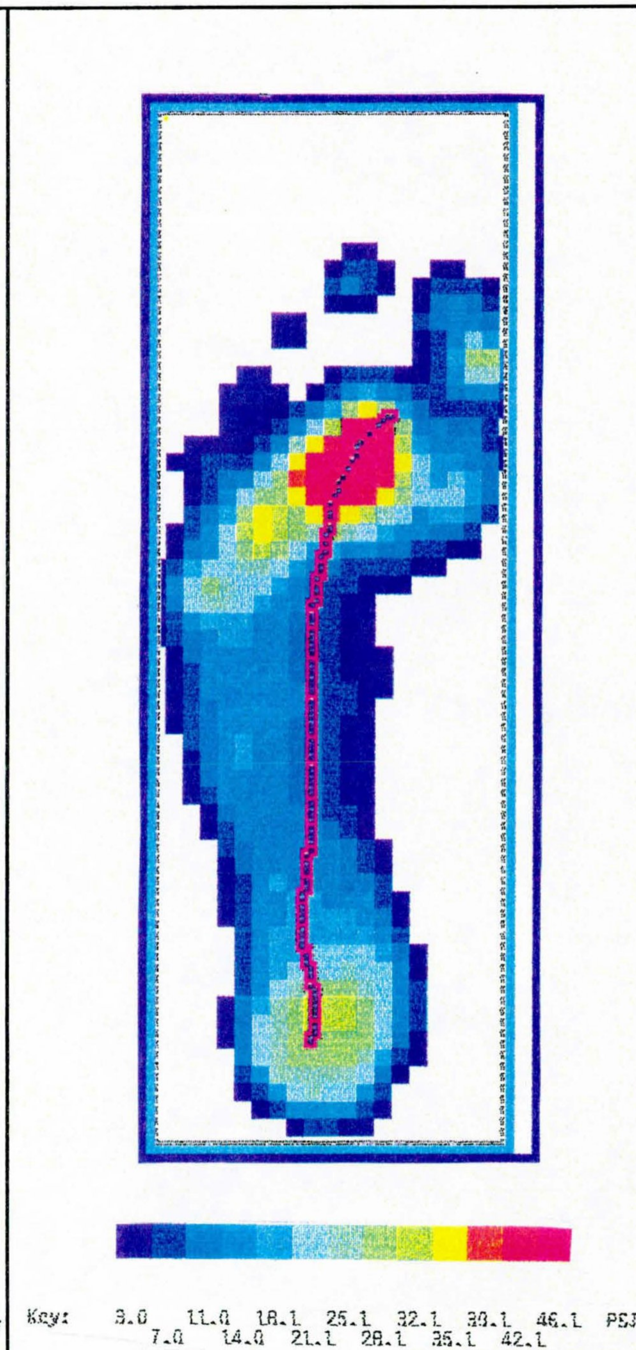

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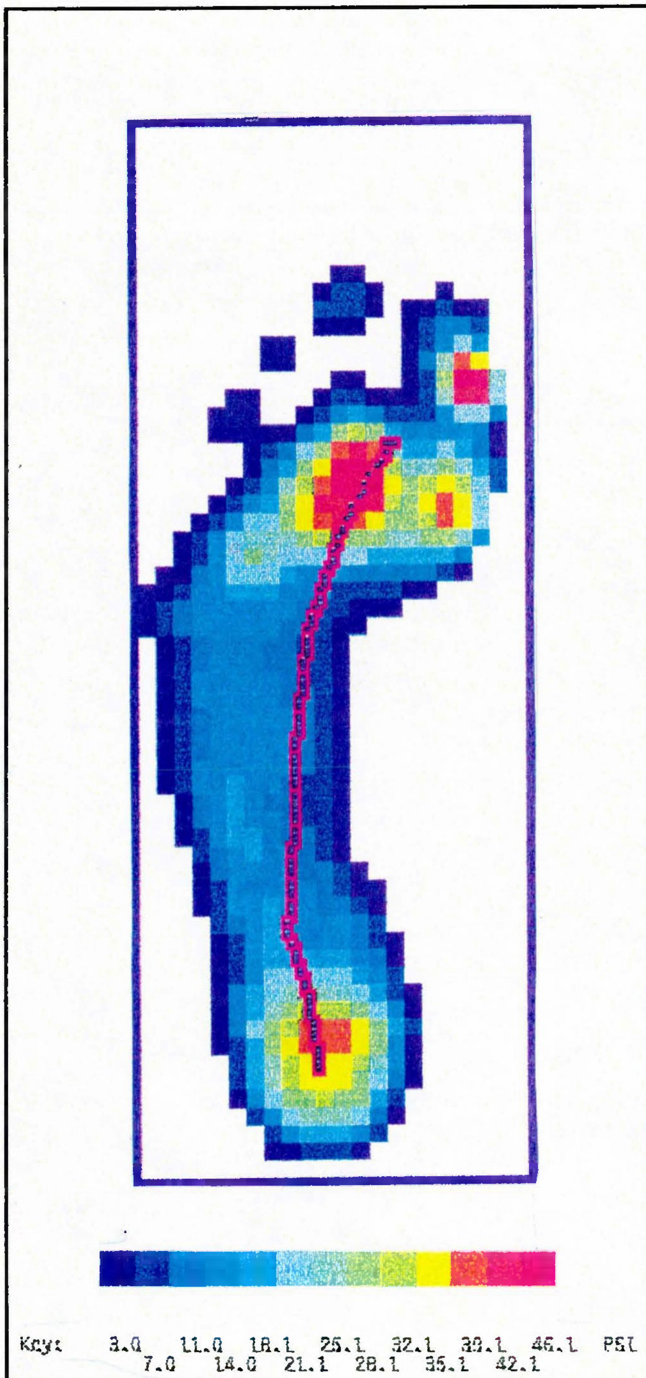

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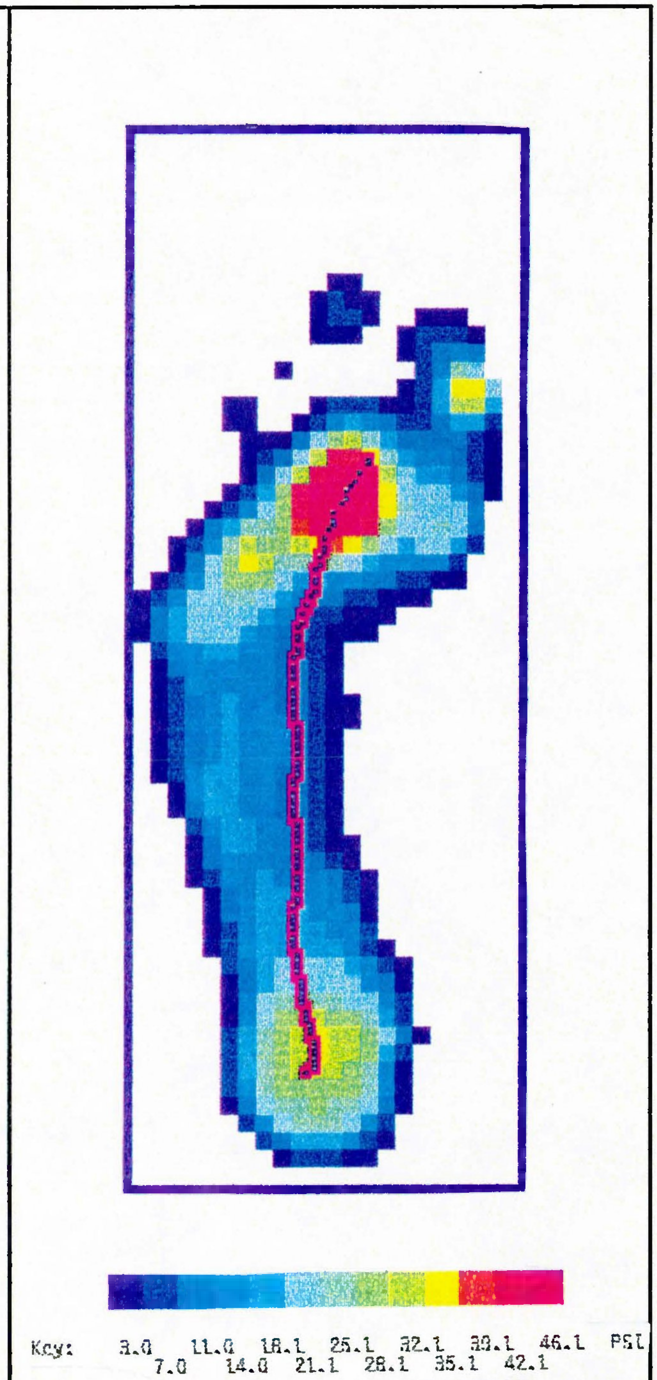

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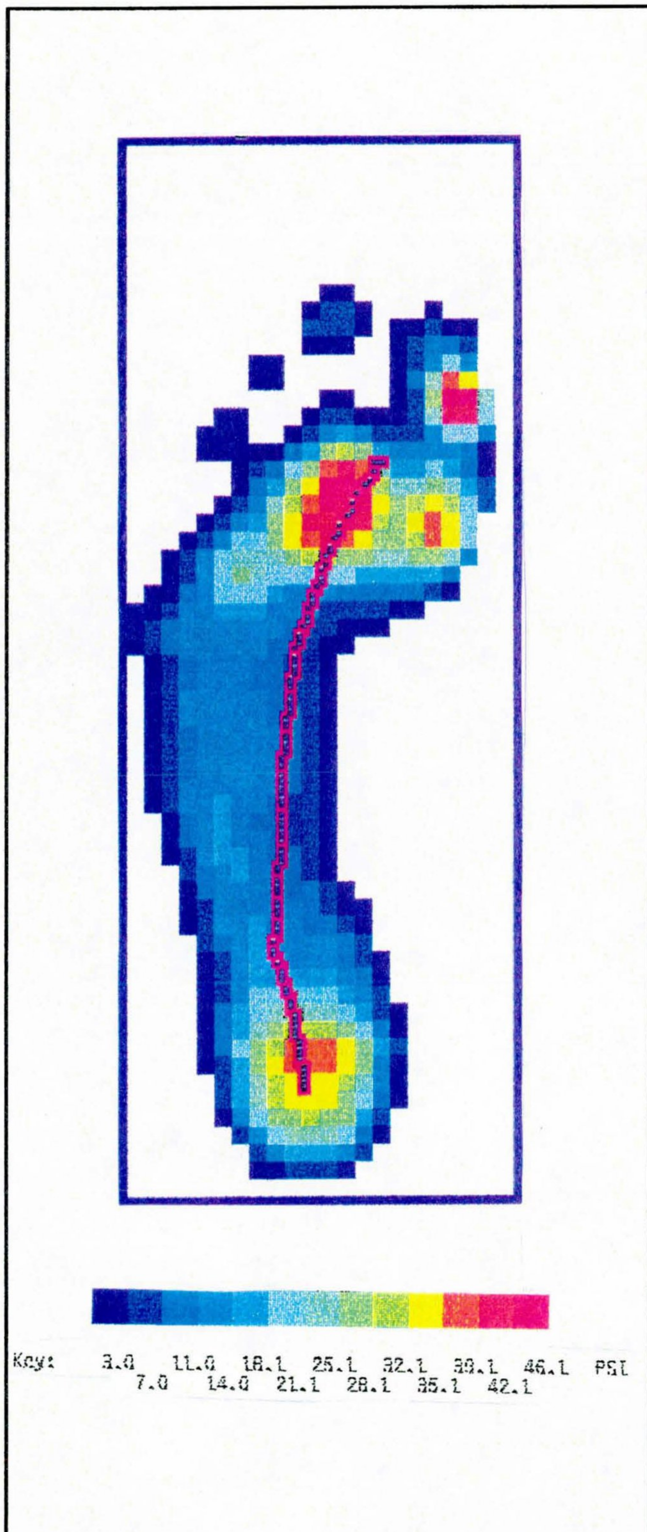

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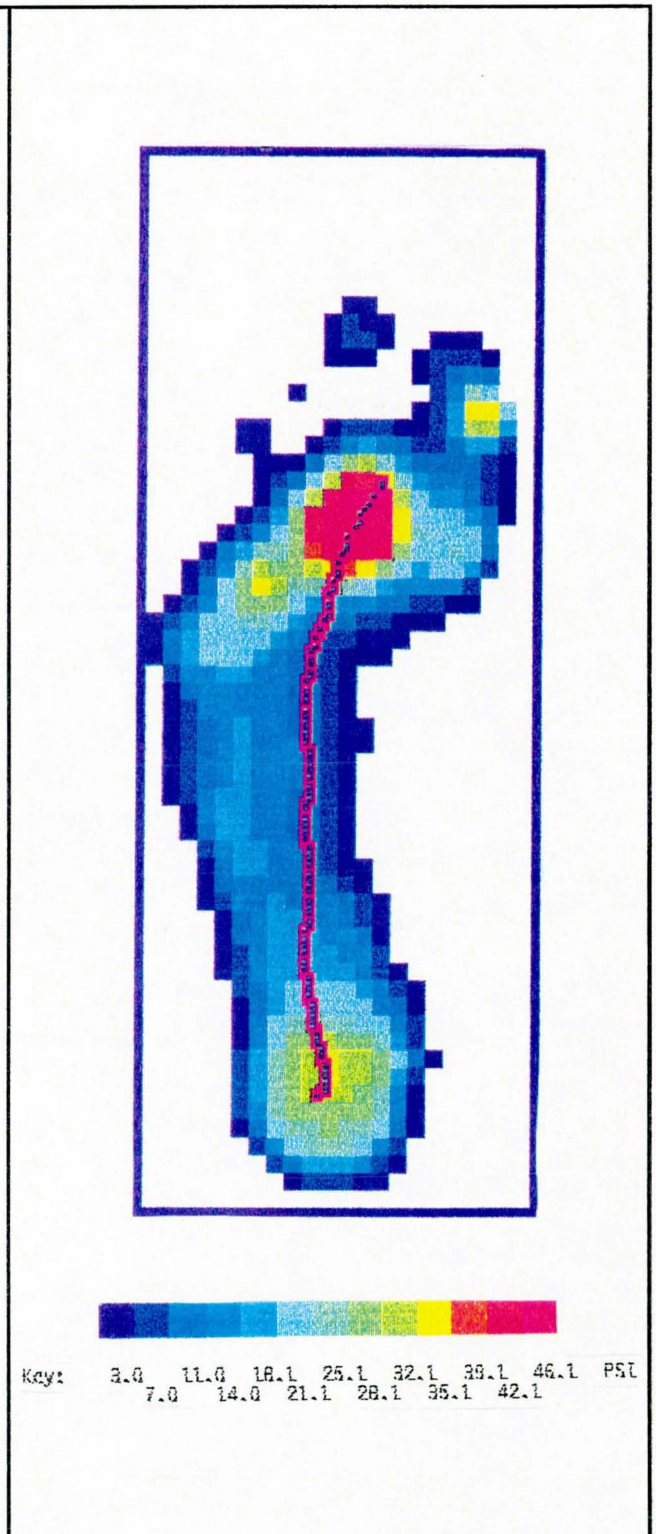

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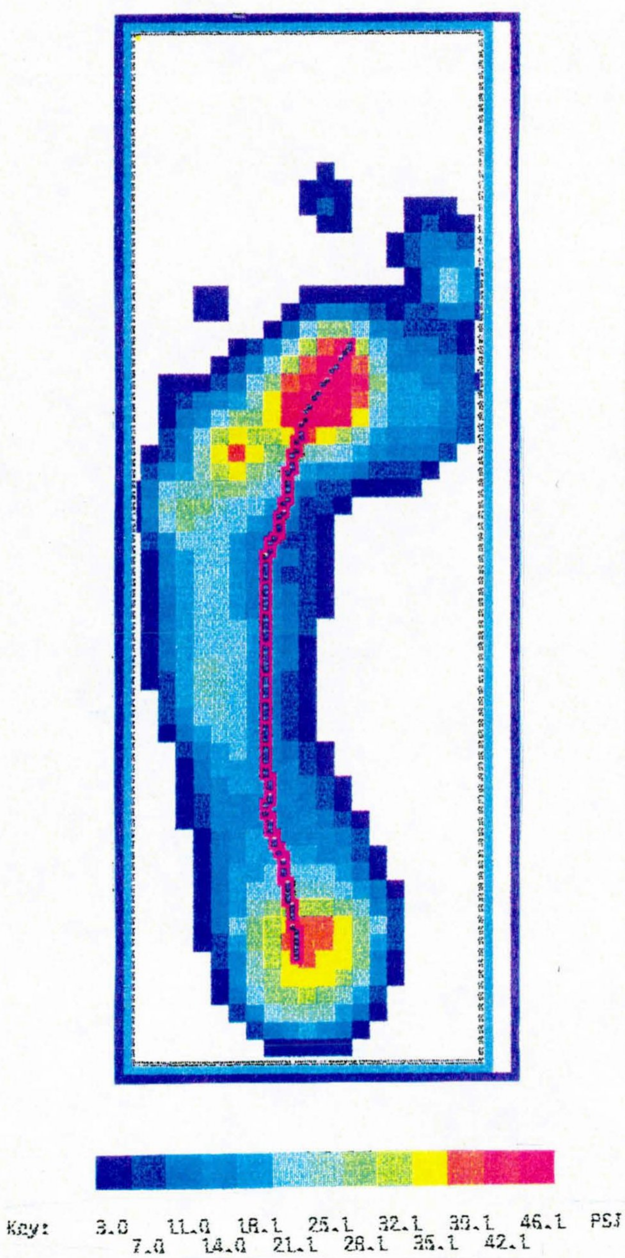

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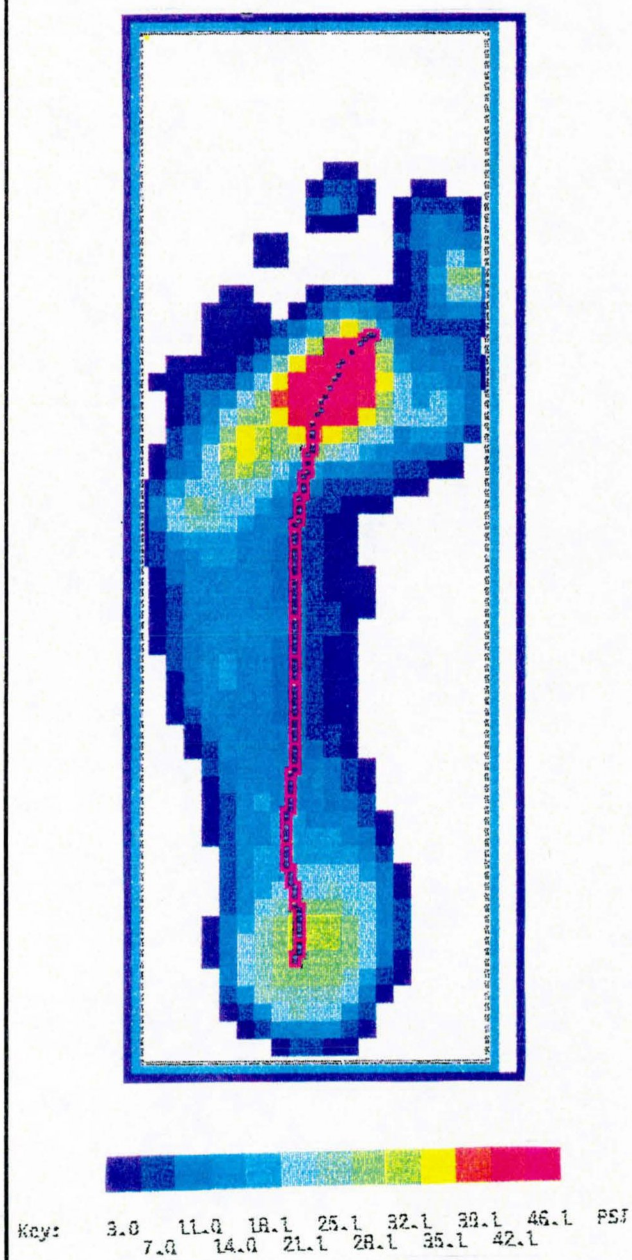

SUBJECT #10:

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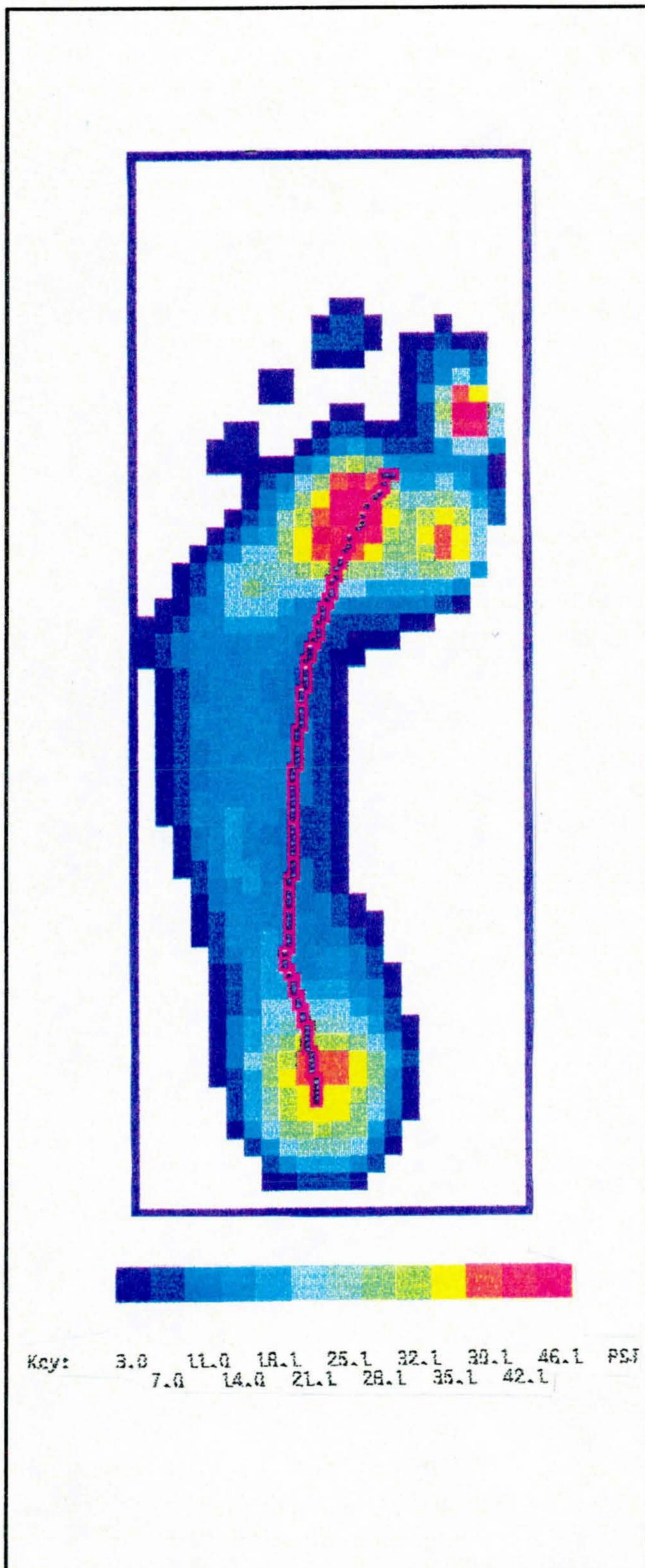

With tape