UNIVERSITY OF ALBERTA

THE EFFECT OF ANKLE SUPPORTS ON POSTURAL SWAY

BY

PAULO HENRIQUE FERREIRA ©

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECT OF ANKLE SUPPORTS ON POSTURAL SWAY submitted by PAULO HENRIQUE FERREIRA in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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DEDICATION

THIS THESIS IS DEDICATED TO MY RECENTLY DECEASED MOTHER, WHO WAS, IS, AND ALWAYS WILL BE MY GREATEST MOTIVATOR

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ABSTRACT

Ankle sprains have been considered the most frequent, single, specific injury in sports. Deficits of postural control, as expressed by excessive sway, have been identified in patients sustaining instability of the ankle joint. At the same time, normal subjects who demonstrate excessive sway run a higher risk of sustaining an ankle injury.

Ankle supports, such as adhesive athletic taping and braces, have been often employed in the rehabilitation and treatment of ankle sprains. Besides their effectiveness in restricting range of motion, a "proprioceptive" role has been ascribed to these supports, which could in turn, enhance postural control.

The objectives of this study were twofold: first, investigate the effect of athletic taping, and two ankle braces, the Airstirrup^{R} brace and the Donjoy^{R} brace, in decreasing postural sway of normal subjects when compared to a no support situation. Second, compare the ankle supports among themselves and establish their relative effectiveness in reducing sway of normal subjects.

A group of twenty, non injured people, were tested in the Chattanooga Balance System^{TM} during the movements of plantar flexion and inversion of the ankle and foot. Postural sway was analyzed in the frontal plane. Results demonstrated that the ankle supports did not reduce postural sway during the plantar flexion test when compared to a no support situation, and no difference was found when supports were

compared among themselves during this test. During the inversion test, both ankle braces were significantly superior in reducing sway when compared to no support; the taping technique demonstrated a trend in decreasing sway in contrast to no support, and the Airstirrup^{R} brace was statistically superior in reducing sway compared to taping.

It was concluded that, non injured people might have positive effects with the application of the ankle supports employed in this study if they wish to prevent a lateral ankle sprain by means of decreasing postural sway during activities involving inversion movements. During activities involving plantar flexion movements, these ankle supports appear not to reduce postural sway in the frontal plane, however, further research is necessary to investigate the effect of these appliances during this movement.

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CHAPTER ONE

INTRODUCTION

PROBLEM STATEMENT

With the increase in popularity of sports and fitness, there has been an increase in the number and range of injuries seen by physiotherapists (Heil, 1992). The majority of sports injuries involve the lower extremity; with the knee, ankle, and foot generally being the three most commonly injured anatomic parts (Garrick & Requa, 1988).

Ankle injuries constitute 20-25 percent of all time-loss injuries in every running or jumping sport (Mack, 1975). Garrick and Requa (1988) have stated that the ankle sprain is probably the most frequent, single, specific injury in sports. It is the most common injury in soccer (Nielsen & Yde, 1989), and the second most common in track and field (Watson & DiMartino, 1987) and basketball (DeHaven & Lintner, 1986). This injury typically occurs to the lateral ligamentous complex of the joint, when the foot is forced into a plantar flexed and inverted position (Alves et al, 1992).

The high incidence of this injury has induced researchers and clinicians to investigate the most effective protocols for treating and preventing this lesion from occurring.

External supports to the ankle, such as adhesive tape and braces, have been widely employed in the prevention, nonoperative treatment, and postoperative rehabilitation of injuries to the lateral ligaments of the ankle (Cass & Morrey, 1984; Konradsen et al, 1991). However, DeMaio et al (1992) have reported the high cost of these prophylactic devices, which makes it imperative to ascertain their real effectiveness.

Freeman et al (1965) first proposed that patients who experienced frequent sprains in the ankle or a feeling that the foot tended to "give way" had impaired muscle reflex stabilisation (loss of proprioception) of the ankle joint due to a loss of afferent input from the damaged ligaments and the capsule. Konradsen et al (1993) have also described the important role of muscle receptors in the proprioceptive system. At the same time, information provided by skin receptors has been considered to be involved in the awareness of joint position (Clark et al, 1979).

Studies using either clinical balance tests (Freeman et al, 1965; Garn & Newton, 1988; Lentell et al, 1990) or computerized measurement of body sway (Friden et al, 1989; Gauffin et al, 1988; Konradsen & Ravn, 1991; Tropp, 1986; Tropp et al, 1985) have detected deficits of postural control in patients with recurrent ankle sprains. At the same time, according to the report of Tropp et al (1984), noninjured athletes who demonstrate excessive postural sway run a higher risk of sustaining an ankle injury.

Besides their mechanical effect of stabilizing the ankle joint by resisting excessive movement, a "proprioceptive" role has been ascribed to ankle taping and orthoses (Firer, 1990; Greene & Roland, 1989). Greene and Roland (1989) have stated that these orthoses may provide an increase in the sensory input, which in turn, may enhance motor control of the muscles of the leg.

The literature addressing the mechanical effect of ankle supports is extensive, however there is still little data available on the effect of these appliances on motor control of the muscles in the leg, as well as on balance control (Feuerbach & Grabiner, 1993). Besides this lack of objective data, to the author's knowledge, no report had compared different ankle supports on this issue.

Postural sway is a technique which has been employed in the motor control assessment of ankle instability (Gauffin et al, 1988; Konradsen & Ravn, 1991; Tropp et al, 1984). Abnormal postural control, expressed by excessive sway, has been detected among unstable ankle patients (Friden et al, 1989; Gauffin et al, 1988; Konradsen & Ravn, 1991).

Because postural impairment (excessive sway) appears to play an important role in ankle instability and a motor control function has been hypothesized for ankle orthoses (Firer, 1990; Greene & Roland, 1989), an investigation of the actual effect of ankle supports on postural control was warranted. Further, objectively documenting the relative effectiveness of each appliance in postural stability could give the clinician a more informed basis upon which to assess the merits of such orthoses.

The purpose of this study was to determine the effectiveness of three ankle supports on postural control of uninjured subjects. A comparison of adhesive ankle taping and two different semirigid orthosis was chosen in order to examine the relative effect of each of these appliances compared to a nonsupported situation on normal subjects.

SIGNIFICANCE OF THE STUDY

Ankle sprains are one of the most common injures in sports (Garrick and Requa, 1988). Previous studies have identified deficits of postural control in patients sustaining these injuries (Friden et al, 1989; Gauffin et al, 1988; Konradsen & Ravn, 1991). The value of postural stability in predicting injury in normal subjects has also been established (Tropp et al, 1984).

External supports such as adhesive taping and orthoses have been widely employed in the prevention and treatment of sprained ankles (Cass & Morrey, 1984; Konradsen et al, 1991). Besides their effectiveness in restricting excessive range of motion, a "proprioceptive" role has been ascribed to these supports (Firer, 1990), which in turn, might enhance motor control (Greene & Roland, 1989). However, few studies have addressed this proposed function (Feuerbach & Grabiner, 1993). Considering the importance of postural stability in patients with unstable ankle joints and the hypothesized proprioceptive role of ankle supports, an investigation of the actual effect of these appliances on postural control was considered reasonable.

OBJECTIVES OF THE STUDY

The first objective of this study was to investigate the effect of an ankle taping technique (closed ankle taping configuration) and two orthoses (AirStirrup Ankle Training Brace™ and Donjoy® Ankle Ligament Protector) on postural sway of noninjured subjects when compared to a nonsupported situation. A balance machine (The Chattanooga Balance System™) was employed for the actual measurements and the parameters that were used in the protocol are:

1) Maximum sway on the frontal plane when the moveable platform caused plantar flexion movement on the ankle joint (plantar flexion test).

2) Maximum sway on the frontal plane when the moveable platform caused inversion movement on the ankle joint (inversion test).

The second objective of this study was to compare the taping technique and the two orthoses among themselves using the parameters noted above and to establish the relative effectiveness of each of the supports on dynamic postural control of normal subjects.

RESEARCH HYPOTHESES

The following hypotheses were investigated:

1. Normal subjects would have their postural sway decreased while wearing ankle supports when compared to a no support

situation during the plantar flexion test.

2. Normal subjects would have their postural sway decreased while wearing ankle supports when compared to a no support situation during the inversion test.

3. Ankle supports would differ significantly with respect to their ability to decrease postural sway during the plantar flexion test in normal subjects.

4. Ankle supports would differ significantly with respect to their ability to decrease sway during inversion test in normal subjects.

OPERATIONAL DEFINITIONS

1. Ankle Supports are appliances originally designed to enhance stability of the ankle joint. For the purposes of this study, an ankle strapping technique using athletic tape (closed ankle taping configuration) and two orthoses (Airstirrup Ankle Training Brace™ and Donjoy® Ankle Ligament Protector) were employed.

2. Plantar Flexion test was the measurement performed with subjects unilaterally standing on a footplate which was situated on a platform that tilted longitudinally, creating a plantar flexion pattern on the ankle joint.

3. Inversion test was the measurement performed with subjects unilaterally standing on a footplate which was situated on a platform that tilted laterally, creating an inversion pattern on the ankle joint.

4. Postural sway was measured as the maximum displacement of

the center of pressure under the foot in the frontal plane.

5. Ankle joint was defined as the joints of the foot-ankle complex- talocrural joint, subtalar joint, midtarsal joints.

DELIMITATIONS

This study was restricted to:

1. Subjects who had not previously had injuries to the lower limb nor problems affecting balance.

2. The use of dynamic postural control characterized by a test situation with a moveable platform.

3. The influence of ankle supports on postural control when compared to nonsupported ankles.

LIMITATIONS

The limitations of this study included:

1. Evaluation of dynamic postural control in the frontal plane using plantar flexion and inversion patterns on the ankle joint according to the movement of the platform.

2. The accuracy of the Balance System™ as a tool for measuring postural control.

3. Results of this study were limited to the three ankle supports: ankle taping-closed technique, Airstirrup Ankle Training Brace™, and Donjoy® Ankle Ligament Protector.

4. The generalization of the results of this study to a clinical population is not recommended since a sample of normal, uninjured people was employed.

CHAPTER TWO

LITERATURE REVIEW

NEUROPHYSIOLOGY OF MECHANORECEPTORS

INTRODUCTION

Mechanoreceptors are structures that provide information about the initiation of movement, the relative position of the joints, and the interaction of the joints with working muscle groups (Zimny, 1988). They are so called due to their response when deformation of their surfaces occurs (Carpenter, 1984).

During the application of a stimulus which causes constant deformation of their surfaces, some receptors tend to show a quick rise in the electrical activity and then a spontaneous fall back to the resting position, while others tend to stay activated during the application of the stimulus. The former ones are called rapidly adapting receptors and the latter are designated slowly adapting receptors (Carpenter, 1984).

Mechanoreceptors can be encountered in articular tissues, skin, and muscles. The discharge provided by these structures is important in the motor control of the body (Gandevia et al, 1992) as well as in the overall mechanics of limb movement (Shutte & Happel, 1990). Thus, a review of the neurophysiology of mechanoreceptors is relevant to the current investigation.

JOINT RECEPTORS

Freeman and Wyke (1965, 1967) performed an anatomical investigation of articular receptors at the ankle joint. These authors divided these receptors basically into types I, II, and III. Type I receptors were found in the superficial layer of the capsule and surface of ligaments. They are thinly encapsulated and are innervated by terminal myelinated fibers. Halata (1977) described these receptors as structures composed of small cylinders, each consisting of an afferent axon with its dendritic processes. These cylinders are situated between several bundles of collagen fibers running in different directions and by this means, they are probably able to monitor tension of several bundles of collagen fibers in the capsule (Halata, 1977). These receptors have a low threshold for activation and are slow to adapt to changes altering their firing frequency (Zimny, 1988). They show a discharge rate during resting and are today referred to as Ruffini-like receptors (Newton, 1982). Grigg and Hoffman (1982) observed that the Ruffini-like receptors are particularly sensitive to capsule stretching but relatively insensitive to compressive stress in a direction perpendicular to the plane of their surfaces. The behavioral characteristics of these receptors categorize them as static and dynamic mechanoreceptors responding to joint movement and muscle contraction (Zimny, 1988).

Type II receptors are encountered in deeper layers of the capsule but are absent in ligaments (Freeman & Wyke, 1967). They are thickly encapsulated and like type I receptors they are innervated by myelinated fibers (Freeman & Wyke, 1965). The core of these receptors is formed by a lamellar system of Schwann cells while their capsule is a continuation of the perineum of the afferent nerves (Halata, 1977). They have low threshold for activation, rapid adaptation, and are presently referred to as Pacinian-like receptors (Carpenter, 1984). They are considered to be dynamic mechanoreceptors, become active at the onset and cessation of joint movement and are entirely inactive in immobile joints (Zimny, 1988). Grigg et al (1982) have studied another type of mechanoreceptor that resembles the Pacinian corpuscle in morphology. These mechanoreceptors are called Golgi-Mazzoni endings and like the Pacinian receptor, have terminal endings within thin encapsulation and are encountered in the inner surface of the capsule (Gould, 1990). However, they are functionally classified as slowly adapting, low mechanical threshold receptors which are sensitive to compression in a plane perpendicular to the plane of the capsule (Grigg et al, 1982).

Type III receptors are confined to the joint ligaments but are absent from all the other articular tissues (Freeman & Wyke, 1967). They are also encapsulated and receive innervation from large diameter fibers (Freeman & Wyke, 1965). Morphologically similar to Golgi tendon organs (receptors encountered in muscle tendons), today they are called Golgi tendon organlike (Gould, 1990) and are the largest of the articular receptors (Newton, 1982). Stimulus response data suggest that these receptors are high-threshold, slowly adapting mechanoreceptors that are completely inactive in immobile joints and become active only when joints are at the extremes of their range of movement (Zimny, 1988). Information regarding the characteristics of these receptors is summarized in table 1.

Receptors	Location	Threshold for activation	Adaptation to stimulus	Behavioral features
Ruffini-like (Wyke's type I)	Superficial layer of capsule/ ligaments	Low	Slow	-sensitive to stretch but not to compressive stress.
Pacinian-like (Wyke's type II)	Deeper layer of capsule - absent in ligments	Low	Rapid	-dynamic receptors -active at onset and cessation of movement
Golgi tendon organlike (Wyke's type III)	ligaments- absent from other articular tissues	High	Slow	-active only at extremes of range of motion
Golgi-Mazzoni endings	Inner surface of capsule	Low	Slow	-sensitive to compression

Table 1- Characteristics of joint mechanoreceptors.

According to Shutte and Happel (1990), the role of joint receptors in limb function is still a source of debate. Sabbahi et al (1990) found that the ability of subjects to detect movement at the ankle joint decreased after anaesthesia of the capsule. This decreased motion sense ability has been detected among subjects with multiple ankle sprains (Garn & Newton, 1988). De Carlo and Talbot (1986) and Konradsen et al (1993) did not detect a decrease in postural control in normal subjects when the ankle joint capsule was injected with anaesthetic. Past research (Appelberg et al, 1979; Freeman et al, 1967; Sabbahi et al, 1990) has demonstrated reflexes in the ankle muscles after stimulation of mechanoreceptors in the capsular tissues, indicating an interaction between receptors and muscle activity.

MUSCLE RECEPTORS

Skeletal muscle and its tendon have specialized mechanoreceptors (Simpson & Fitch, 1980). These receptors have been described by Carpenter (1984) and comprise the muscle spindle and the Golgi tendon organs.

The muscle spindle consists of a capsule whose ends are attached to neighbouring muscle fibers. Inside is a small number of muscle fibers called intrafusal fibers, each having contractile ends, and a region in the middle that is not contractile. Two kinds of afferent fibers innervate the spindle: larger fibers (group Ia) and smaller fibers (group II). Besides the two kinds of afferent fibers, spindles also receive a motor innervation from the gamma fibers.

Muscle spindles are placed in parallel with extrafusal fibers and provide signals of both the degree and velocity of stretch (Simpson & Fitch, 1980). Williams (1981) has pointed out the importance of these structures in providing information regarding the position of the joint. In fact, Konradsen et al (1993), in a study of the ankle joint, have observed that subjects recover their position sense when the calf muscles are activated, despite regional block of the ankle and foot with local anaesthetic. Muscle reflexes at the ankle joint depend upon the discharge provided by spindle receptors (Konradsen et al, 1993; Sabbahi et al, 1990; Simpson & Fitch, 1980). Therefore, these structures seem to be crucially involved in informing and controlling movement occurring at the ankle joint.

Golgi tendon organs are situated in muscle tendons, in series with the contractile elements (Carpenter, 1984). Unlike the spindle, the tendon organs respond to tension produced in the muscle, thus being stimulated whether the muscle contracts or stretches (Simpson & Fitch, 1980).

SKIN RECEPTORS

Skin mechanoreceptors have been divided into two groups according to their velocity of adaptation to the applied stimulus (Gandevia et al, 1992). Rapidly adapting receptors include Meissner's corpuscles and Pacinian corpuscles while slowly adapting receptors comprise Merkel cells and Ruffini endings (Gandevia et al, 1992).

Pacinian and Meissner corpuscles are particularly sensitive to vibration and thus are suited for contributing to the sense of roughness characteristic of the skin (Carpenter, 1984).

Studies by Chambers and Iggo (1967, 1968) have identified characteristics that distinguish the two types of slowly adapting skin receptors. Merckel cells (type I) are called "touch corpuscles". They are excitable in a restricted area around or on the receptor organ and their units lack a resting discharge. Ruffini endings (type II) are exited from a larger area and usually carry a resting discharge. Type II skin receptors are easily excited by stretching of the skin whereas type I units require local deformation (Chambers et al, 1972).

Information provided by skin receptors has been considered to be involved in the awareness of joint position (Clark et al, 1979). Simpson and Fitch (1980) have stated that cutaneous receptors in skin overlying the joints become progressively more important at distal joints for signalling joint movement. Sabbahi and De Luca (1982) identified a decrease of the achilles tendon reflex after skin desensitization, implying an effect of skin receptors upon muscle coordination in the leg.

Although the concept that different mechanoreceptors may show specific functions in the motor control of the body seems attractive, some authors have advocated a mutual interaction between the different afferent systems (Shutte & Happel, 1990; Williams, 1981). In fact, joint afferents have been found to be influenced by tension developed by the muscles acting at the joint (Millar, 1973). On the other hand, fusimotor neurones can be excited by joint afferent stimulation (Appelberg et al, 1979), thus indicating that the afferent systems may be integrated and modulate each other.

MOTOR CONTROL IN THE UNSTABLE ANKLE

Ankle sprains usually involve injury to the lateral ligaments of the joint (Zimmer, 1991). The three principal lateral ligaments of the ankle are the anterior talofibular, calcaneofibular, and posterior talofibular (Lassiter et al, 1989). The anterior talofibular ligament has been thought to resist the movement of inversion if the ankle is in plantar flexion, and the calcaneofibular ligament has been thought to resist inversion if the foot is in the neutral position (Cass & Morrey, 1984). Adduction of the forefoot and inversion of the subtalar joint when the ankle is plantar flexed (the combination of these movements is called supination) mainly sprains the anterior talofibular ligament, the most common structure injured in ankle sprains (DeMaio et al, 1992). Adduction of the forefoot and inversion of the subtalar joint with the ankle in neutral mainly sprains the calcaneofibular ligament, the second most often injured ligament (DeMaio et al, 1992). The posterior talofibular ligament is the strongest of the three lateral ligaments and the least injured (Lassiter et al, 1989). It is most commonly injured with extreme inversion and dorsiflexion (DeMaio et al, 1992).

Functional instability of the ankle is a term proposed to designate the disability to which patients refer when they say that their foot tends to "give way" as well as the report of frequent ankle sprains (Freeman et al, 1965). The three most common factors presented in the literature that have been suggested as the cause of functional instability of the ankle are: mechanical instability caused by ligamentous tears, weakness of the peroneus longus and brevis muscles, and deficits in proprioception caused by rupture of nerve fibers and receptors that lie in ligaments and capsule (Lentell et al, 1990). Even though the concept that loss of proprioception coming from the ligaments still remains as a cause of functional instability, the information provided by the muscles seems to be the afferent system responsible for dynamic ankle protection against sudden ankle inversion (Konradsen et al, 1993).

Freeman et al (1965) first proposed that functional instability of the ankle was due to motor incoordination of the muscles in the leg due to articular de-afferentiation, i.e. rupture of nerve fibers and receptors. Since then, researchers have attempted to confirm this theory and identify what aspects of motor control are affected in unstable ankle patients.

Garn and Newton (1988) performed a study to determine whether decreased kinaesthetic awareness occurred in individuals with recurrent ankle sprains. They defined kinesthesia as the ability to discriminate joint motion. Subjects were asked whether they perceived a movement or not when a platform was moved passively. Results indicated that subjects had significantly greater difficulty detecting passive motion in the ankle with lateral ligament sprains as compared with the uninjured ankle.

Gross (1987) examined the effects of recurrent ankle sprains on judgements of joint position. Subjects attempted to replicate predetermined ankle joint positions in the inversion-eversion range of motion. No significant effect was caused by joint injury. Similar results were found by Konradsen et al (1993) when ankle joints of normal subjects were injected with local anaesthetic.

Another aspect of motor control that has been examined in functional ankle instability is peroneal reaction time. The rising interest in the performance of the peronei muscles is basically due to their proposed contribution to dynamic stability of the ankle joint (Cass & Morrey, 1984). The peroneal reaction time is usually defined as the time to onset of motor response in these muscles after an angular displacement of a platform that supports the foot, dropping the ankle into supination (Nawoczenski et al, 1985). Karlsson and Andreasson (1992) identified an increase in the reaction time of the peronei muscles of unstable ankles when compared to stable ones, indicating a delay on the activity of the peroneal musculature of unstable joints. Konradsen and Ravn

(1990, 1991), comparing the peroneal reaction time of normal subjects and those with functional unstable joints, observed prolonged reaction time in the pathological group. Similar results were found by Brunt et al, (1992).

Studies by Johnson and Johnson (1993) and Nawoczensky et al (1985) revealed a trend towards delayed peroneal response in injured ankles compared to noninjured ones, however no significant difference was detected.

Konradsen et al (1993) assessing the role of ankle receptors in motor control, observed no change in the reaction time of peronei muscles after anaesthesia of the ankle joint.

Postural control has been the focus of interest of investigators dealing with functional ankle instability since the pioneer work by Freeman et al (1965). These authors assessed postural stability using a clinical balance test (modified Romberg test), in which the patients' stability was evaluated when standing on the injured foot and compared with the noninjured foot. They reported balance impairment (decreased ability to maintain the upright posture) when subjects stood on an unstable ankle.

Garn and Newton (1988) and Lentell et al (1990) also employed clinical balance tests to examine postural control in ankle instability patients. In both studies, the authors observed deficits in the control of posture when ankle instability patients stood on the injured foot.

In order to more objectively evaluate postural control in ankle instability, objective methods have been employed, replacing the clinical balance tests (Gauffin et al, 1988). These methods usually express the amplitude of sway of the center of pressure during limb stance on a force plate (Konradsen & Ravn, 1991).

Using measurement of sway in all planes in an attempt to quantify postural control in unstable ankle subjects, Tropp et al (1984a, 1984b) did not identify any deficits in balance of subjects with ankle instability. Later, the same authors did observe impaired postural control as expressed by excessive sway when patients used their injured ankles compared with noninjured joints (Tropp, 1986), as well as when subjects with unstable ankles were compared with those without any symptoms of ankle sprains (Tropp et al, 1985).

Friden et al (1989) proposed the assessment of sway in the frontal plane only, arguing that this approach could improve the sensitivity of the test for detecting differences in postural control of unstable ankles. These investigators found an increase in sway when patients stood on the injured foot compared to the noninjured one and also compared to normal subjects. Gauffin et al (1988) as well as Konradsen and Ravn (1991) used the method proposed by Friden et al (1989) and obtained similar results.

Therefore, impaired postural control seems to be involved in the pathologic process of ankle instability, and increase of sway in the frontal plane appears to be present in patients with unstable ankle joints.

POSTURAL CONTROL DURING STANDING

Postural control is the ability of an individual to maintain equilibrium in a gravitational field by keeping or returning the projection of the center of body mass over its base of support (Horak, 1987).

Sensory processes in balance control involve interaction among orientation inputs from somatosensory (joint, muscle, and skin receptors information), visual, and vestibular systems (Cook & Horak, 1986). The sensory input from these systems provides information for the coordination of postural movements, which are assumed to restore equilibrium in varied circumstances, such as in response to unexpected disturbances to equilibrium (Cook & McCollum, 1985).

Horak and Nashner (1986), studying automatic postural reactions in standing human subjects, observed that when subjects stood on a support surface exposed to forward and backward horizontal perturbations, the muscle activation was initiated in the ankle muscles (gastrocnemius and tibialis anterior) and then radiated in sequence to thigh and trunk muscles. This pattern of activation was termed "ankle strategy", because it restored equilibrium by moving the body primarily around the ankle joints. Conversely, when the support surface was replaced by another one shorter in relation to foot length, the trunk and thigh muscles were activated first, and the activation radiated distally to the ankle joint muscles. This pattern was called "hip strategy", because the resulting motion was focused primarily about the hip joints.

Brunt et al (1992) have investigated postural responses of healthy subjects following a platform perturbation that created sway in the frontal plane. This perturbation had the effect of everting and loading one limb while inverting and unloading the contralateral limb. Responses in the posterior tibialis muscle of the loaded limb and in the peroneus longus muscle of the unloaded (inverted) limb was noted following the perturbation.

Researchers have also attempted to identify the real significance of each different somatosensory system on postural stabilization (Diener et al, 1984; Cohen et al, 1993; Dickstein & Dvir, 1993).

Diener et al (1984) investigated the role of sensory input from skin and joint receptors at the ankle joint on postural control. Results demonstrated that after application of ischemia above the ankle (excluding afferent information from skin and joint), subjects showed an increase in sway with horizontal displacement of the support platform. However, with sudden ramp movements of the measuring platform (angular displacement), body sway was not affected with blockage of skin and joint afferents. Konradsen et al (1993) did not identify increased postural sway in normal subjects after regional block of the skin and ankle joint receptors.

The vestibular apparatus forms part of the inner ear, being responsible for signalling movement of the head and consequently controlling posture (Carpenter, 1984). Cohen et al (1993), using a clinical balance test (clinical test of sensory interaction and balance), detected impaired performance of patients diagnosed with vestibular disorders when compared to an age-matched group. Conversely, Nashner (1982) has observed that impaired vestibular patients did not lose their balance when standing on a moveable platform.

Vision, as a system which is involved in the detection of motion of the body, has been ascribed an important role in postural control (Cook & McCollum, 1985). Studies by Dickstein and Dvir (1993) and Kollegger et al (1989) have objectively determined an increase in sway of normal and neurological subjects when standing with eyes closed compared to eyes open.

ANKLE SUPPORTS IN JOINT MOTION RESTRICTION

Due to the high incidence of ankle sprains, health care professionals have attempted to devise methods to protect the ankle joint from initial and recurrent injury (Gross et al, 1987).

The application of adhesive tape to the ankle has been used in the athletic environment for several decades (Greene & Wight, 1990). Ankle orthoses have also been designed as alternative means of support (Alves et al, 1992). These devices range from cloth lace-on braces to semirigid orthoses made of plastic polymers and thermoplastic materials (Greene & Hillman, 1990).

Ankle taping has been found to decrease the amount of inversion occurring at the subtalar joint by 63% immediately after application (with no activity in between) when this movement was assessed radiologically (Vaes et al, 1985). Taping also restricted movements of supination (combination of plantar flexion at the ankle joint, inversion at the subtalar joint, and adduction at the midtarsal joints) by 47% after application when compared to a pre-application situation (Wilkerson, 1991). However, studies have indicated losses in taping restriction of inversion and supination movements by 20% after twenty minutes (Greene & Hillman, 1990) and sixty minutes of exercise (Myburgh et al, 1984).

Past research has indicated that ankle braces can be effective in restricting motion at the ankle joint (Bruns & Staerk, 1992; Greene & Roland, 1989; Kimura et al, 1987). The AirStirrup Ankle Training Brace™ is a semi-rigid orthoses with inflatable air cylinders and rigid medial and lateral stirrups (Greene & Wight, 1990). This ankle support has been found to reduce inversion movement at the subtalar joint by 33% after application (Kimura et al, 1987). Bruns and Staerck (1992) also observed inversion movement restriction by 38% when lace-on braces were analyzed.

The question that arose was which method of support was most effective in preventing ankle sprains? Bunch et al (1985) compared ankle taping with lace-on braces in restricting inversion movement. Taping was found to be the most effective after application but also the type of support that demonstrated the greatest percent of loss (21%) in support after twenty minutes of exercise. Gross et al (1987) carried out a comparison of support provided by athletic taping and the AirStirrup Ankle Training Brace[TM]. Post-application and post-exercise inversion motion was significantly less than pre-application motion for both supports. Taping decreased inversion range of motion by 34% after application and by 24% after exercise compared to pre-application. The AirStirrup restricted the inversion movement by 40% after application and by 39.5% after exercise in comparison with the pre-application moment. However, the semirigid orthosis limited inversion motion 15% more than taping following exercise.

Comparative support evaluations of different ankle orthoses have indicated a tendency towards better support being provided by semi-rigid ankle orthoses when compared to lace-on braces (Alves et al, 1992).

The Donjoy[R] Ankle Ligament Protector is a brace consisting of a single posterior strut attached to a heel cup which contains the heel of the foot (Greene & Wight, 1990). This orthoses demonstrated 6% better restriction of inversion movement when compared to the AirStirrup Ankle Training Brace[TM] following application and following exercise (Gross et al, 1992). Greene and Wight (1990) have observed that both AirStirrup Ankle Training Brace[TM] and Donjoy[R] Ankle Ligament Protector offer an average of 15% more ankle inversion motion restriction than lace-on braces.

EFFECT OF ANKLE SUPPORTS ON MOTOR CONTROL

Although the literature has been widely addressing the mechanical effect of ankle supports, there is still little data available on the effect of these appliances on postural sway (Feuerbach & Grabiner, 1993).

Kozar (1972) investigated the effect of ankle taping upon dynamic balance. Subjects stood bilaterally on a platform while photo transistors recorded the amount of sway. Results demonstrated no significant difference between taped and nontaped situations. Tropp et al (1984), using a different technique of balance evaluation (force plate platform), measured sway in all directions of a group of soccer players taped and nontaped. Taping showed no effect in decreasing sway of the athletes.

Taping has been found to stimulate the peroneal musculature and keep the peroneus muscles functioning for a longer period of time compared to a nontaped situation (Glick et al, 1976). Karlsson and Andreasson (1992) measured the reaction time of peroneus muscles of unstable ankles before and after application of athletic taping. The reaction time was established as the time difference between the start of the tilting of a support platform upon which the subjects stood, and the first muscular response registered by electromyography. The reaction time was significantly shortened in unstable ankles when measured with the application of adhesive tape compared to no tape being applied. The authors pointed out that the mechanism behind the function of ankle tape might be related to proprioception stimulation of the ankle joint. This effect could not be verified by Konradsen and Ravn (1991), since a shortening effect on the reaction time of the peroneal musculature was not observed.

Few studies have examined the effect of ankle orthoses on postural sway (Feuerbach & Grabiner, 1993; Friden et al, 1989). Friden et al (1989) observed a reduction in sway in the frontal plane measured by a force plate platform when unstable ankles were braced with the AirStirrup Ankle Training Brace™. The same orthoses was employed in a investigation performed by Feuerbach and Grabiner (1993). Using normal subjects, these authors detected a decrease in sway after the application of the ankle support. However, no study has compared different types of braces and ankle taping in postural performance.

SUMMARY

Impaired postural control appears to be involved in the pathologic process of ankle instability. As a means of preventing ankle sprains in the normal population and in unstable ankle patients, health care professionals have employed taping techniques and designed new ankle braces. A "proprioceptive" function has been ascribed to these ankle supports but their actual effect on this phenomenon is not well established and, to the author's knowledge, no study has compared different types of supports in postural sway.

CHAPTER THREE

METHODS AND PROCEDURES

STUDY DESIGN

This was a within subject control, one group pre-test post-test study. Twenty healthy, normal participants with no previous injury to the lower limb affecting balance were recruited and their dynamic postural control was assessed as a one-time measure at that time.

Participants had only the dominant right lower limb employed in the test. They were tested in two different movement situations occurring at the joints of the ankle complex. One situation employed movement of the platform on which subjects stood unilaterally, that created a plantar flexion pattern (plantar flexion test) on the joints of the foot and ankle. The second situation employed movement of the platform creating inversion (inversion test) on the foot-ankle complex while the subjects stood on unilaterally.

For each of the two movement, one-legged tests (plantar flexion and inversion tests), the subjects were measured in four different support situations: nonsupported, taped, wearing the AirStirrup Ankle Training Brace™, and wearing the Donjoy® Ankle Ligament Protector Brace (A.L.P.). Initially, for each subject, the order of the supports being used was defined by means of randomization. The same procedure was used to determine the order of the movement tests i.e. plantar flexion test initially and then the inversion test or inversion test first and then the plantar flexion test. For instance, if the order of the supports would have found to be the following: taping, no support, Airstirrup^{R}, and Donjoy^{R} then the next step was to determine the order of movement for the tests. If this order was defined as plantar flexion test first and inversion test second, then, for all the support situations (taping, no support, Airstirrup, Donjoy), the plantar flexion test would be performed first and the inversion test immediately after (Figure 1).

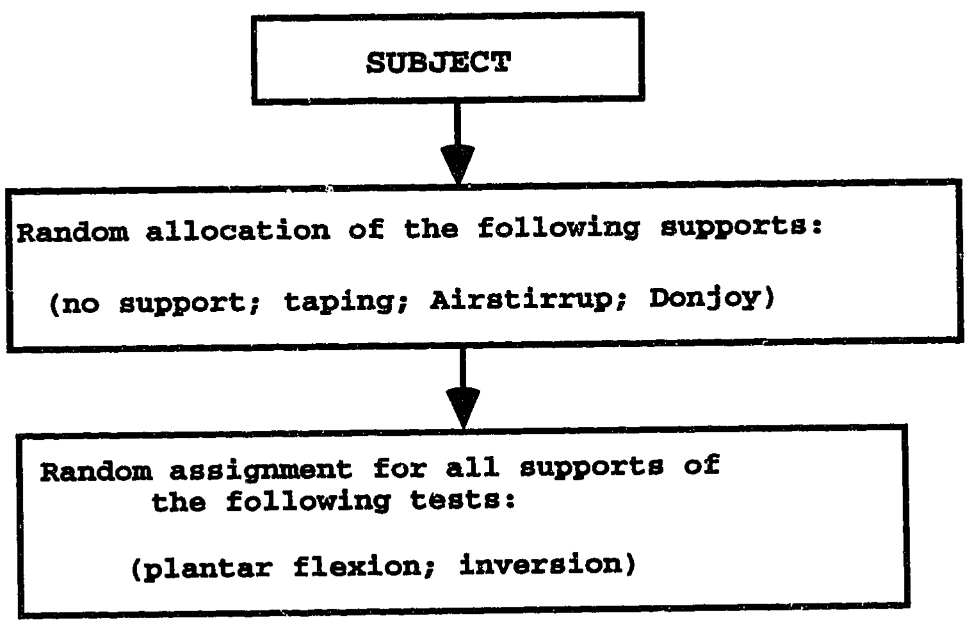

Figure 1- Flowchart of study design.

The same right-dominant limb was used as a control because there is a great deal of individual variability in balance strategies that one can employ in order to maintain the upright posture (Dickstein & Dvir, 1993).

Within subject design has also been employed by Feuerbach and Grabiner (1993) in a study evaluating the effect of an ankle brace (AirStirrup Ankle Training Brace™) on postural control, however no comparison of different types of ankle supports was performed.

SUBJECT RECRUITMENT

Subjects, both males and females, were recruited from students, staff, and faculty in the Faculty of Rehabilitation Medicine. Subjects were also recruited via posters on the University of Alberta campus. A participant information sheet (Appendix A) was distributed among students, staff members, and other potential subjects. All subjects signed a consent form (Appendix B) before participating in the study.

A goal of twenty subjects was determined using a sample size calculation (Appendix C).

STUDY PARTICIPANTS

A total of 20 normal, healthy volunteers participated in the study. Subjects had no past history of any episode of ankle sprain or complaints of pain, swelling, weakness, or a feeling that the foot "gave way" as described by Freeman et al (1965). Lentell et al (1990) detected increased sway of patients who presented with symptoms noted above, and therefore, the exclusion of subjects with these characteristics was an attempt to avoid history influences due to previous injury on the outcome.

Subjects with a history of musculoskeletal injuries to the lower limbs characterized by fractures, contusions with consequent muscle fiber rupture, second or third degree muscle strains, and second or third degree joint sprains were also rejected. These types and degrees of musculoskeletal lesions are characterized by disruption of tissues such as bone, muscle, ligament and capsule and therefore might be accompanied by ruptures of nerve fibers which have a low tensile strength (Freeman et al, 1965). Injury to the nerve fibers might have caused motor incoordination of the muscles in the lower limb and affected the measurements.

Individuals with history of vestibular disease, "dizziness", or ataxia were not included in the study since patients with these conditions are known to have impaired balance performance when compared to normals (Cohen et al, 1993).

Volunteers participating in the study were between 20 and 33 years old with a mean age of 25. Black et al (1982) have identified no difference in postural sway in different age groups within the range noted above. No difference in postural sway between males and females has been found (Black et al, 1982; Friden et al, 1989), and therefore male and female subjects were included in the study.

DATA COLLECTION

PROCEDURE

Initially, posters containing introductory information were posted at the Faculty of Rehabilitation Medicine and on campus of the University of Alberta. A participant information sheet (Appendix A) describing the purposes of the study, including the contact name and telephone number was distributed among students, staff members, and other potential subjects. If the individual responded to a poster, he/she was provided with the information contained on the information sheet verbally. The individual was also questioned regarding inclusion/exclusion criteria to determine eligibility for the study. Following initial contact with the study investigator, an appointment for the testing was made at a mutually convenient time.

The assessment of dynamic postural control took place in Corbett Hall at the Sports Physical Therapy Laboratory, University of Alberta. The evaluation took approximately two hours per subject and was a one-time measure. Data were collected solely by the investigator.

All subjects were questioned with respect to age, gender, ocurrence of ankle sprains, musculoskeletal injuries to the lower limb, and vestibular disease.

The plantar flexion test was performed with the footplate positioned on the moveable platform forming a 84 degree angle of alignment with the transverse axis of rotation of the platform which ran right below the medial malleolus. This disposition was an attempt to adjust the axis of rotation of the machine with the axis of rotation of the ankle joint where the majority of the plantar flexion movement occurs (Kotwick, 1982), (Figure 2).

Once the test started, the platform moved 4 degrees downward, creating a plantar flexion pattern on the foot. The platform then moved back to its original horizontal position. This test was employed because the anterior talofibular ligament, the most common ligament injured in ankle sprains (DeMaio et al, 1992), is particularly sensitive to the plantar flexion movement, being the most important ligament in stabilizing the ankle in this position (Nigg et al, 1990; Stephens & Sammarco, 1992). Thus the employment of this test offered the opportunity to examine the effect of ankle supports in decreasing sway when the ankle joint was unstable in this position.

The inversion test was performed with the footplate aligned at a 23 degree angle with the transverse axis of rotation of the moveable platform which ran right below the medial malleolus. This disposition was an attempt to position the axis of rotation of the machine in accordance with the axis of rotation of the subtalar joint, where the majority of the inversion movement occurs (Kotwick, 1982), (Figure 3).

With the movement of the platform downwards 4 degrees, an inversion movement occurring primarily at the subtalar joint takes place. This test was employed because the inversion movement with the ankle in neutral or slight plantar flexion position primarily stresses the calcaneofibular ligament (Nigg et al, 1990), the second most often injured ligament in the ankle (DeMaio et al, 1992).

Subjects were tested in 4 situations: 1) nonsupported, 2) supported with adhesive taping, 3) supported with the AirStirrup Ankle Training Brace™, and 4) supported with the Donjoy® Ankle Ligament Protector.

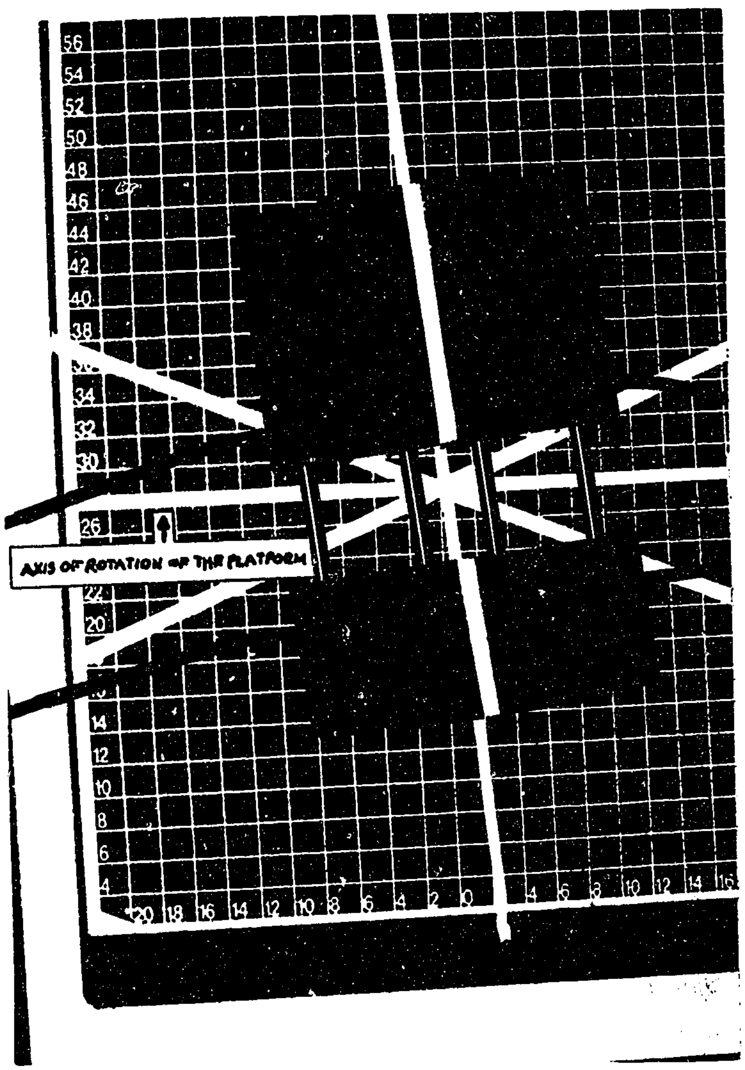

Figure 2- Alignment of footplates for the plantar flexion test.

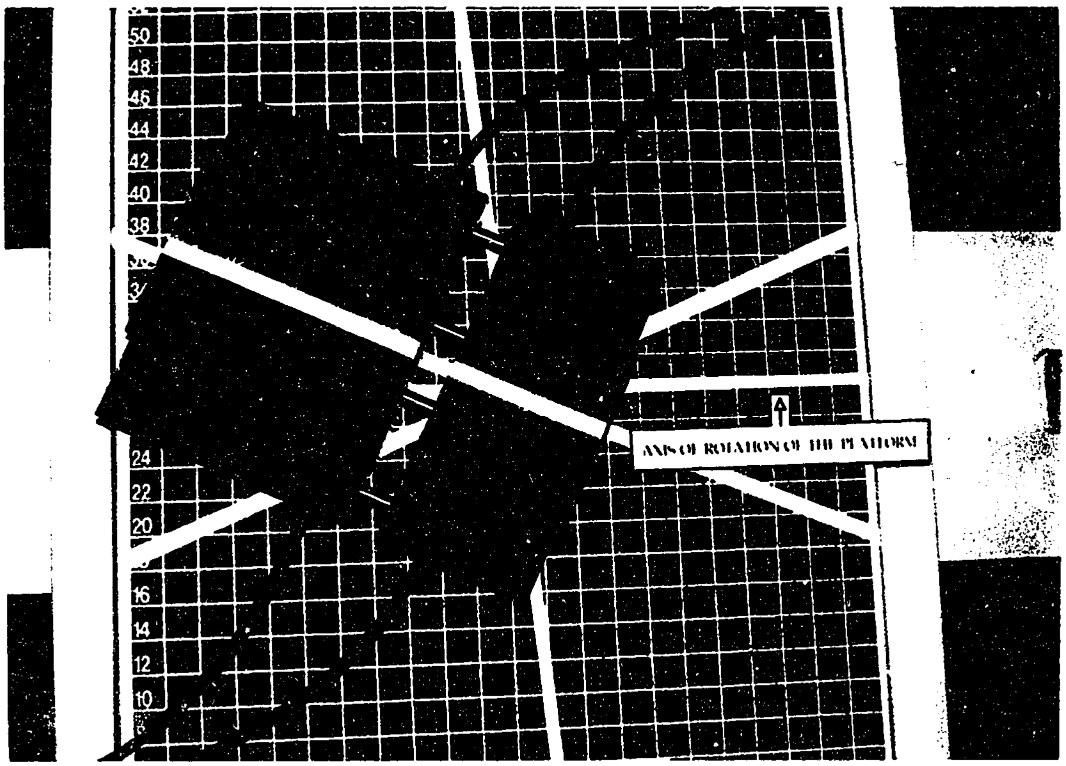

Figure 3- Alignment of footplates for the inversion test.

All subjects were tested with eyes open, looking at a fixed target localized at 120 centimeters from the platform. This distance was felt to be the most appropriate for the subjects because they were able to easily focus on the target given the location of the balance machine in the room. Subjects stood on one foot with the knee fully extended, arms along the body and the contralateral lower limb flexed at the knee at 90 degrees. The platform was set up to move at 20% of its total maximum speed. This parameter allowed a cycle of movement from the initial horizontal position to a complete 4 degrees downwards position. Diener et al (1984) have observed that proprioceptive input from skin receptors of the foot and ankle plays a significant role when the moveable platform moves at low frequencies. Therefore, by having decreased the speed of the platform and number of cycles of movement subjects would more likely rely on the skin input on which ankle supports are supposed to act.

MATERIALS AND EQUIPMENT

Subjects had their postural control tested with the Chattanooga Balance System (Appendix D). This tool consisted of footplates provided with electronic pressure transducers. Each plate had two parts: a heel plate and a toe plate. The heel and toe plates for each foot were connected, yet adjustable one behind the other. The gap between the forefoot and heel transducers was adjustable so that the plate could accomodate for different foot sizes. The footplates were freely moved and the subjects stood on a moveable platform base which had a grid marked on the surface that assured standardization of the footplate positions for repeated testing of an individual subject (Figure 4).

The footplates can be aligned in different angles with the platform. The platform moves in an angular pertubation from horizontal to 4 degrees (toes down position), to level again. The distribution of pressure over the footplates showed fluctuations of weight displacements which reflected the amount and direction of the center of pressure in forward, backward, and left/right directions. Data from the transducers were collected, stored and analyzed via an attached IBM pc computer.

Reliability of sway measurement using the Chattanooga Balance System™ has been investigated by Dickstern and Dvir (1993). The Test-retest Correlation Coefficient during angular displacement of the platform was 0.65. Subjects were measured with eyes open and sway was calculated in both sagittal and frontal planes. Friden et al (1989) found a Test-retest Correlation Coefficient of 0.71 for sway in the frontal plane; however, subjects stood on a stable platform.

For the purposes of this experiment, a pilot study (Appendix E) revealed coefficients of variation for the Chattanooga Balance System™ of 8.7% and 5.2% for the plantar flexion test and inversion test respectively.

Measurement of sway in the frontal plane has been able to detect deficits in postural control (excessive sway) in patients with unstable ankle joints (Friden et al, 1989; Gauffin et al, 1988, Konradsen & Ravn, 1991). Concurrent validity of the Chattanooga Balance System™ has also been investigated by Dicksten and Dvir (1993). These authors found similar values for postural sway when comparing their results of standing balance with existing knowledge on stance performance in comparable populations. The Chattanooga Balance System™ was also reported to be able to detect decreased sway when subjects wore an ankle brace (Feuerbach & Grabiner, 1993).

The ankle taping technique employed in this study was the closed configuration with a heel lock and figure eight (Figure 5 and Appendix F). Initially pro-wrap was applied to the skin in order to avoid skin irritation. A tape adherent was used so that taping could be better attached to the skin. One and a half inch athletic non-elastic adhesive tape was used. Landmarks were placed over the head of the fifth metatarsal and over the musculotendinous junction of the gastrocnemius-soleus group of each subject to assure consistency in the limits of taping application.

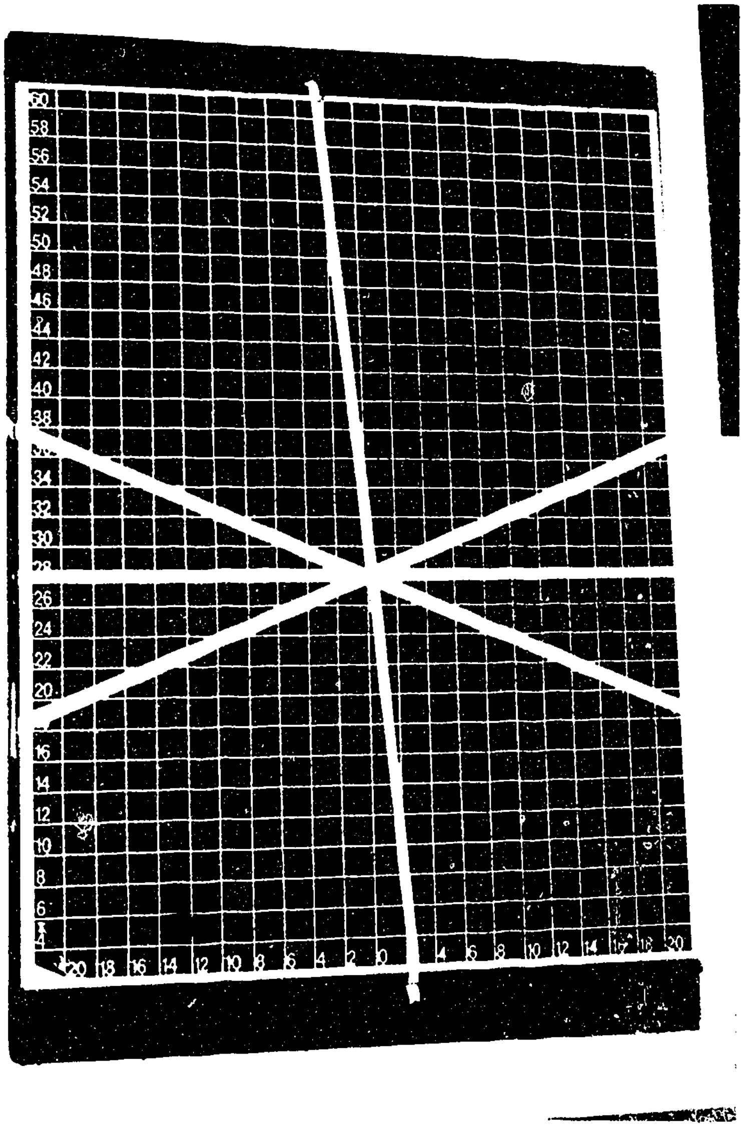

Figure 4 - Moveable platform base.

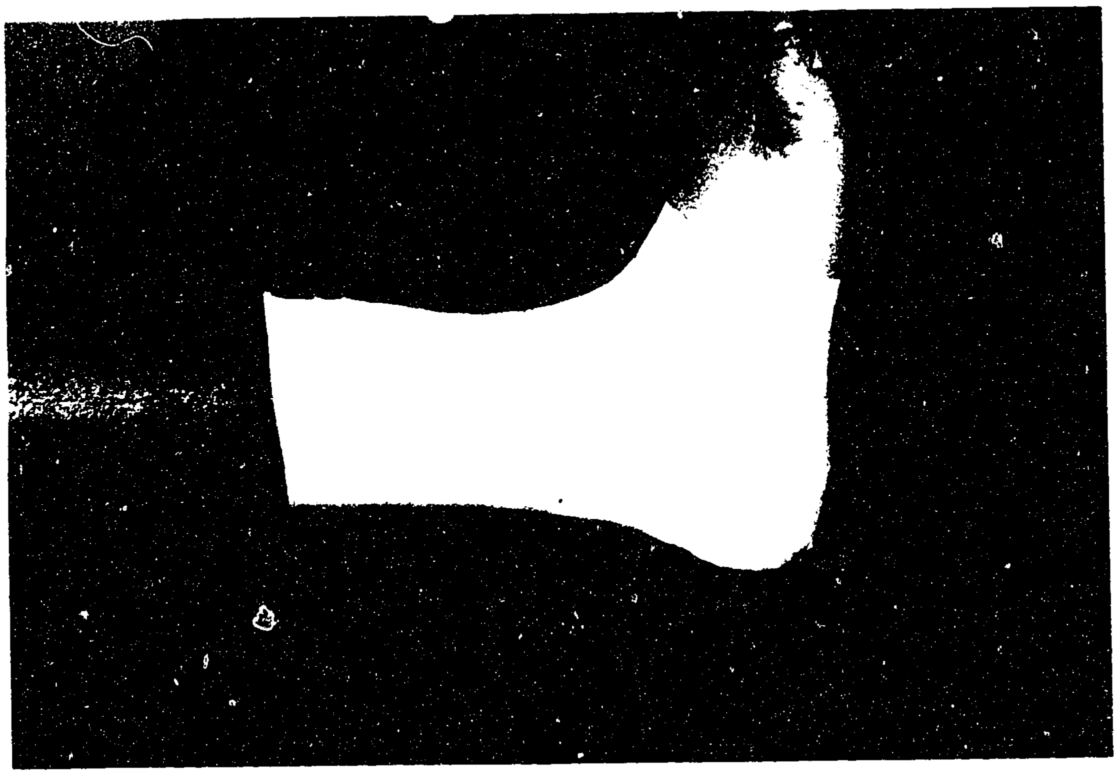

Figure 5- Closed ankle taping technique.

The AirStirrup Ankle Training Brace (Aircast Inc., Summit, NJ 07901) was a semi-rigid orthosis with inflatable air cylinders designed to conform to the bony contours of the ankle complex (Figure 6 and Appendix G). External to the air cells are rigid medial and lateral stirrups which extended approximately 6 inches superior to the malleoli. The support was applied according to the manufacturer's instructions (Appendix G).

The Donjoy Ankle Ligament Protector (Donjoy Orthopedic, Carlsbad, CA 92008) consisted of a single posterior strut which was positioned along the posterior aspect of the tibia (Figure 7 and Appendix H). The strut connected a contoured heel cup which contained the heel, with a spring-loaded tibial cuff. The heel cup was secured to the heel counter of the subjects' shoes with velcro tab fasteners, and a flexible, velcro calf strap affixed the brace proximally in a 90 degrees with the posterior strut according to the manufacturer's instructions (Appendix H).

Both braces were applied over the subject's own socks. Subjects were required to wear cotton sports socks in order to prevent the braces from slipping. For the taping test situation, participants wore socks over the tape. Subjects wore shorts and the same type of low-top court shoes for all bracing and taping conditions. The same brace was used by each subject to assure consistency. Once the brace and taping were applied and adjusted, no further adjustments were made during the testing session for that subject. The same investigator applied the ankle taping and braces throughout the study.

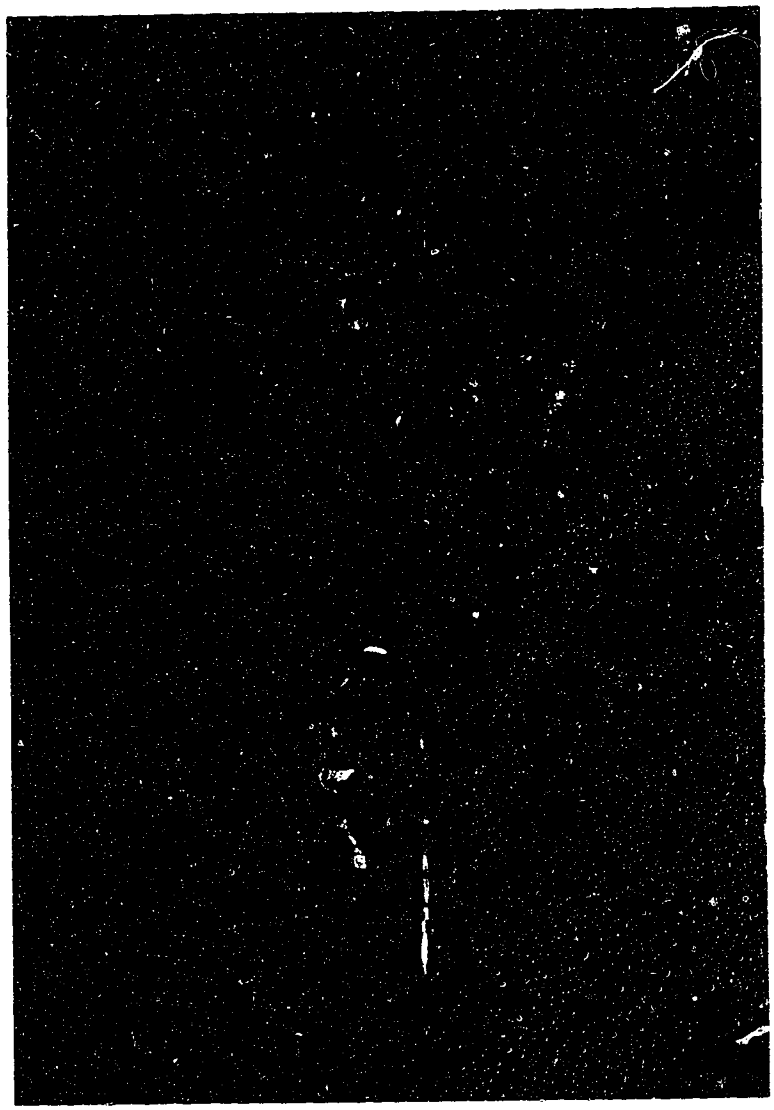

Figure 6- The AirStirrup Ankle Training Brace.

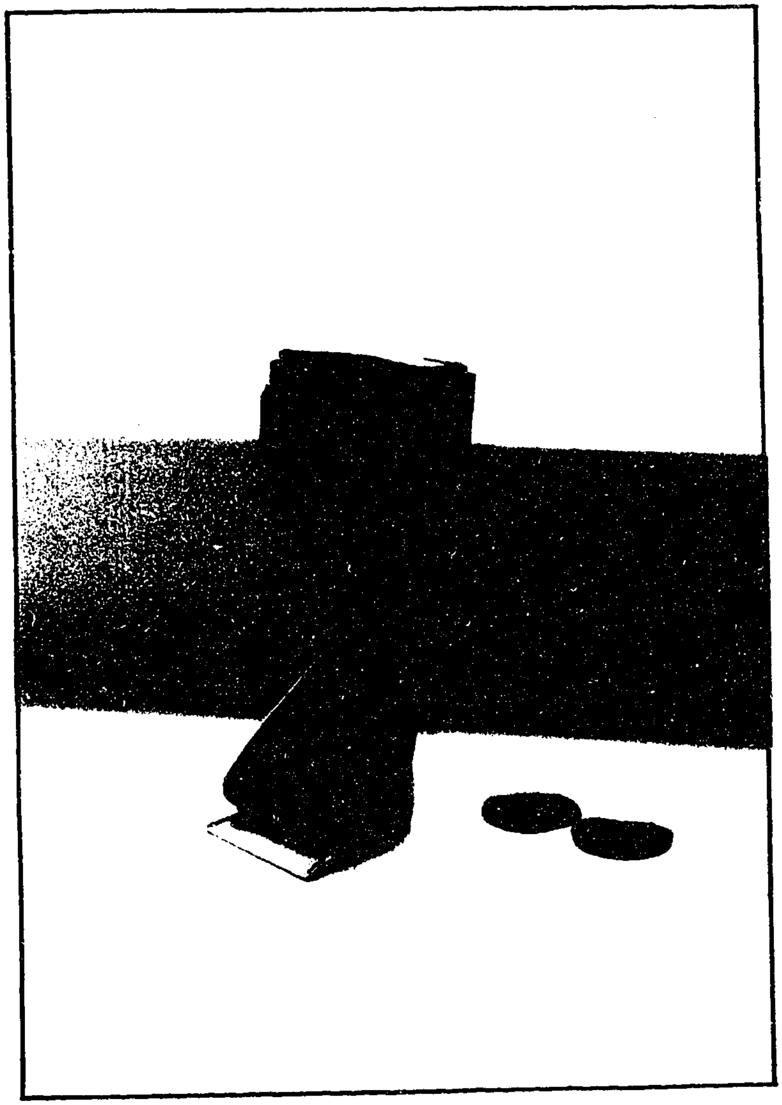

Figure 7- The Donjoy Ankle Ligament Protector.

TESTING PROTOCOL

Once the order of ankle supports and order of movement (plantar flexion or inversion test), had been established, the footplates were adjusted to the platform according to the first test situation. A longitudinal line was drawn on the footplate to serve as a reference point for the alignment of the footplates with the platform. For the plantar flexion test, the longitudinal line on the footplate lay exactly over a line drawn in the platform forming an 84 degree angle with its transverse horizontal axis. For the inversion test, the longitudinal line on the footplate lay exactly over a line drawn on the platform forming a 23 degree angle with its transverse horizontal axis. Then the subject had his/her foot measured on the footplate. The ball of the foot was aligned with a horizontal line drawn on the ball footplate. The middle of the calcaneous was aligned with a horizontal line drawn on the heel footplate. These lines were marked on the low top court shoes so that subjects could be correctly positioned on the footplates while wearing shoes. The distance from the lateral side of the footplate to the lateral side of the shoe was the same as the distance from the medial side of the footplate to the medial side of the foot. The measurements of the size of the footplate, size of the gap between the ball plate and the heel plate, and the size of the space from sides of the footplates to the shoe were recorded and used to ensure constant foot position for each subject.

Subjects stood on the footplate and practiced for 15 seconds, looking at a fixed target localized at 120 centimeters in front of them. This procedure was employed in order to allow the subject to become familiar with the movement of the platform. The 15-second-period was choosen because it has been demonstrated that test-retest reliability decreases in balance tests of healthy subjects when the test lasts longer than 15 seconds as a result of contamination due to artifacts and biasing such as fatigue (Goldie et al, 1989). Subjects were informed about the type of movement of the platform and time of practice. The standardized common commands were: "Try to keep your balance as best as you can, moving as little as you can during the whole movement of the platform until it stops completely".

Once the initial practice was performed, the tests of the different situations (nonsupported, taping, braced with the AirStirrup, and braced with the Donjoy Ankle Ligament Protector[R]) took place in an order previously decided by randomization. A 5-minute-period was timed immediately after the initial practice so that enough time is allowed to apply the different supports. This period of time was kept even for the nonsupported situation in order to maintain consistency in the measurement and avoid fatigue of the subjects during this test situation. The parameter of 5 minutes was chosen since this amount of time added to the amount of time involved in the test itself did not put the supports at risk of loosening (Greene & Hillman, 1990). Before the nonsupported test situation, subjects lay on a bench the same way as for application of the supports. Once the 5-minute-period had expired, the subjects walked around the laboratory for 2 minutes in order to get used to the appliance. Subjects performed this task even if no support was applied.

Subjects then stood on the footplate with the designated limb and performed a practice trial of 15 seconds with eyes open in order to familiarize themselves with the movement of the platform in the new supported situation. Subjects during the nonsupported situation did not perform these practices since it had already been performed in the initial practice.

A 2-minute-period of rest was allowed between the last practice and the measurement. The measurement consisted of 3 trials of 15 seconds with 2 intervals of 2 minutes between them. These parameters, including the amount of time for resting have been used elsewhere (Friden et al, 1989) in which a 0.71 correlation coefficient was obtained for test-retest reliability, and therefore was employed in this study.

Subjects were then assessed in the next test situation (plantar flexion or inversion test) with the 5-minute-period being given for changes in footplate position. The same procedures was employed in each subsequent support situation (Figure 8).

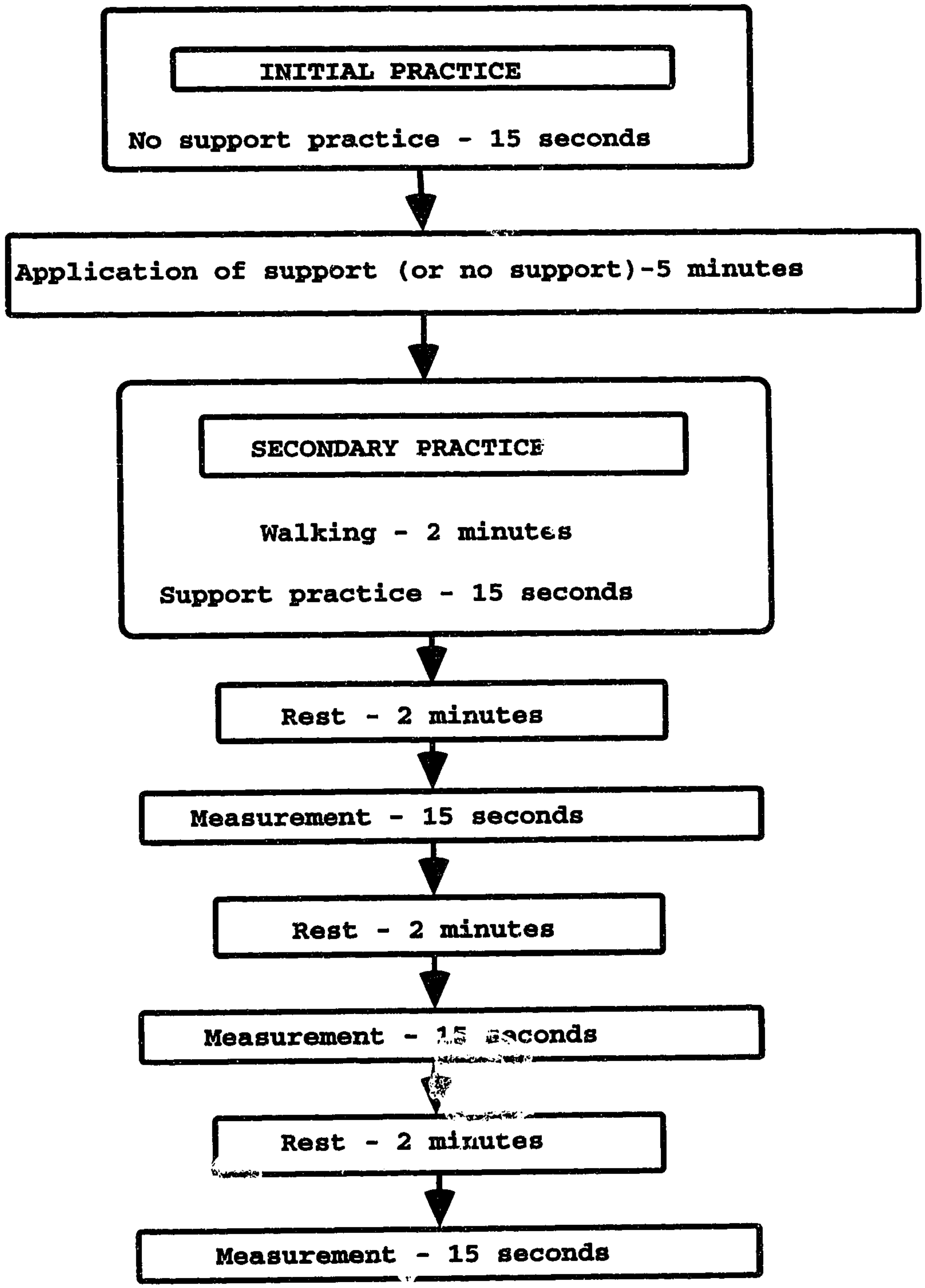

Figure 8 - Testing protocol

STATISTICAL ANALYSIS

Postural sway in the frontal plane (dependent variable) was calculated for each subject as the mean of the three measurements taken for each of the four conditions (nonsupported, taping, AirStirrup, and Ankle Ligament Protector) in each test. Deficits of sway in the frontal plane have been involved in the mechanism of ankle instability (Friden et al, 1989; Gauffin et al, 1988; Konradsen & Ravn, 1991) and were analyzed in this study. The software of the Chattanooga Balance System™ which provided sway in the frontal plane expressed the maximum sway in centimeters around the mean center of posture. Since only the maximum sway could be assessed, the mean of the three measurements was computed in order to assure good reliability of the measurement. Means and standard deviations of postural sway in the frontal plane for each condition were then calculated .

The independent variables were characterized by the supports, measured on four levels and test situations, measured on two levels. A 4 X 2 way ANOVA with repeated measures on both factors (test and support) and contrast analysis were used to reveal whether there was a significant difference in postural sway when the different supports were compared with the nonsupport situation as well as when the supports were compared among themselves. The 4 X 2 way ANOVA also indicated if there was an interaction effect between the conditions (nonsupported, taping, AirStirrup, and Ankle

Ligament Protector) across the two test situations, i.e. whether the supports behaved differently according to the movement ocurring on the platform and at the ankle-foot complex (Figure 9). A p-value of 0.05 was selected as evidence of statistical significance.

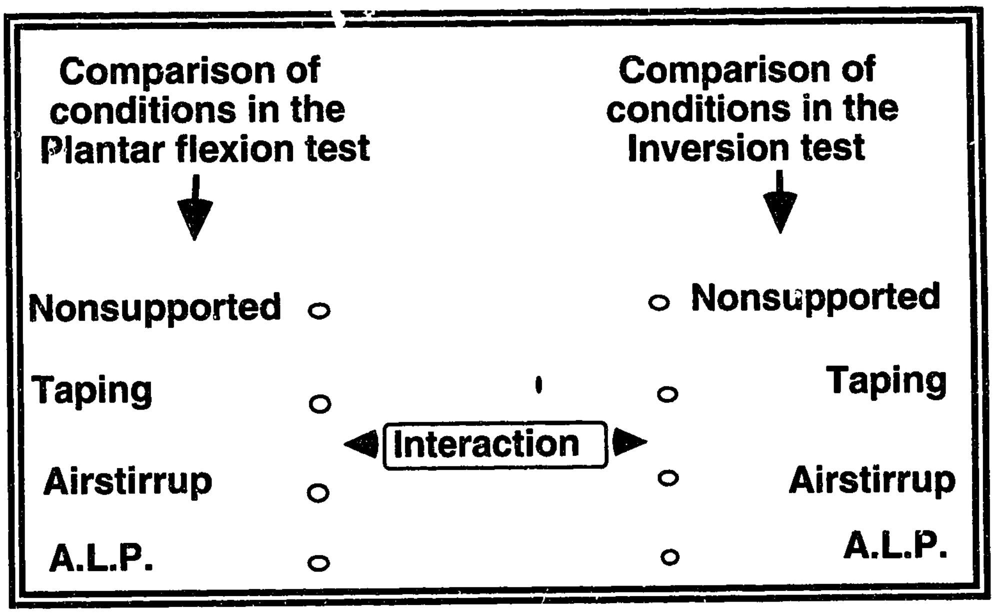

Figure 9- Flowchart of 4 X 2 way ANOVA.

ETHICAL CONSIDERATIONS

Subjects were told the objectives of this study and all the procedures involved. On the day of the test, it was explained to them what movements would be performed and the types of supports that would be employed. The supports were applied over the socks and a pro-wrap was applied on the skin before the application of taping to avoid skin irritation.

The subjects were given an opportunity to read and sign the consent form (Appendix B) and ask any questions concerning the study. There was no obligation to participate in the study. The subjects had the right to withdraw from the study at any time and confidentiality was assured.

CHAPTER FOUR

RESULTS

INTRODUCTION

Subject recruitment and data collection took place between March and May 1994. The entire procedure for testing lasted approximately two hours for each of the twenty volunteers who fit the inclusic iteria. The majority of the subjects tested we students from the Department of Physical Therapy at the University of Alberta. Table 2 provides descriptive characteristics of the sample. A full description of all subjects employed can be found in Appendix I.

	Mean	Range
Age (years)	25	20 - 33
Height (m)	1.67	1.57 - 1.86
Weight (Kg)	65	49.2 - 83.4
Gender	**Males = 6**	**Females = 14**

Table 2- Descriptive characteristics of the sample.

The results for the measurement of postural sway in the two movement tests (plantar flexion and inversion) for the four support situations (nonsupported, taping, Aircast[R], Donjoy[R]) are presented in Table 3. These results express the maximum sway of the center of pressure underneath the foot measured in the frontal plane. The raw data for all subjects is included in Appendix J. Figure 10 depicts a comparison of the performance of the supports across the two movement tests.

	Plantar flexion		**Inversion test**	
	Mean	**SD**	**Mean**	**SD**
No Support	3.176	0.569	3.787	0.672
Taping	3.126	0.525	3.597	0.678
Aircast	3.132	0.546	3.374	0.636
Donjoy	3.265	0.615	3.500	0.689

Table 3- Means and standard deviations in cm for measurement of postural sway in the two movement tests for the four support conditions.

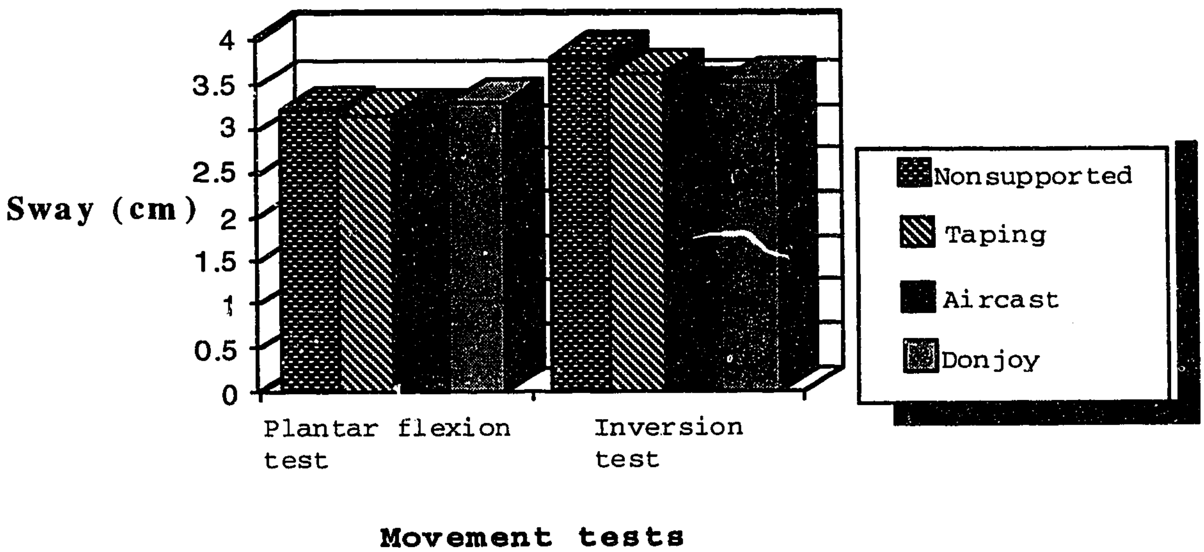

Figure 10- The amount of postural sway ocurring during each support situation in both movement tests.

The ANOVA results revealed that when tested during the plantar flexion movement, subjects demonstrated less postural sway when compared with the inversion test. These results indicate that values of postural sway for supports grouped into the plantar flexion test were statistically smaller when compared with support values grouped into the inversion test (Table 4 and Figure 11).

The ANOVA results also showed that even though not statistically significant, the interaction effect approached the p-value of 0.05 (Table 5). This effect demonstrates that the supports did not act equally during the movements occurring at the ankle joint: supports that performed well during one test situation did not necessarily repeat this performance in the other test.

Source	**df**	**Sum of Squares**	**Mean Squares**	**F-Value**	**P-Value**
Test	1	6.080	6.080	24.594	***0.000**

Table 4- ANOVA- Effect of tests (* indicates significant difference between the two movement tests).

Source	**df**	**Sum of Squares**	**Mean Squares**	**F-Value**	**P-Value**
Test X Support	3	1.012	0.337	2.717	**0.053**

Table 5- ANOVA for the interaction effect.

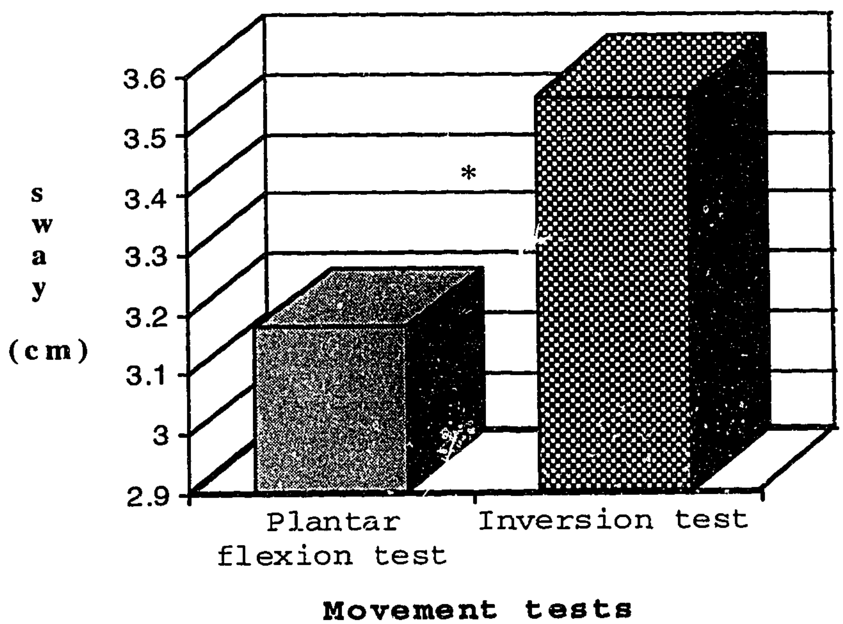

Figure 11- Graph showing the greater amount of postural sway ocurred during the inversion test compared to the plantar flexion test (* indicates a significant difference between the two movement tests).

THE PLANTAR FLEXION TEST

The first research hypothesis stated that normal subjects would have their postural sway decreased while wearing ankle supports when compared to a no support situation during the plantar flexion test. The third research hypothesis stated that ankle supports would differ significantly with respect to their ability to decrease postural sway during the plantar flexion test in normal subjects. During the plantar flexion test, subjects demonstrated the best performance (least postural sway) while wearing the taping technique (Figure 12). However, no single comparison, either when supports were compared with the no support situation or when supports were compared among themselves, produced a significant difference as revealed by the contrast analysis (Table 6 - Figure 13). Therefore, results during this test situation did not support the first nor the third research hypotheses.

Comparison	**df**	**Sum of Squares**	**Mean Square**	**F-Value**	**P-Value**
Nonsupported Vs Taping	1	0.025	0.025	0.201	**0.655**
Nonsupported Vs Aircast	1	0.019	0.019	0.156	**0.694**
Nonsupported Vs Donjoy	1	0.078	0.078	0.631	**0.430**
Taping Vs Aircast	1	3.600	3.600	0.003	**0.957**
Taping Vs Donjoy	1	0.192	0.192	1.545	**0.218**
Aircast Vs Donjoy	1	0.176	0.176	1.414	**0.239**

Table 6- Contrast analysis for plantar flexion test.

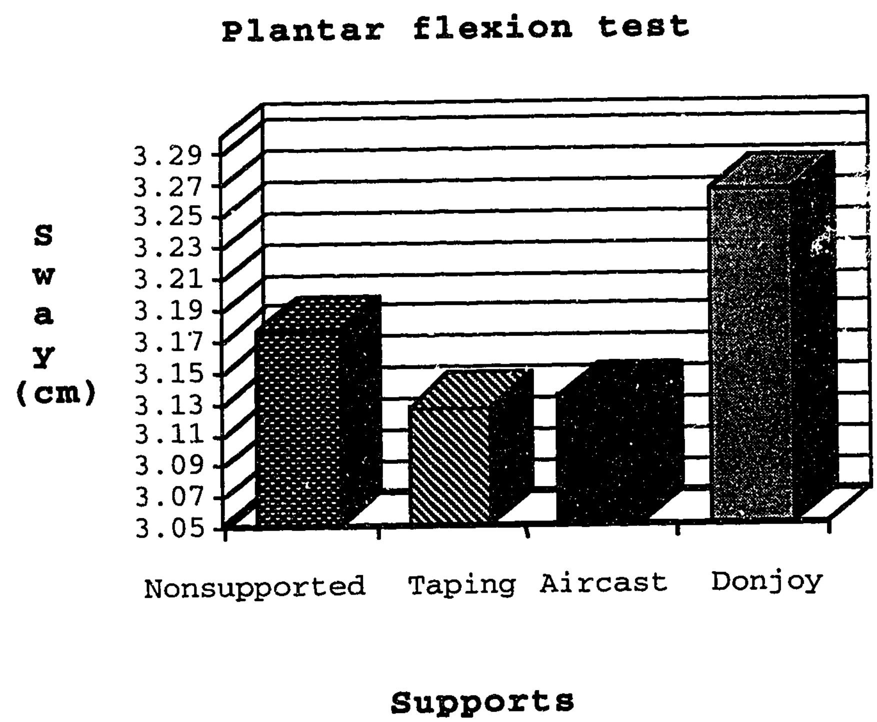

Figure 12- Comparison of amount of postural sway for the different support situations during the plantar flexion test.

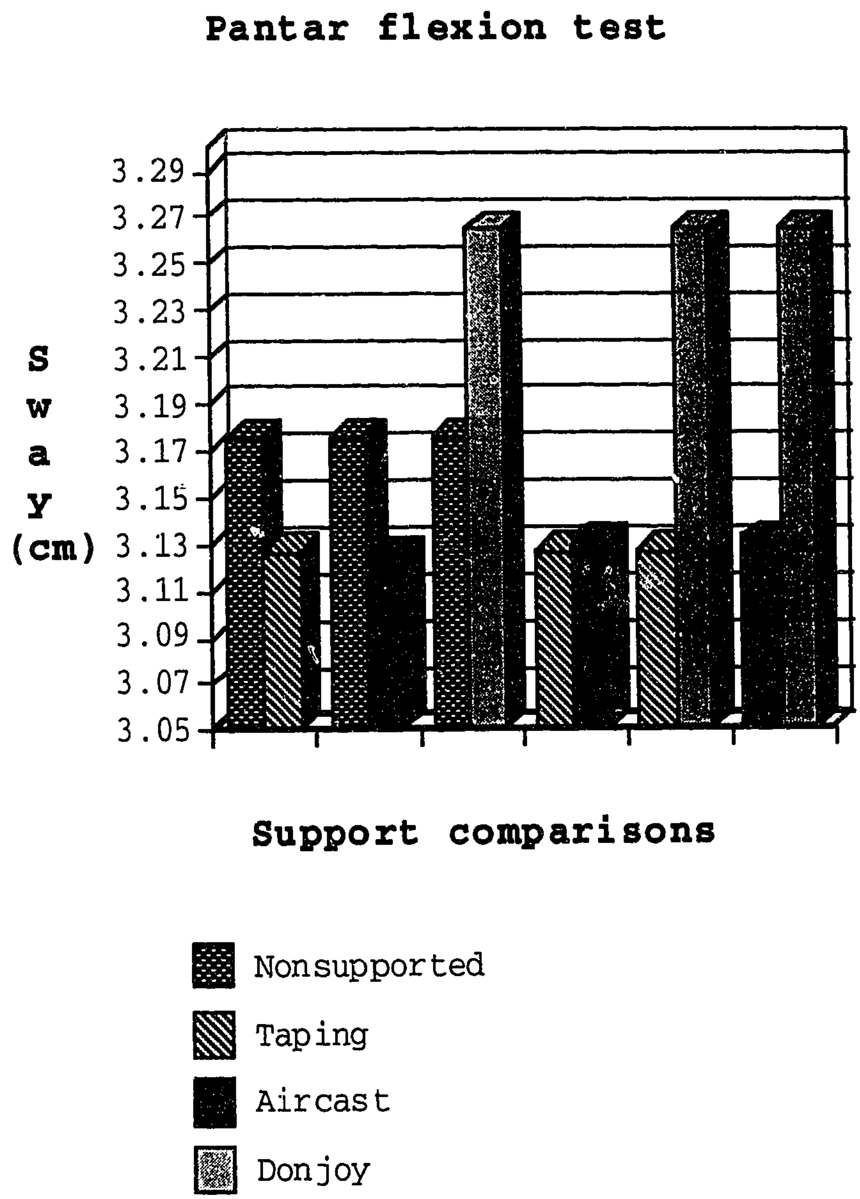

Figure 13- Graph showing amount of postural sway during single comparisons of support situations in the plantar flexion test.

THE INVERSION TEST

The second research hypothesis stated that normal subjects would have their postural sway decreased while wearing ankle supports when compared to a no support situation during the inversion test. During this test situation, the Aircast[R] allowed subjects to have the least amount of sway in the frontal plane among all support situations (Figure 14). Significant differences for single comparisons were revealed by the contrast analysis (Table 7). Subjects showed significantly less sway when wearing both Aircast[R] brace as well as Donjoy[R] brace when compared to the no support situation. Taping was also superior relative to the no support situation, and even though not statistically significant, the result of contrast analysis for this specific comparison approached the p-level of 0.05. Therefore, the second research hypothesis was largely supported. The fourth research hypothesis stated that ankle supports would differ significantly with respect to their ability to decrease sway during the inversion test in normal subjects. The Aircast[R] brace was found to be statistically more effective in decreasing sway as compared to the taping technique. However, the Aircast[R] brace was not statistically superior to the Donjoy[R] brace in reducing sway during this test condition. Comparison of Donjoy[R] brace and taping did not result in significant difference. Therefore, the fourth research hypothesis was minimally supported. Figure 15 depicts single comparisons of the support situations during the inversion test.

Comparison	df	Sum of Squares	Mean Square	F-Value	P-Value
Nonsupported Vs Taping	1	0.361	0.361	2.908	**0.093**
Nonsupported Vs Aircast	1	1.706	1.706	13.740	***0.000**
Nonsupported Vs Donjoy	1	0.824	0.824	6.635	***0.012**
Taping Vs Aircast	1	0.497	0.497	4.006	***0.050**
Taping Vs Donjoy	1	0.094	0.094	0.758	**0.387**
Aircast Vs Donjoy	1	0.159	0.159	1.279	**0.262**

Table 7- Contrast analysis for inversion test (* indicates significant difference between support situations).

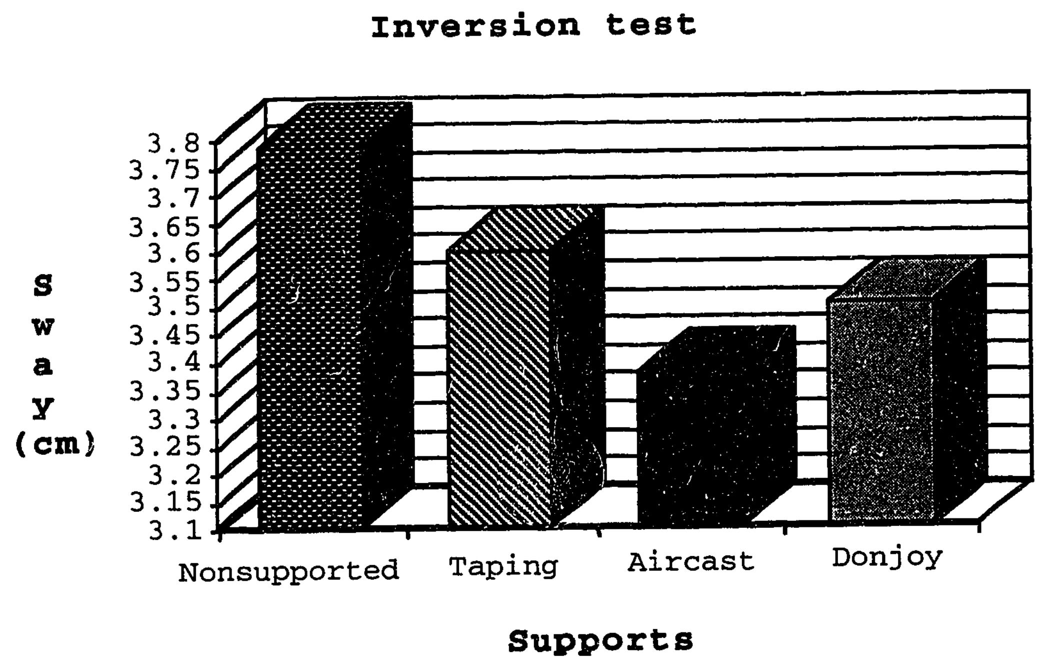

Figure 14- Comparison of the amount of postural sway for different support situations during the inversion test.

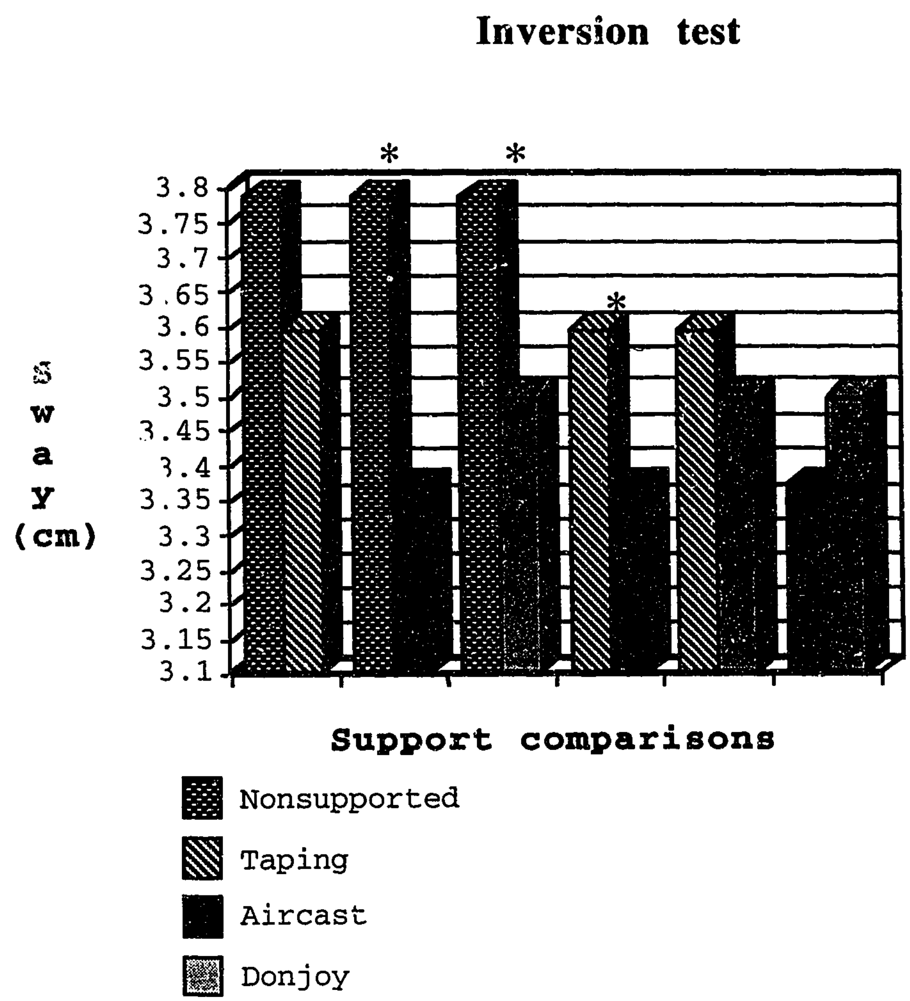

Figure 15- Graph showing amount of postural sway during single comparisons of support situations in the inversion test (* indicates significant difference between support situations).

CHAPTER FIVE

DISCUSSION

INTRODUCTION

The intricate mechanism of ankle sprains usually involves a combination of movements that take place at the foot-ankle complex in the sagittal, frontal, and transversal planes. Typically, the lateral ligaments of the ankle joint are the most frequently affected, when the foot is forced into a plantar flexed and inverted position (Alves et al, 1992). Among all ligaments of the lateral complex, the anterior talofibular ligament and the calcaneofibular ligament are the most often injured (DeMaio et al, 1992).

In order to examine how the ankle supports act in controlling postural sway when the ankle joint is unstable at different positions, the plantar flexion movement and the inversion movement of a moveable platform were chosen for the current investigation. This represented an attempt to highlight situations that could stress these two common injured ligaments in a specific manner, since the talofibular ligament is particularly sensitive to the plantar flexion movement while the calcaneofibular ligament is more stressed by the inversion movement (Nigg et al, 1990; Stephens & Sammarco, 1992).

The results of this study indicated that when measured during the inversion test, subjects demonstrated a significantly greater amount of sway than when measured during the plantar flexion test (p=0.000). Postural sway was measured in the frontal plane since previous studies indicated that increase of postural sway in this plane was often present in the pathological process of ankle sprain (Friden et al, 1989; Gauffin et al, 1988; Konradsen and Ravn, 1991). Since the inversion movement primarily occurs in the frontal plane, subjects in the present study would be likely to sway more during the inversion test which might explain findings of higher values of postural sway in the test situation.

The two-way ANOVA approached a significant interaction effect. A p-value of 0.053 was reported which approached the acceptance level of 0.050. Subjects could therefore, not be following the same pattern of performance when wearing ankle braces and taping across the two movement tests, and specific analysis for each of these situations was warranted.

THE PLANTAR FLEXION TEST

As described in the results section, the taping technique demonstrated the best performance in reducing subjects' postural sway among all support situations. With the application of the Donjoy^{R} brace, the amount of sway was observed to be the greatest among all ankle supports and no support situations. However, none of the single comparisons, either when supports were contrasted with the no support situation or when the supports were compared among themselves, produced a significant difference.

The ankle joint has its stability decreased during the plantar flexion movement and this instability is attributed to a narrower attitude of the talus underneath the tibia and fibula in plantar flexion (Kotwick, 1982). The purposes of employing a test with the platform moving into plantar flexion was to attempt to put the ankle in this unstable situation and observe how postural sway would be affected by the different ankle supports as compared to no support and compared among themselves. However, the moveable platform of the Chattanooga Balance System™ only allows four degrees of downward movement and even though it is impossible to determine accurately the real range of motion taking place at the ankle-foot complex, the small amount of movement of the platform probably did not allow the joints to reach a "dangerous" point and therefore the supports could not demonstrate any significant favorable effects. Besides, postural sway was not measured in the sagittal plane where the plantar flexion movement occurs, and the sample used in this investigation consisted of healthy, noninjured people, who had not sustained any injury to the ankle and had no known instability. Thus, the probabilities of finding a significant effect when using the supports might have been decreased.

Similar results have been described in the literature addressing the effect of ankle taping on postural stability. Kozar (1974) measured a group of healthy physical education majors on a stationary stabilometer machine connected with photo transistors. A group of fifteen subjects were tested with no support attached to the ankle and another group of fifteen volunteers were tested while wearing a closed basketweave taping technique. Time in balance was considered to be within five degrees of horizontal body displacement recorded by the photo transducers. No difference between the two groups was identified when t-test analysis was applied. The methodology used by Kozar involved an immovable platform and subjects were tested while standing on both legs. Therefore, stability could be well assured and the taping technique might not have had any additional benefit.

Using force plate stabilometry equipment, Tropp et al (1984) tested soccer players with functional instability of the ankle joint with and without a "stirrup and horseshoe" followed by a figure of eight and heel lock taping technique. Subjects stood on a seesaw, half-cylindric in shape lying on the force plate. Postural sway was measured according to the sway of the center of pressure on the sagittal and frontal planes. No significant difference was encountered between supported and nonsupported situations. Stabilometry measured in the frontal plane only has been found to be more sensitive in quantifying postural sway and detecting excessive sway in patients with unstable ankles (Friden et al, 1989). By including sway in the sagittal plane, Tropp et al (1984) might have diminished the sensitivity of the measurement in finding decreased postural sway with the application of taping.

The finding of the Airstirrup Ankle Training Brace™ not being capable of decreasing postural sway when compared to a no support situation during the plantar flexion test in the present investigation is not entirely supported by the current literature. This discrepancy might be due to the nature of the test employed in this study since exact similar testing conditions have not been described. Friden et al (1989) identified a decrease in the amplitude of sway in the frontal plane when injured subjects received the application of the Airstirrup® brace. However, besides being uninjured, subjects in Friden et al's study were tested on a platform which remained fixed and had their hips and knees flexed in front of the body during the test. The greater projection of the limb away from the body with this position as compared with the present study in which volunteers were tested only with their knees flexed might have increased the difficulty in controlling posture and stressed the function of the Airstirrup® brace in decreasing postural sway.

Feuerbach and Grabiner (1993) used a similar methodology as the one employed in the present study to research the effect of the Airstirrup® in postural sway of normal subjects. Employing a within subject design, these authors tested a group of uninjured subjects on a static and dynamic platform. The dynamic test consisted of sinusoidal rotation similar to the plantar flexion test. When sway amplitude was calculated in the frontal plane, no difference was detected between the braced and nonbraced trials, agreeing with the results found in the present study.

In the present investigation, subjects demonstrated the greatest amount of sway when tested with the Donjoy[R] Ankle Ligament Protector relative to the other supports and to the no support situation despite no significant differences being demonstrated during single comparisons (Figure 16). The possible mechanisms which could explain the function of the supports according to the results found are discussed later in this chapter. Nevertheless, it is appropriate to point out that the Donjoy[R] brace might have allowed a greater range of movement in the sagittal plane than the range of motion tested (4 degrees), due to the design of its heel cup. No study comparing ankle supports in postural sway could be identified in the literature and comparison of the results of the between supports analysis of this study with existing studies was not possible.

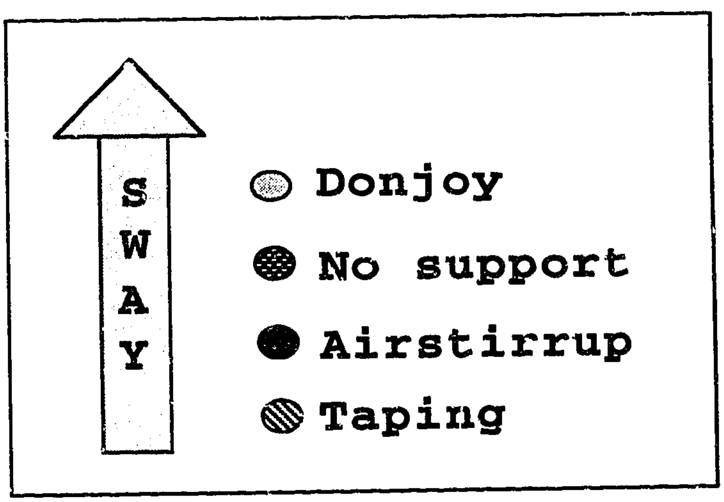

Figure 16- Trend of increased postural sway of the support situations during the plantar flexion test.

THE INVERSION TEST

The great majority of ankle sprains affect the lateral ligament complex of the joint which has the calcaneofibular ligament as one of its constituents (Alves et al, 1992). This structure is the second most often injured ligament in the ankle (DeMaio et al, 1992) and is primarily stressed by the movement of inversion at the subtalar joint when the ankle is in neutral position or in slightly plantar flexion (Nigg et al, 1990). For the present study, the axis of rotation of the moveable platform of the Balance System^{TM} was aligned with the axis of rotation of the subtalar joint as described by Kotwick (1982) in an attempt to reproduce this situation.

The specific design of the ankle supports as a means of preventing the movement of inversion along with the fact that postural sway was measured in the same plane in which the movement of inversion occurred (frontal), allowed the contrast analysis to reveal significant differences during single comparisons. However, further research would need to be done to clarify this issue.

When support situations were contrasted with the no support situation in the present study, it was observed that both ankle braces, Airstirrup^{R} and Donjoy^{R}, were statistically superior in decreasing postural sway. In spite of using different test situations and populations, Feuerbach and Grabiner (1993) and Friden et al (1989) found the same results with respect to the positive effects of the Airstirrup^{R} ankle support. Feuerbach and Grabiner (1993) employed a dynamic test with the platform moving only in the frontal plane while Friden et al (1989) tested subjects with functional instability of the ankle in a stationary force plate. The results of the Donjoy^{R} brace could not be compared with findings from the literature since no study addressing its role in controlling sway could be found.

The taping technique did not prove to be statistically superior to the no support situation for the range of motion tested (4 degrees). These findings are in agreement with results obtained by Kozar (1974) and Tropp et al (1984). Kozar (1974) tested healthy subjects standing on both limbs on a static platform and Tropp et al (1984) measured postural sway in both sagittal and frontal planes using procedures which differed from those used in the current investigation. In the present study, the employment of a dynamic platform forcing the ankle joint to reach an inversion position and postural sway being analyzed in the frontal plane might explain the trend towards a better performance by subjects when supported by taping as compared to the no support situation even though this difference did not achieve statistical significance (p=0.093).

When supports were compared among themselves, the analysis revealed that the Airstirrup^{R} brace significantly reduced postural sway when compared to the taping procedure. The Donjoy^{R} ankle brace was not statistically superior to taping and the Airstirrup^{R} brace did not significantly reduce sway compared to the Donjoy^{R} brace. It was observed that, for the range of motion tested (4 degrees), both ankle braces performed well during the inversion test since subjects demonstrated less sway wearing these supports in comparison to the taped and no support situations (Figure 17). This same performance was not shown in the plantar flexion test since the taping technique performed better than both braces in this situation. This difference for supports might have accounted for the interaction effect approaching the 0.05 level of significance.

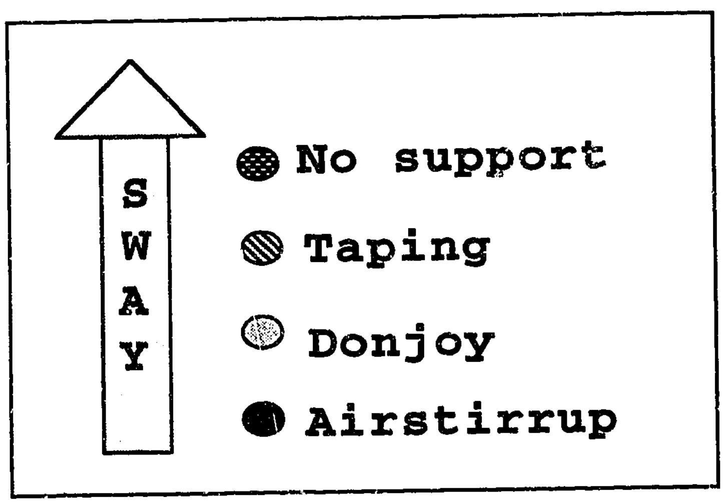

Figure 17- Trend of increased postural sway of the support situations during the inversion test.

POSSIBLE MECHANISMS OF ACTION OF ANKLE SUPPORTS

The intricate mechanisms involved in the control of posture with regards to motor control aspects as well as the biomechanical concepts of joint movements make it difficult to point out specifically which mechanism or mechanisms of action were responsible for the findings observed in this investigation. Equipment such as electromyography and video cameras were not used in this study and these limitations add even more obstacles to answering this question. However, it is imperative to address some of the possible mechanisms behind the role of ankle supports in controlling postural sway in order to make this discussion more complete.

The question that has occurred to some investigators dealing with disabilities caused by functional instability of the ankle is whether or not ankle supports have the ability to affect the motor control of the muscles of the leg in addition to their already known effect of restricting range of movement at the ankle-foot complex (Greene & Hillman, 1990; Greene & Wight, 1990; Gross et al, 1987; Myburgh et al, 1984). These two points appear to be pivotal to this dilemma and therefore will be discussed as the two possible mechanisms responsible for the results in the present study.

ANKLE SUPPORTS AND PROPRIOCEPTION

Sherrington (1906) first proposed the term proprioception to describe reactions produced by deep receptor organs localized in the vestibular system, joints, and muscles. Proprioception inputs that come from these receptors are sent to the nervous system but are not necessarily consciously perceived (Williams, 1981). According to Sherrington (1906), receptors localized on the skin surface are part of an "extero-ceptive" field that is basically stimulated by the outward environment. This extero-ceptive field and its receptors are capable of affecting and interacting with the activity in the proprioceptive field and therefore the whole system should be called proprio-ceptive (Sherrington, 1906). Whether or not this is always true is beyond the scope of this study. For didactic purposes however, the term proprioception will be used to address the possible roles of ankle supports on the afferent system and will be contrasted with the mechanical effect of these appliances.

Freeman et al (1965) were probably the first researchers to propose that functional instability of the ankle was caused by processes other than pure mechanical instability of the joint. These authors suggested that articular de-afferentiation following an ankle sprain led to motor incoordination of the muscles in the leg which could induce a chronic pathology. Since then, aspects of motor control and proprioception have been the focus of studies addressing the problem of ankle sprains and prophylactic devices such as joint supports (Brunt et al, 1992; Konradsen & Ravn, 1991; Feuerbach & Grabiner, 1993).

Reaction time of the peronei muscles is one factor constantly investigated by researchers in the ankle physiology field (Brunt et al, 1992; Konradsen & Ravn, 1991, Nawoczenski et al, 1985). These muscles are considered dynamic stabilizers of the ankle joint (Cass & Morrey, 1984) and this might explain the rising interest in their performance. Peroneal reaction time is usually measured with a platform which drops the foot into supination and the time to onset of motor response of these muscles after the angular displacement occurs is recorded (Nawoczenski et al, 1985). In fact, a prolonged peroneal reaction time has been identified in patients sustaining functional instability of the ankle joint, supporting the theory of a proprioceptive deficit being partially responsible for ankle instability (Brunt et al, 1992; Konradsen & Ravn, 1991, 1990). In their work, Konradsen and Ravn (1991) observed that besides demonstrating a delay in the reaction time of the peronei muscles, patients sustaining ankle instability also showed increased postural sway. An interesting finding of Konradsen and Ravn (1991) was the fact that postural sway and peroneal reaction time had a high degree of correlation (Spearman's rho=0.92).

One might argue that since postural sway correlates well with peroneal reaction time, a possible decrease in postural sway with the application of ankle supports could be explained by the interaction of these orthoses with the mechanism of reaction time of the muscles of the leg, provided that peroneal reaction time could be decreased with the application of the supports. In fact, Karlsson and

Andreasson (1992) observed a shortening in the reaction time of the peroneal muscles in subjects sustaining ankle instability with the application of athletic taping. Glick et al (1976) found that the peroneus brevis muscle of ankle instability patients functioned for longer periods of time during the swing phase of the gait when taping was applied to the ankle joint.

The peroneal response usually takes place 60-90 msec after the drop of the platform that supports the foot of subjects being measured (Karlsson & Andreasson, 1992). It is most likely mediated by a spinal reflex arc and a conscious control of the reaction within this initial period of time is unlikely (Konradsen & Ravn, 1991). Simpson and Fitch (1980) stated that the reflex which follows an abruptly stretched muscle is mostly monosynaptic, having the muscle spindle as the primary sensitive organ and is called a phasic stretch reflex. Two questions arise at this point: first, is skin afferent information really important for the modulation of these reflexes? This question is particularly important since from a proprioceptive point of view ankle supports act mainly on the skin neurophysiology. Secondly, are these quick, abrupt reflexes involved in the type of test situation employed in the present study?

Diener et al (1984) investigated the effect of skin and ankle joint afferent information on reflex responses of the triceps surae and anterior tibial muscles after ischemia of the foot and ankle. No alteration was found in the response of stretch and medium latency reflexes when information from the skin and joint was removed. Sabbahi and De luca (1982) even observed an increase in the amplitude of monosynaptic reflexes (Hoffman reflex) after topical anesthesia of the skin around the leg and ankle. These studies point towards a less important role of skin input in modulating these types of reflexes that might be involved in peroneal reaction time.

The present study involved a test situation in which the moveable platform rotated in a slow rate at 20% of its maximum speed, performing 1 cycle of movement per test. This procedure was employed according to the findings of Diener et al (1984) who observed that during low frequency movement of the support platform, the proprioceptive input from the skin receptors around the ankle tended to play an important role in controlling posture. However, it is unlikely that the fast, sudden muscle reactions characteristic of measurements of peroneal reaction time are encountered with such a slow, smooth movement of the support platform.

Therefore, it appears that under the circumstances of the test situation, the effect of ankle supports in decreasing the reaction time of the muscles of the leg through the stimulation of skin afferents and a consequent decrease in postural sway is not so strongly supported. In fact, Glick et al (1976) as well as Karlsson and Andreasson (1992) found that the peroneal reaction time in stable ankles was not shortened with the application of taping.

Another aspect of proprioception that has been investigated as possibly being implicated in the pathology and treatment of ankle instability is joint position sense. Joint position sense is usually measured and defined as the subjects' ability to accurately match predetermined reference joint angles without visual feedback (Feuerbach et al, 1994). Using a Cybex II isokinetic dynamometer, Gross (1987) attempted to identify deficits of active and passive judgments of joint position in subjects with recurrent lateral sprains. No significant effect caused by ankle injury could be identified.

Important for the present investigation is whether or not skin input is important in joint position sense; if ankle supports are capable of improving this judgment; and, if this possible increase is relevant for the control of postural sway under the circumstances of the test situation and population employed. Feuerbach et al (1994) performed an investigation in order to analyze the effect of the Airstirrup^R ankle support on ankle joint position sense. Normal subjects were asked to actively match predetermined positions with and without the brace. Results indicated that the orthosis significantly improved the ability of subjects to match the reference ankle positions. Eccles (1981) has stated that control of posture by the cerebellum is exerted on the basis of a wide range of spinocerebellar pathways that convey information from skin, muscles, and joints. It seems appealing to affirm at this point that since ankle appliances might have the ability to improve joint position sense by means of increasing skin input, an improvement in postural control is automatically achieved. However, this statement should be further analyzed.

De Carlo and Talbot (1986) assessed postural sway of normal subjects after injecting an anesthetic into the anterior talofibular ligament of the ankle. No deficits in postural control as evaluated by a multiaxial balance evaluator was observed without the afferent information of the anterior talofibular ligament. Feuerbach et al (1994) arrived at the same conclusions after anaesthetizing both the anterior talofibular ligament and calcaneofibular ligament. Konradsen et al (1993) performed tests of active and passive ankle joint position sense as well as postural sway after an anaesthetic blockade of ligaments, joints, and skin receptors. Passive position sense, assessed with the muscles relaxed, was impaired by anaesthesia but active position sense and postural sway were unchanged. Therefore, it seems that skin information did not exert a crucial role in the active judgment of joint position and in the control of postural sway since the information provided by muscle receptors appears to be adequate for these tasks. As a consequence, a positive effect of ankle supports in increasing skin input leading to a better position sense and decreased postural sway cannot be considered as the main explanation for the findings of the present investigation.

In fact, if proprioception could be considered the most important mechanism responsible for the present results, one should expect the taping procedure to be the most effective in decreasing sway since tape is well attached to the skin with greater surface of contact than any of the other supports. However, subjects did not have postural sway significantly decreased with the application of taping when compared to the no support situation and when compared with the ankle braces during both the plantar flexion test and inversion test. Besides, both ankle braces demonstrated good performances only during the inversion test, which leads one to conclude that if an effective proprioceptive role was taking place, these supports would result in decreased postural sway during the plantar flexion test in addition to the inversion test.

ANKLE SUPPORTS AND MECHANICAL STABILITY

Another mechanism that should be considered when explaining how ankle supports can affect postural sway is the mechanical stability provided by them. Support of the ankle-foot complex and restriction of excessive movement are the primary purposes of these ankle appliances. Their effect on mechanical stability of the ankle is usually assessed by devices that passively move the joint until a predetermined magnitude of force is reached and the range of motion achieved at that point is recorded.

Before examining the literature addressing this topic, it is mandatory to consider some other issues. Several studies that investigated the effect of ankle supports on joint motion were designed to compare their effectiveness before and after exercise with the purposes of examining how stress activities could interfere with the effectiveness of these supports. In fact, taping has been found to have its restriction of inversion movement decreased by 20% after twenty minutes (Greene & Hillman, 1990) and sixty minutes of exercise (Myburgh et al, 1984). However, one should realize that exercise activities employed in these studies involved high-stress situations like volleyball practice (Greene & Hillman, 1990) and a squash match (Myburgh et al, 1984). The test situation employed in the present investigation did not include any stress activity before measurement. Subjects were asked to walk around the laboratory for only two minutes in order to familiarize themselves with the supports, and therefore, it is assumed th pliances did not have their mechanical ability oosening. Besides, in the present discussion with the literature addressing joint moti made to a pre-exercise moment.

The application of e taping has been found to significantly decrease talar tilt of unstable ankle joints when compared to a pre-application moment as assessed radiologically (Vaes et al, 1985). Studies have also shown that taping significantly decreased the movement of inversion in healthy, noninjured subjects when compared to a no support situation (Greene & Hillman, 1990; Gross et al, 1987; Myburgh et al, 1984). Studies by Greene and Wight (1990), Gross et al

(1992), Gross et al (1987), and Kimura et al (1987) have identified the inversion movement restrictive capabilities of the Airstirrup[R] brace in noninjured subjects compared to a pre-application situation. Similar positive results have been ascribed for the Donjoy[R] brace in studies using the same methodology (Greene & Hillman, 1990; Greene & Roland, 1989; Greene & Wight, 1990; Gross et al, 1992).

In the present investigation, both ankle braces significantly decreased postural sway when compared to a no support situation during the inversion test. However, the taping procedure did not significantly decrease postural sway during this test. The protocols that are usually applied in the assessment of restriction of movement by ankle supports employ measurement of subjects in a non-weightbearing position with a passive force being applied to the joint resulting in a large range of passive motion being achieved with the application of the force. In this study, subjects were measured in a weightbearing position, with a small range of rotation of the platform (4 degrees), and no external passive force was applied. Therefore, the ability of taping to reduce the inversion motion at the ankle-foot complex in this study, could not be fairly tested. Also, taping could have demonstrated a small degree of stretching due to its cloth-made structure which may not have prevented movements at the subtalar joint which would have resulted in a substantial decrease in sway.

In the present investigation, the Airstirrup[R] brace did significantly reduce postural sway when compared to the taping technique during the inversion test. Gross et al (1987) observed that the Airstirrup[R] brace reduced more inversion movement at the ankle-foot complex than the application of taping, but this difference was not found to be statistically significant. The external rigid medial and lateral stirrups of the Airstirrup[R] orthosis might have prevented less stretching in the small range of movement employed in this protocol.

The Donjoy[R] ankle support was not significantly superior to taping in decreasing sway during the inversion test. However, it did prove to be significantly effective enough to reduce sway when compared to a no support situation. This effectiveness was not demonstrated in the taping-nonsupported comparison. Therefore, it appears that if one of these two supports has to be chosen to prevent postural sway in similar conditions as the ones used in this movement test, the Donjoy[R] brace would be the choice.

Aistirrup[R] and Donjoy[R] braces were not significantly different in decreasing sway during the inversion test even though the performance demonstrated by the Airstirrup[R] brace was found to be greater. Greene and Wight (1990) as well as Gross et al (1992) have observed superiority of the Donjoy[R] brace in restricting inversion movement compared to the Airstirrup[R] brace in a post-application moment. However, in their study, Greene and Wight (1990) applied the Donjoy[R] brace using athletic tape which might have improved its effectiveness. In the present study, the Donjoy[R] brace was attached to the ankle without any application of tape according to the manufacturer's instructions, so that the specific influence of the brace could be assessed. Besides, according to Gross et al (1992), caution has to be exercised in generalizing results of open-chain testing procedures to the ability of these supports to act during a weight-bearing activity.

In a study of postural control in single-limb stance, Tropp and Odenrick (1988) have observed that rotation of the limb with inversion at the subtalar joint caused elevation of medial side of the foot. Thus, rotation of the limb with small displacement of the ankle and leg in the frontal plane created large displacements of the center of pressure. Therefore, by restricting the inversion movement at the subtalar joint, the ankle braces might have decreased rotation of the leg and resulted in a smaller displacement of the center of pressure underneath the foot and reduced postural sway.

The contrast analysis did not reveal any significant difference for the single comparisons during the plantar flexion test. As mentioned previously, postural sway was measured in the frontal plane which was perpendicular to the sagittal plane where the plantar flexion movement occurred. This fact together with the specific design of these supports to prevent inversion movement instead of plantar flexion might have contributed to the nonsignificant result found during this test situation. In fact, Hamill et al (1986) observed that ankle taping did not affect any ground force variables measured on the frontal plane when normal subjects walked in a straight fashion on a force plate.

Even though not statistically significant, subjects had the least amount of sway with the application of the taping technique during the plantar flexion test. No study comparing the ability of ankle supports in controlling plantar flexion could be identified in the literature. However, Myburgh et al (1984) observed a significant restriction of plantar flexion movement when normal subjects wore athletic tape when compared to no support. By restricting plantar flexion movement, taping might prevent the talus from being unstable underneath the tibia and fibula and thereby reduce postural sway.

CONCLUSIONS

In conclusion, the Airstirrup[R] and the Donjoy[R] ankle braces decreased postural sway of normal subjects when compared to a no support situation with an inversion movement occurring at the ankle-foot complex. A taping procedure (closed ankle technique), appears to be effective in decreasing sway of normal subjects during the inversion movement of the ankle when contrasted to a no support situation, however, in the present investigation, this trend was not statistically significant. With the inversion movement occurring at the ankle joint, the Airstirrup[R] brace was superior to the taping technique in reducing sway but no statistical difference was found when the two braces were compared.

During the plantar flexion movement of the ankle-foot complex, none of the ankle supports used in this study were found to significantly reduce postural sway of normal subjects when compared to a no support situation. During the plantar flexion movement, a trend was shown towards a better performance of the taping procedure in decreasing sway in comparison to the other supports. A mechanical effect characterized by restriction of range of motion at the ankle appears to be responsible for the findings of the present study, however, further research is necessary to clarify this issue.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions were reached based on the results of this research project:

1. The Airstirrup[R] and the Donjoy[R] ankle braces significantly reduced postural sway of normal subjects when measured on a moveable platform performing an inversion movement of the foot when compared to a no support situation.

2. The closed ankle taping technique appeared to be effective in reducing postural sway of normal subjects with an inversion movement of a moveable support platform when contrasted to a no support situation. In the present study however, this comparison was not statistically significant.

3. The Airstirrup[R] ankle brace was statistically superior to the closed taping technique in reducing postural sway of normal subjects when an inversion movement on a moveable support platform occurred.

4. When the Airstirrup[R] and the Donjoy[R] ankle braces were compared during the inversion test, no statistical difference was found even though a trend towards a better performance of the Airstirrup[R] brace was observed.

5. When a moveable support platform moved into plantar flexion, none of the ankle supports used in this study (the closed ankle taping technique, the Airstirrup[R] brace, and the

Donjoy[R] brace) statistically reduced postural sway of normal subjects when compared to a no support situation.

6. A trend towards a better performance of the closed ankle taping technique, compared to the Airstirrup[R] and Donjoy[R] braces, appeared to exist in decreasing postural sway during the plantar flexion movement of the moveable platform. These comparisons, however, were not statistically significant.

CLINICAL RELEVANCE OF THE STUDY

In the present investigation, a sample size of normal, uninjured subjects was employed. Therefore, the findings observed in this study have potential applicability to normal individuals who wish to prevent an ankle sprain by wearing an ankle support. The extrapolation of these results to an injured population is not recommended because of the mechanical and proprioceptive deficits found in these people which are not characteristic of a normal sample.

Based on the results of this study, if one wishes to avoid sprains of the ankle joint during activities that involve constant inversion movement of the subtalar joint with small ranges of plantar flexion movement and consequently more stress applied to the calcaneofibular ligament, ankle supports, particularly braces such as the Airstirrup[R] and the Donjoy[R], appear to be helpful as a means of reducing postural sway. One might argue that, in activities involving plantar flexion movement of the ankle, ankle supports would not be effective in preventing sprains of the talofibular ligament if only the postural sway issue were considered. However, in the present study, the moveable platform underneath the foot moved only 4 degrees of plantar flexion, and this small range of motion could have prevented the supports, particularly the taping technique, from reducing postural sway of normal subjects.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the information derived from this study, further research should look at:

1. The effect of ankle supports in decreasing postural sway in patients sustaining chronic instability of the ankle joint in order to ascertain the therapeutic effects of these supports in a patient population.
2. How ankle supports act in reducing sway at extremes of range of motion, when the majority of ankle sprains occur.
3. How these appliances specifically act on the proprioceptive system and on the mechanical stability of the ankle joint during measurement of postural sway.

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APPENDIX A

PARTICIPANT INFORMATION SHEET

INFORMATION FOR STUDY PARTICIPANTS

I am conducting a study of the effect of ankle supports on balance under the direction of Dr. D. Magee. If you do not have ankle problems, you may be eligible to participate in this study.

The study involves a one-time visit for assessment of your balance. The assessment will take place at Corbett Hall, University of Alberta at a mutually convenient time. It will take approximately 2 hours and you will be required to bring your low top sport shoes and cotton socks. It will involve measurement of balance while wearing no supports and ankle supports such as taping and two different braces. The measurement will consist of two tests that employ movement of a platform in two different planes. In each of these two tests, there will be no support, application of adhesive taping and application of two different semi-rigid braces to the ankle joint. An underwrap protection will be applied over the skin before the application of taping in order to prevent irritation. In each test, the platform will move down and up over 15 seconds. In addition, each subject will have two initial practice movements that will allow familiarization with the equipment and supports.

There are no known risks involved with this type of evaluation. Your participation will help in assessing the effect of different supports on balance and may indirectly help to prevent sprains of the ankle.

If you are willing to participate in the project or wish further information, please contact me at 433 9943 or at my office (Room 1-75) at Corbett Hall.

Paulo Henrique Ferreira BPT - Master's candidate

APPENDIX B

INFORMED CONSENT FORM

INFORMED CONSENT FORM

Title : The Effect of Ankle Supports on Dynamic Balance.

Investigators : - Paulo Henrique Ferreira, Master student, Department of Physical Therapy, University of Alberta and Dr. David Magee, Professor, Department of Physical Therapy, University of Alberta.

Purpose : The purpose of this study is to investigate balance of normal subjects with no ankle problems while wearing different types of ankle support.

Consent :

I, ______________________________ agree to participate in the above named project. I understand that my participation in this project is voluntary and I may withdraw from the study at any time without penalty.

I understand that ankle instability can be a significant problem for the population in general, and that the objective of this study is to investigate the effect of ankle supports in improving balance and consequently helping to prevent ankle sprains.

In agreeing to participate in this study, I understand that my right ankle will be tested on a balance machine on which I will stand with my eyes open. I also understand that my ankles will receive the application of adhesive taping and semi-rigid braces. I have read the information sheet and understand what is involved in this study.

I understand that there are no risks involved in this type of study. I understand that an underwrap will be applied over my skin to avoid skin irritation and that if for any reason I lose my balance while doing the test, I will be able to hold onto horizontal and vertical bars which will surround me.

I also understand that all information given or result found will be treated confidentially. I will be free to ask further questions at any time.

______________________________ - __________.

Participant's signature date

______________________________ - __________.

Principal investigator's signature date

______________________________ - __________.

Supervisor's signature date

APPENDIX C

SAMPLE SIZE CALCULATION

SAMPLE SIZE CALCULATION (from Cohen, 1988)

Effect Size = $\frac{M1 - M2}{SD}$ where M1-M2 = Difference between means expected to be significant.

SD= standard deviation from the literature.

Effect size = $\frac{0.23}{0.80}$ = **0.29**

From table 8: u = k - 1 where K= number of repeated measures.

For a Effect Size of .3, u=3, power=.8:

n' = 31

n' to detect effect sizes						
	Effect sizes					
Power	0.05	0.10	0.15	0.20	0.25	0.30
0.10	79	21	10	6	4	3
0.50	577	145	65	37	24	16
0.70	881	221	99	56	36	25
0.80	1096	274	123	69	45	**31**

Table - sample size table for analysis of variance (from Cohen, 1988).

$$N = \frac{(n' - 1)(u + 1)}{\text{number of cells}} + 1$$

where N= number of subjects.

$$N = \frac{(31 - 1)(3 + 1)}{8} + 1$$

$$N = \frac{(30)(4)}{8} + 1$$

$$N = \frac{120}{8} + 1$$

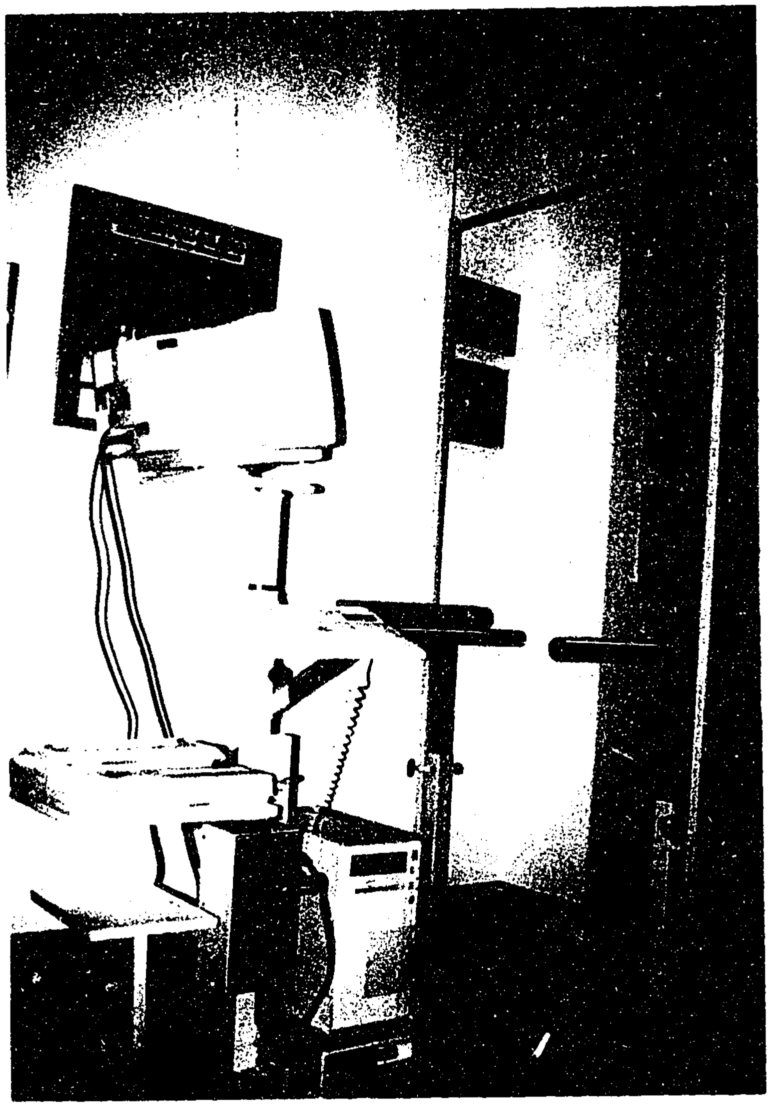
$$N = 16$$

Therefore for the purpose of this study, a goal of 20 subjects was established.

APPENDIX D

CHATTANNOGA BALANCE SYSTEM^{TM}

CHATTANOOGA BALANCE SYSTEM™



APPENDIX E

PILOT STUDY

PLANTAR FLEXION TEST

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5
1st try	4.33	3.90	3.03	3.68	3.96
2nd try	3.68	5.09	4.17	4.44	3.90
3rd try	5.20	4.33	3.96	4.66	3.31

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5
MEAN	4.40	4.44	3.72	4.26	3.72

MEAN OF TRIALS = 4.11

SD = 0.36

$$\text{Coefficient of Variation} = \frac{\text{SD}}{\text{Mean}} \times 100\%$$

$$\text{CV} = \frac{0.36}{4.11} \times 100\%$$

CV = 8.7%

INVERSION TEST

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5
1st try	4.88	4.28	2.98	3.25	4.93
2nd try	3.52	3.03	3.74	3.36	4.01
3rd try	2.76	3.20	4.88	3.74	2.60

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5
MEAN	3.72	3.50	3.87	3.45	3.85

Mean of Trials = 3.68

SD = 0.19

$$\text{Coefficient of Variation} = \frac{\text{SD}}{\text{Mean}} \times 100\%$$

$$\text{CV} = \frac{0.19}{3.68} \times 100\%$$

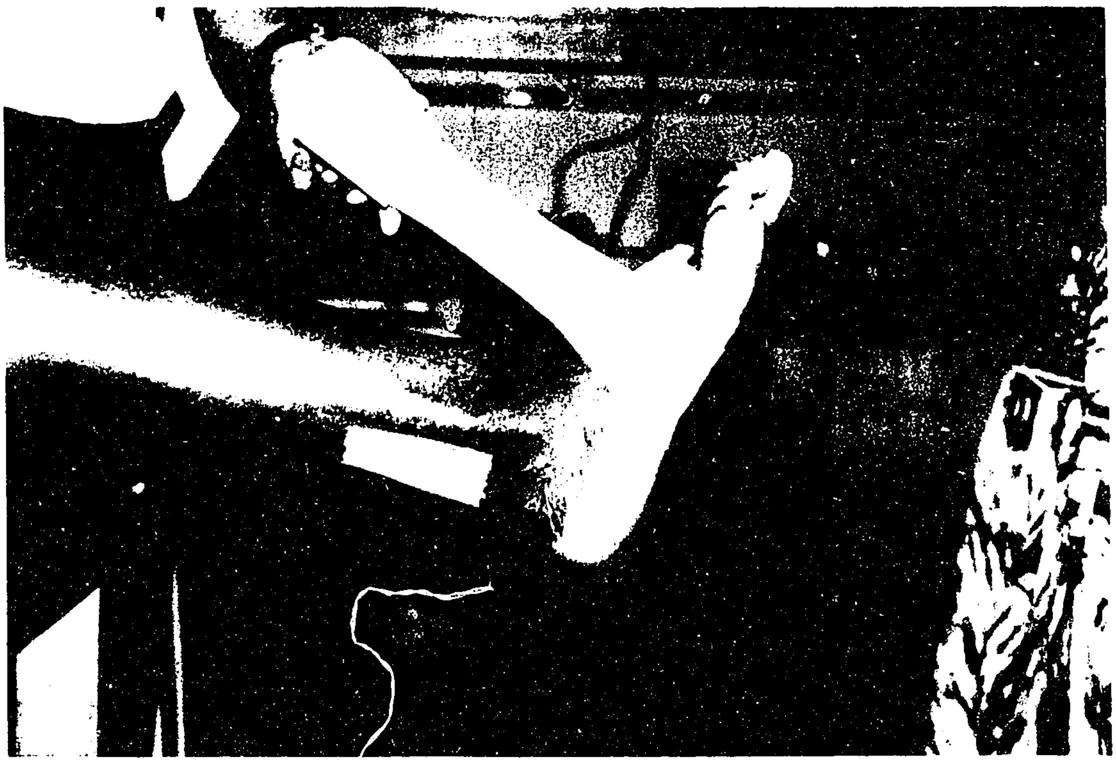
CV = 5.2%

APPENDIX F

CLOSED ANKLE TAPING CONFIGURATION

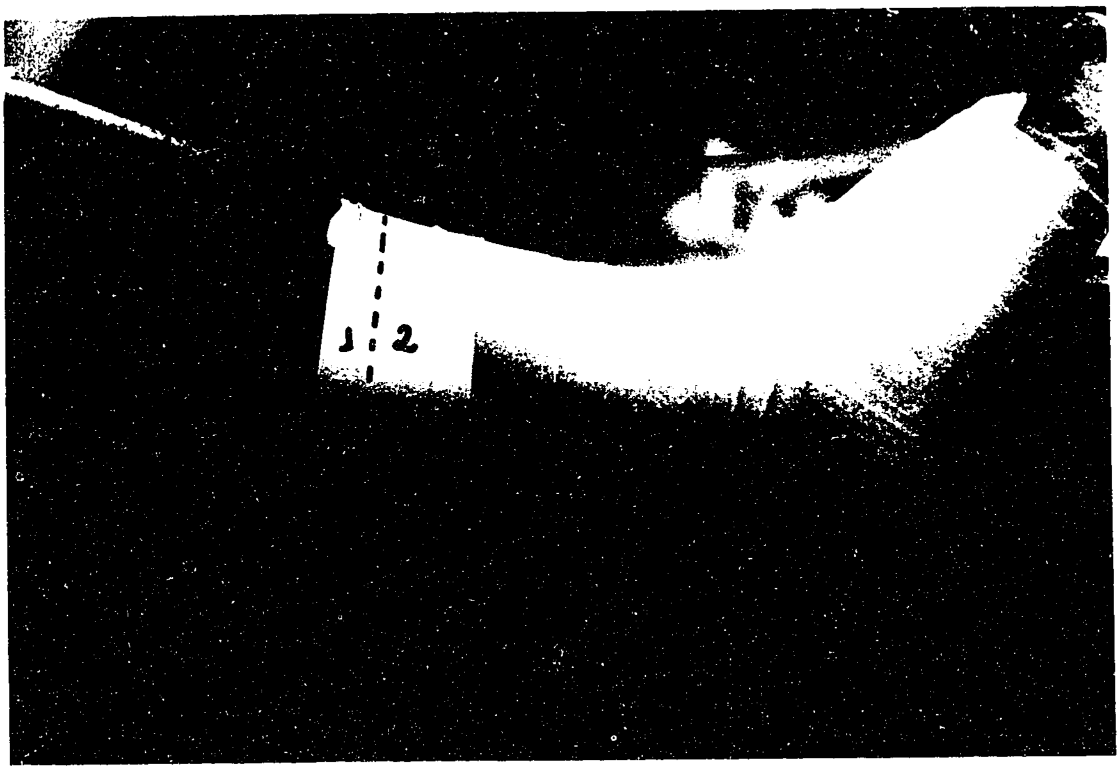
CLOSED ANKLE TAPING CONFIGURATION

STEP 1- PREPARATION



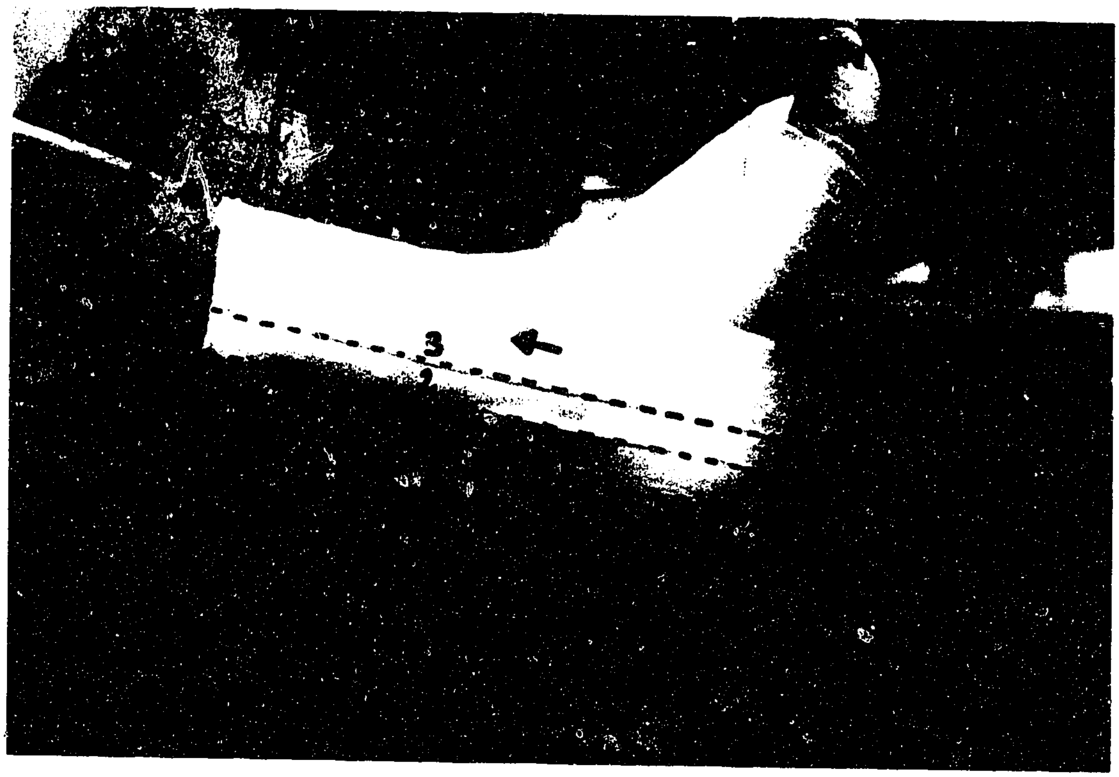
The skin is prepared with lubricated foam pads which are applied over the achilles tendon area and dorsal aspect of the foot in order to decrease friction. Then underwrap is applied in a continuous fashion from the head of the fifth metatarsal up to the musculotendinous junction of the gastrocnemius-soleus group to avoid skin irritation.

STEP 2- ANCHOR STRIPS



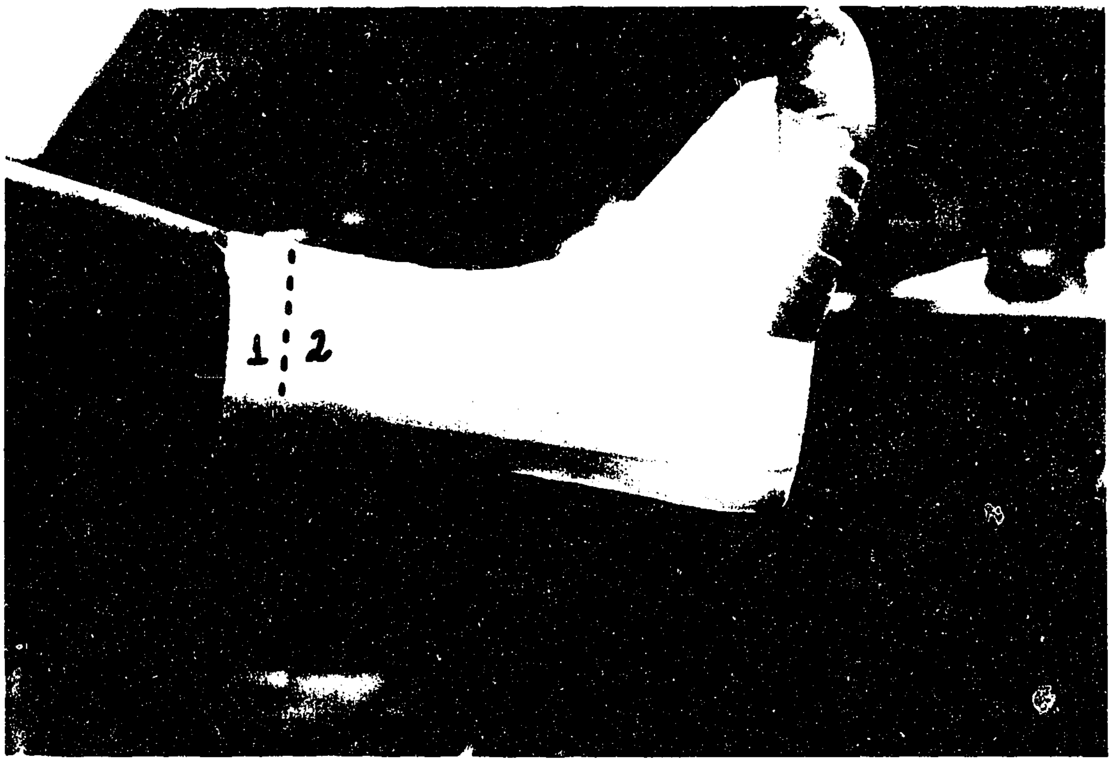
Application of the tape begins with 2 anchor strips placed just beneath the musculotendinous junction of the gastrocnemius-soleus group. Each strip overlaps the preceding one by one-half.

STEP 3 - STIRRUPS



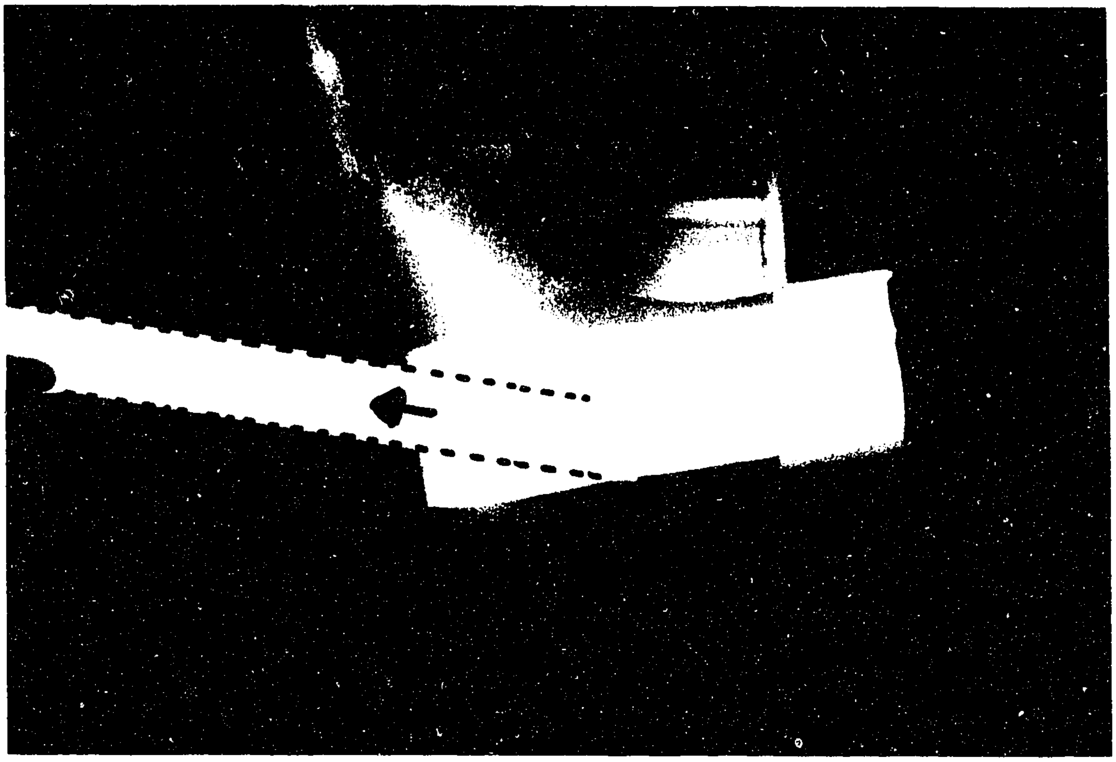
Three stirrups are then applied in a medial to lateral direction, beginning and ending at the calf anchor. The first stirrup is directed behind the malleoli and runs parallel to the achilles tendon. Each consecutive strip overlaps the previous one by one-half.

STEP 4- REANCHORING THE STIRRUPS



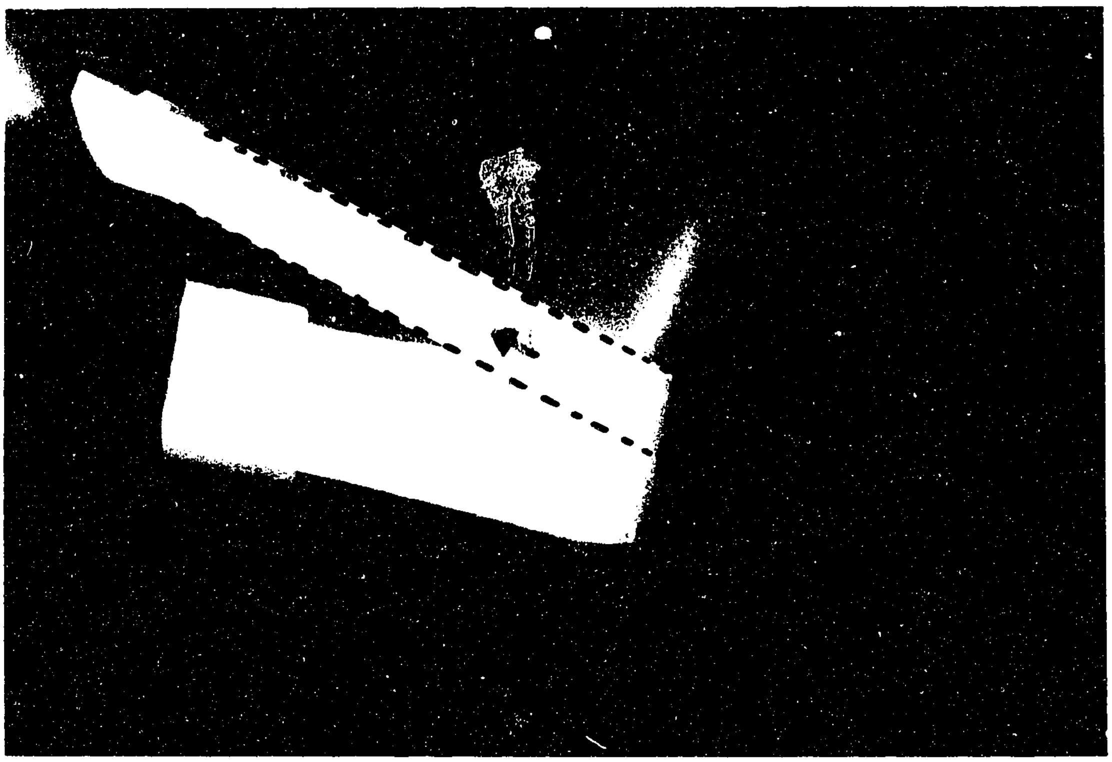
The stirrups are reachored with 2 strips starting from the top of the stirrups.

STEP 5- FIGURE-OF-EIGHT



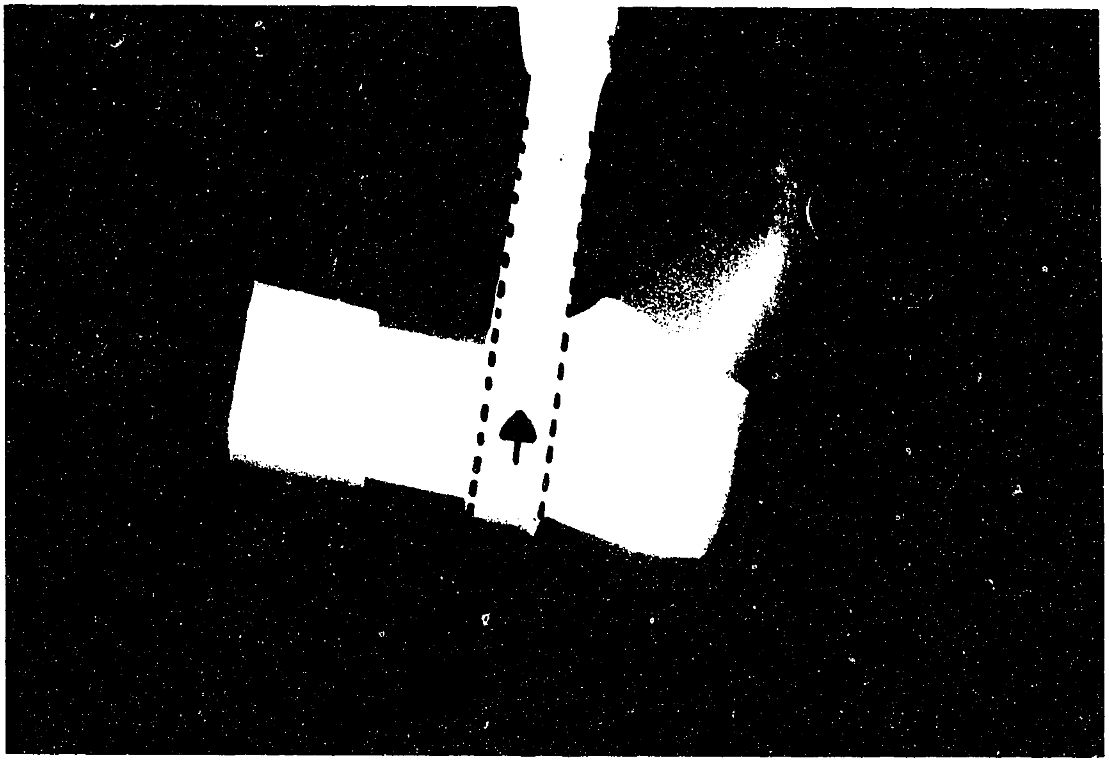
The figure-of-eight anchor begins medially at the malleolus.

STEP 5- FIGURE-OF-EIGHT (cont)



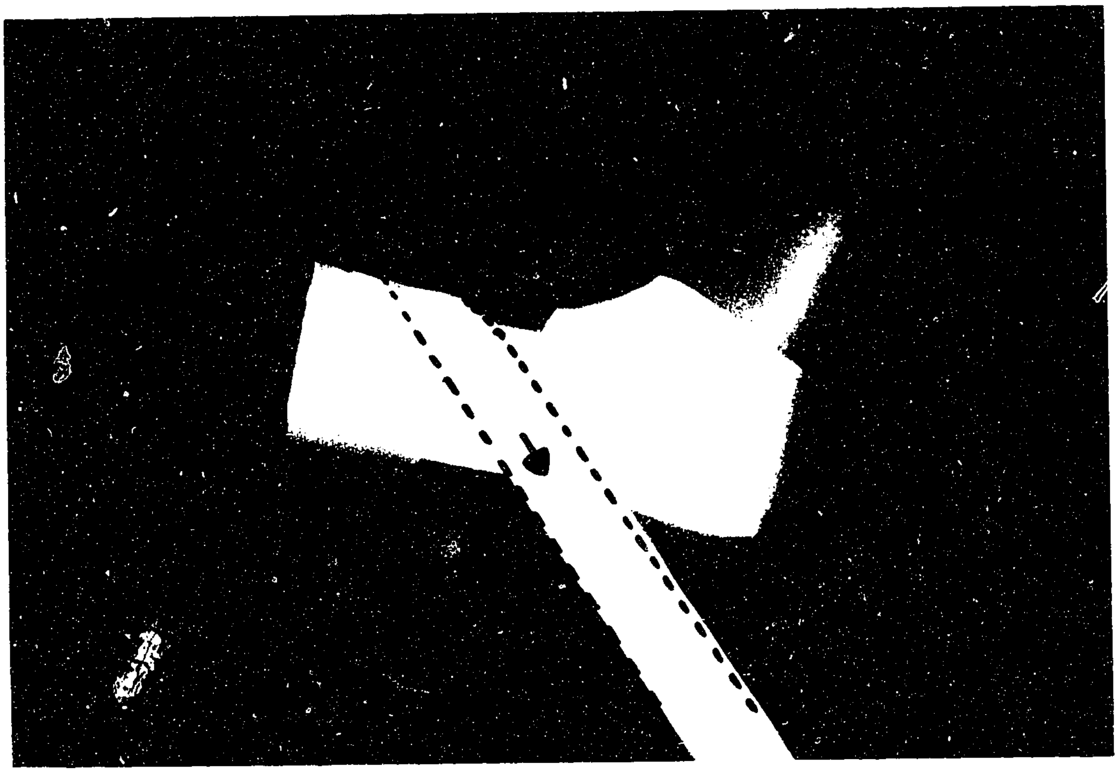
The tape is pulled under the arch and up and around the outside of the foot, staying just behind the base of the fifth metatarsal.

STEP 5- FIGURE-OF-EIGHT (cont)



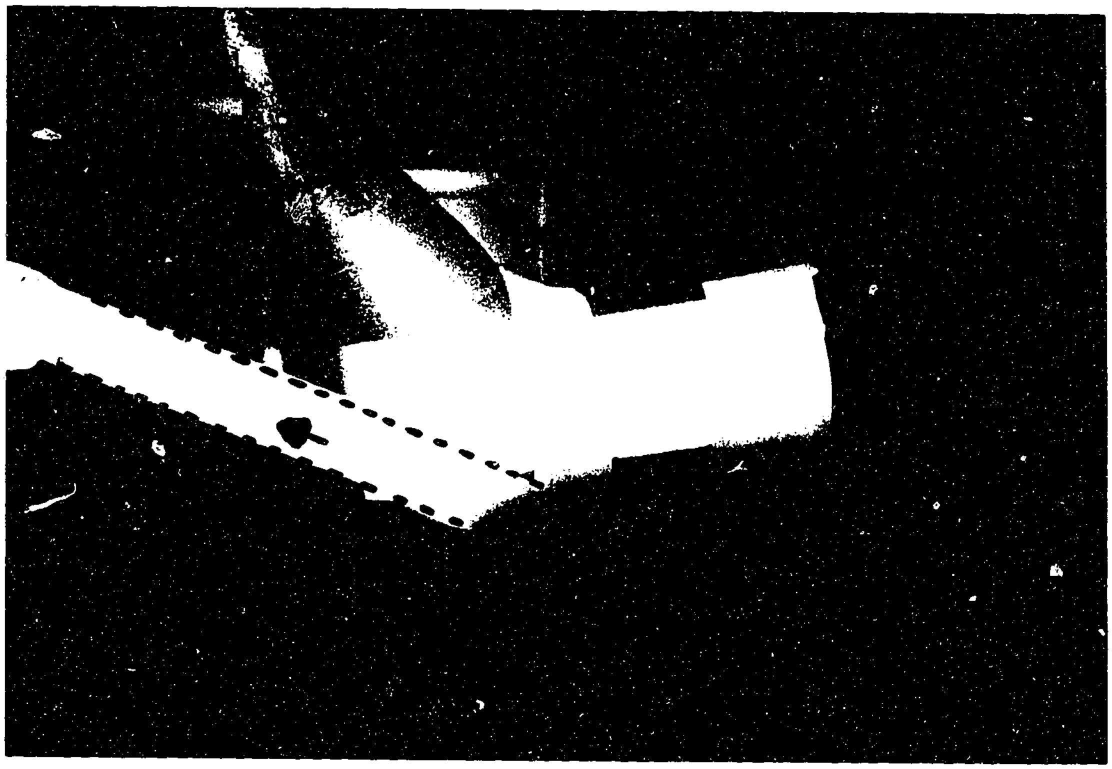
The upper portion of the eight is completed by directing the tape horizontally around the distal aspect of the tibia and fibula.

STEP 6- HEEL LOCK



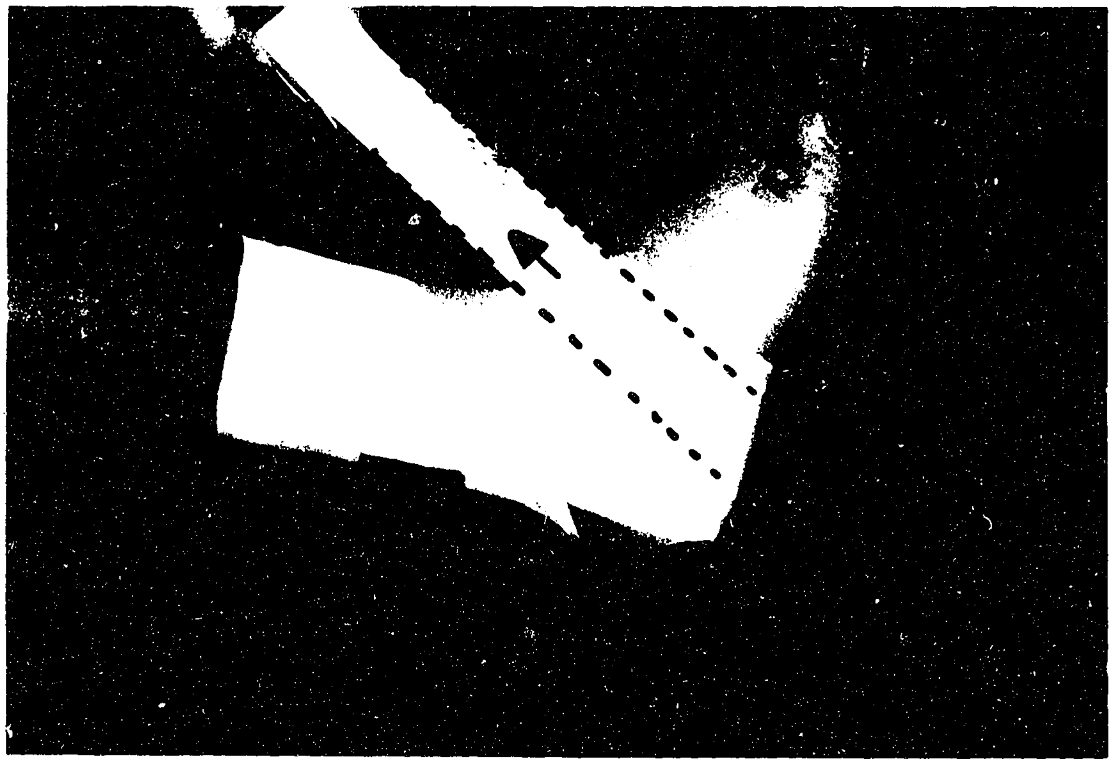
The heel lock begins at the calf anchors, passes downward behind the lateral malleolus, and crosses the achilles tendon.

STEP 6- HEEL LOCK (cont)



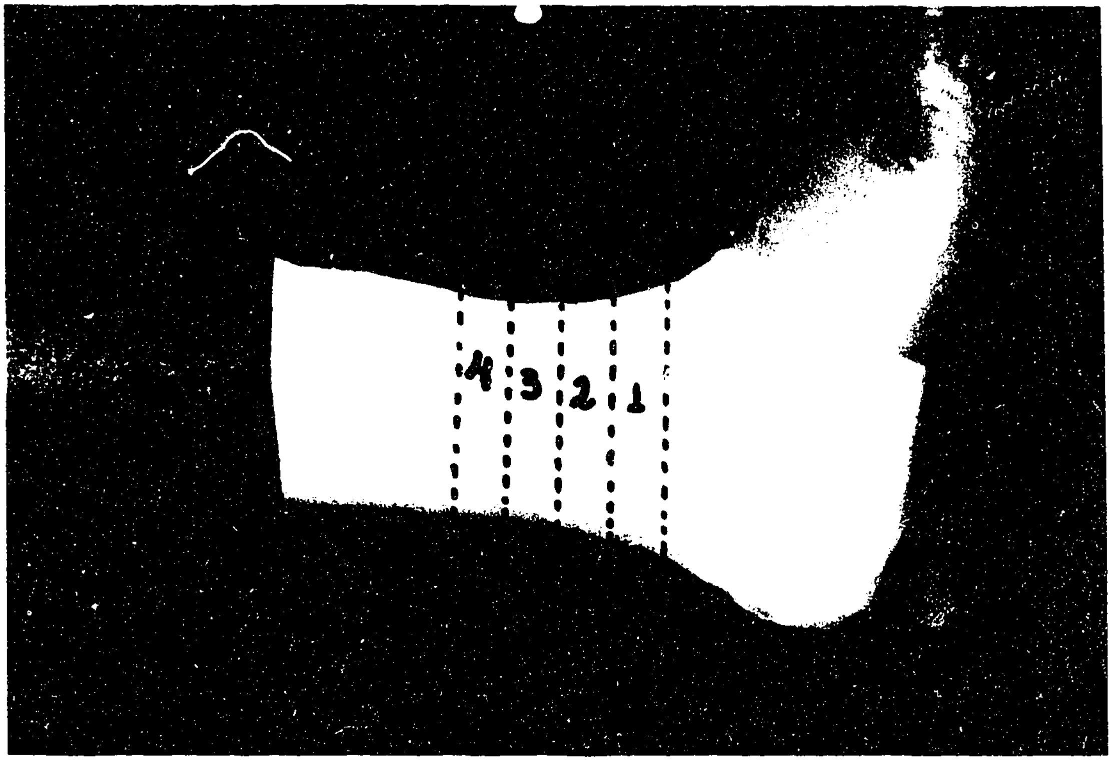
The tape then passes the inside of the calcaneous.

STEP 6- HEEL LOCK (cont)



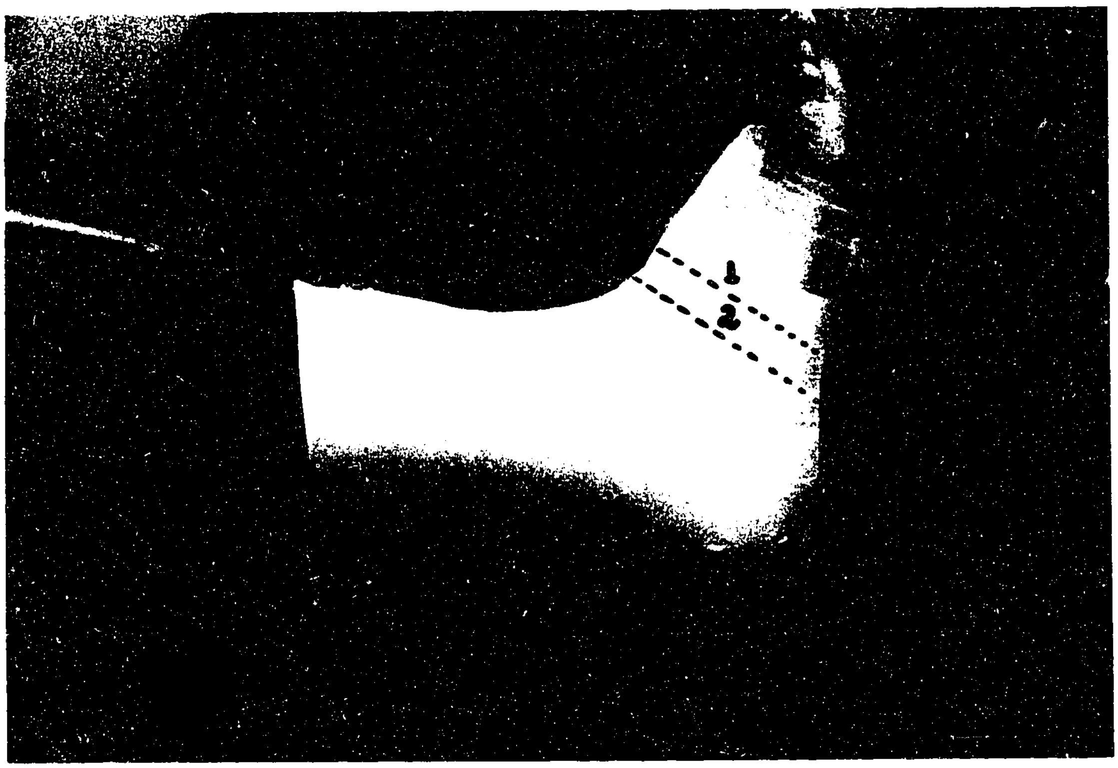
The tape passes around the outside of the foot and ends at the medial aspect of the calf anchors. A medial heel lock is then applied with a reversal of the previous pattern.

STEP 7- CLOSE-OFF



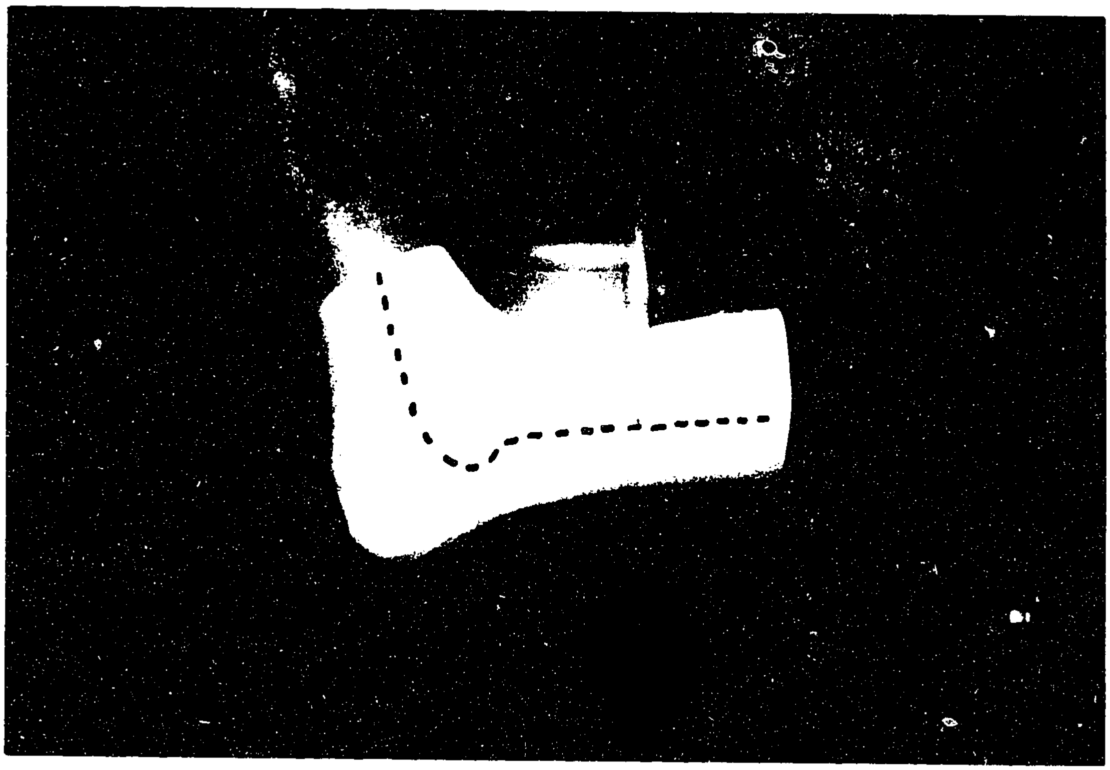
The close-off procedure begins with four horizontal strips placed around the periphery of the foot. The first strip is applied beneath the malleoli and each consecutive strip overlaps the previous one by one-half. The procedure continues by circumferential application of tape up the lower leg to the calf anchor.

STEP 7- CLOSE-OFF (cont)



Two close-off strips are also circled around the arch.

STEP 8- REMOVAL



The tape is removed by cutting along the medial aspect of the foot, behind the malleolus, and up along the medial aspect of the tibia.

APPENDIX G

AIRSTIRRUP ANKLE TRAINING BRACE™

AIRSTIRRUP ANKLE TRAINING BRACE™

The AirStirrup Ankle Training Brace™ before application.

AIRSTIRRUP ANKLE TRAINING BRACE™

The Airstirrup Ankle Training Brace™ after application.

AIRSTIRRUP ANKLE TRAINING BRACE™ -

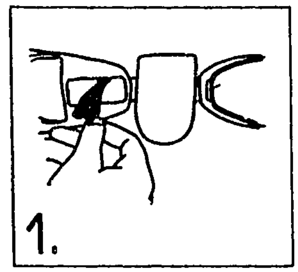
MANUFACTURER'S INSTRUCTIONS FOR APPLICATION

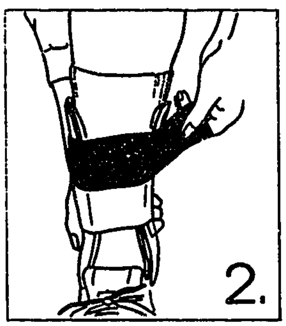
Fitting Instructions

Two initial adjustments will customize the Sport-Stirrup* to your ankle. From then on, just strap it on and tighten to comfort.

PLEASE REMEMBER:
Always wear an absorbent sock.
The aircells are pre-inflated and rarely require adjustment.*

1. Adjust the heel width so the sides are snug on your ankle but not too tight. Peel back the tip of the aircells for the Velcro on the heel pad.

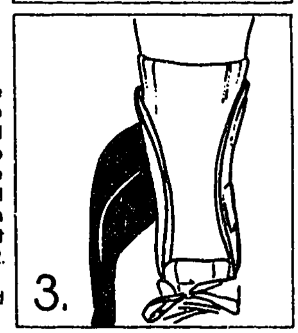




2. Center the shells on the sides of your ankle. The bottom edges of the shells should follow the sides of your foot. Otherwise, an edge may pinch. Hold the sides in this position while you wrap around and tighten the straps. Then check the alignment. Readjust as necessary.

3. When removing the Sport-Stirrup, release the straps only from the medial (inside) shell. Do not disturb their attachment to the Velcro dots on the lateral (outside) shell. This will retain the "centering" adjustment you made in Step 2.

Next time, just slip it on and tighten to comfort.



*At high altitude the aircells will expand beyond their pre-inflation level of 1/4". Too much air adds bulk in the shoe and reduces support.

To adjust, insert the filling tube (or a straw) into the valve (tucked in the top of the aircell) and squeeze out the excess air. With the valve open, the foam liner will expand to the proper level. Then remove tube and fold valve back to original position.

In the rare case where more air is needed for comfort, follow the same procedure, but add a small amount by blowing into the filling tube.

MAINTENANCE

The entire brace can be hand washed in luke warm water with a mild soap or detergent. Air dry without artificial heat. If a heel pad should become worn, or an aircell punctured (less than 1% do), please call Aircast toll free for prompt replacement.

WARRANTY POLICY

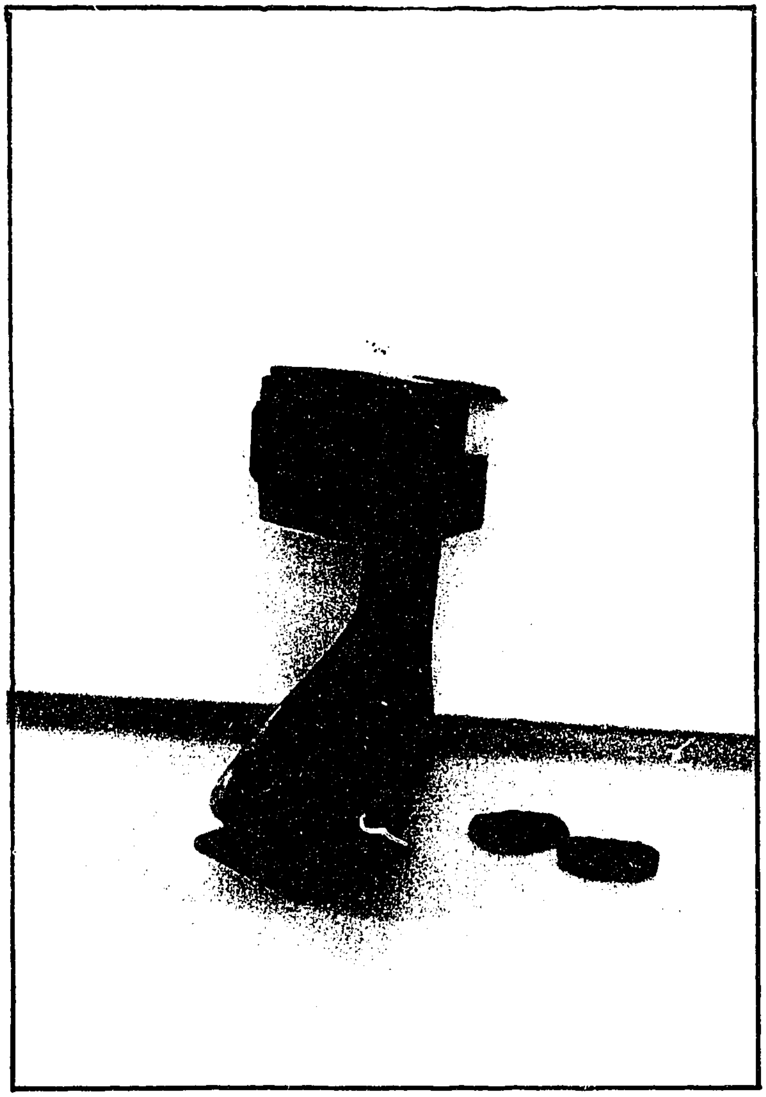
Satisfaction—Aircast will provide prompt refund for any product that does not provide satisfaction for any reason.

Durability—Aircast will provide replacement parts for any Sport-Stirrup that becomes unserviceable for any reason for a period of one year from date of sale, provided the worn part is returned to Aircast for analysis.

APPENDIX H

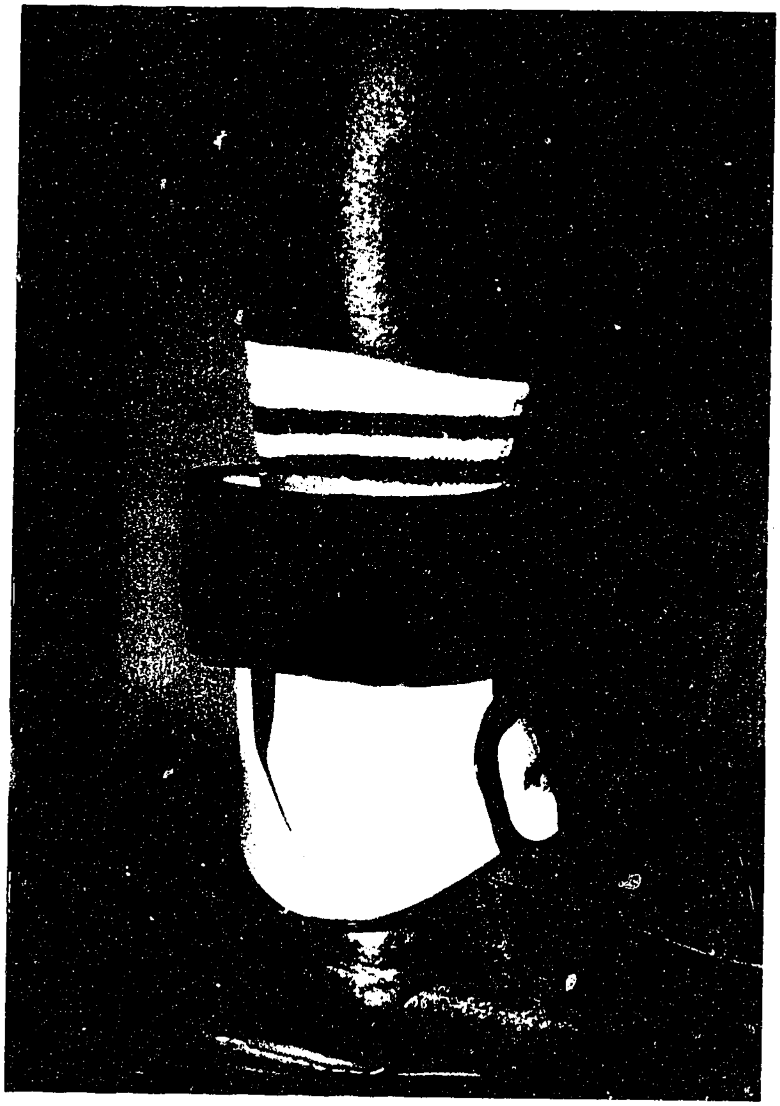
DONJOY^{R} ANKLE LIGAMENT PROTECTOR

DONJOY[R] ANKLE LIGAMENT PROTECTOR



The Donjoy[R] Ankle Ligament Protector before application.

DONJOY® ANKLE LIGAMENT PROTECTOR



The Donjoy® Ankle Ligament Protector after application.

DONJOY® ANKLE LIGAMENT PROTECTOR

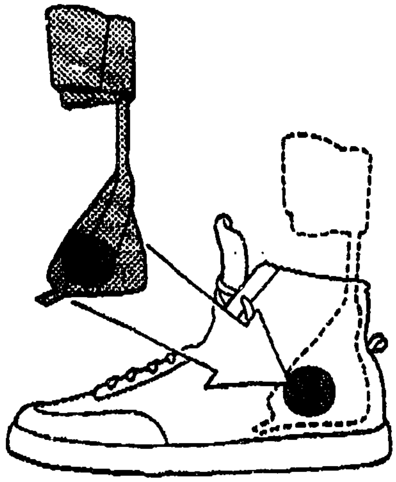
MANUFACTURER'S INSTRUCTIONS FOR APPLICATION

NOTE: This brace is designed to work in conjunction with a shoe to provide maximum stability.

A. Select the appropriate size brace from the ankle sizing chart provided. (The brace should fit over a heavy athletic sock.)

B. Position the brace in the shoe to be utilized with the heel of the brace positioned firmly in the back of the shoe.

1

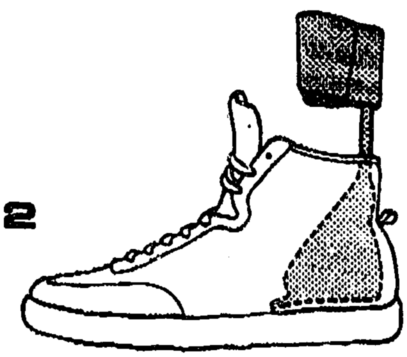


You will note that there are patches of hook fastener on either side of the brace. These are included to provide for a more secure interface between the shoe and the brace. With the brace in the shoe, locate the appropriate position for the matching patches of loop fastener provided. Remove the brace from the shoe.

Peel the protective backing off the loop patches, position them in the shoe and press firmly to engage the adhesive on the back of the patch.

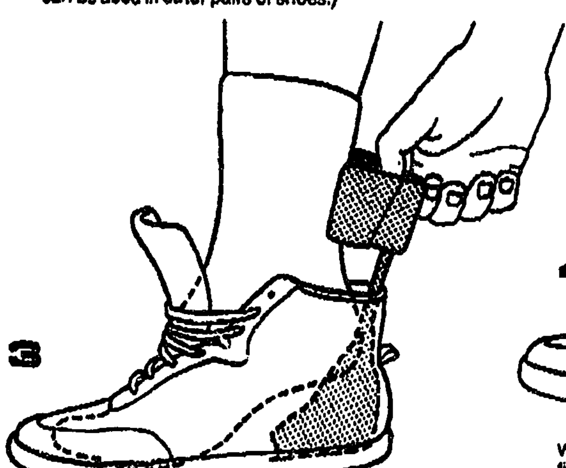
(Additional patches have been provided so that the brace can be used in other pairs of shoes.)

2



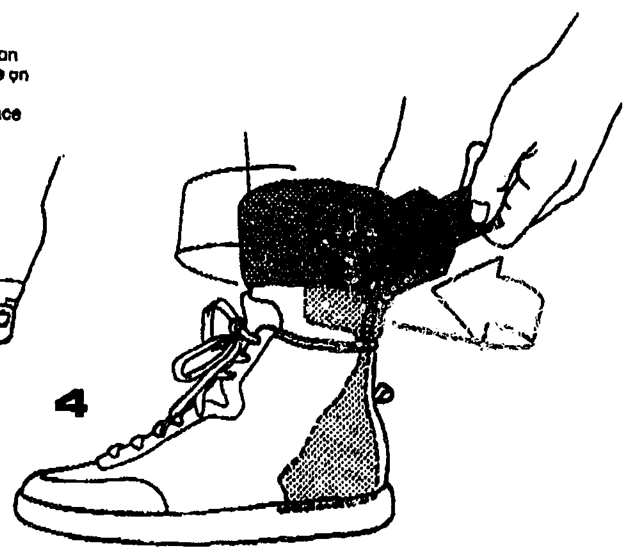
With the loop patches installed in the shoe, reposition the brace in the shoe with the heel cup of the brace as far back in the shoe as possible.

3



Now step into the shoe, using the brace as a shoe-horn.

4



With the calf-cuff against the leg, fasten the neoprene strap with firm pressure but not tight enough to compromise circulation to the lower leg. (This calf-cuff is spring loaded to allow free flexion and extension in use. It should be in its uppermost position when the brace is applied. The extensions of this cuff are pliable and will mold to the leg when the strap is applied.)

APPENDIX I

SUBJECTS CHARACTERISTICS

SUBJECTS CHARACTERISTICS

Subject	Age (years)	Height (m)	Weight (Kg)	Gender
EA	29	1.74	69.4	male
TL	21	1.57	56.3	female
JM	29	1.86	79.3	male
HM	33	1.66	83.4	female
LH	21	1.60	54.5	female
MK	20	1.63	68.5	female
JS	26	1.63	62.7	male
IP	24	1.61	57.3	female
LC	20	1.63	53.7	female
AP	25	1.61	76.4	female
JE	20	1.73	64.0	female
SS	28	1.79	71.5	female
JS	30	1.57	74.0	female
AC	22	1.66	58.7	male
LP	22	1.70	62.7	female
CJ	23	1.81	63.7	male
MV	21	1.65	49.2	female
KN	20	1.68	68.1	female
AT	32	1.68	64.6	male
KB	23	1.62	57.0	female

APPENDIX J

RAW DATA

POSTURAL SWAY (cm) - PLANTAR FLEXION TEST

Subject	No support	Taping	Aircast	Donjoy
EA	2.35	2.28	2.80	3.66
TL	4.37	3.32	3.66	3.88
JM	2.80	2.84	[illegible]31	2.56
HM	3.79	3.67	3.[illegible]	3.99
LH	3.07	3.97	3.27	3.31
MK	4.03	2.55	3.11	3.21
JS	3.31	3.43	3.60	4.22
IP	2.87	2.57	2.28	2.40
LC	3.40	3.36	3.43	4.08
AP	3.40	3.40	2.71	3.32
JE	2.20	2.51	1.90	2.35
SS	3.65	3.41	2.91	3.40
JS	2.76	3.65	3.31	2.80
AC	3.32	2.40	3.07	2.45
LP	2.95	3.31	2.94	3.07
CJ	2.80	3.49	3.56	3.38
MV	2.83	2.75	2.96	2.87
KN	3.94	3.92	3.97	3.74
AT	3.04	3.14	4.14	4.05
KB	2.64	2.55	2.48	2.55

POSTURAL SWAY (cm) - INVERSION TEST

Subject	No support	Taping	Aircast	Donjoy
EA	2.91	3.34	3.52	2.64
TL	4.66	4.21	3.67	3.41
JM	3.16	3.25	3.20	3.99
HM	4.95	4.37	3.94	4.17
LH	3.40	3.34	3.88	4.10
MK	3.32	3.05	3.25	3.40
JS	4.51	4.73	4.35	4.26
IP	3.96	3.36	2.55	2.82
LC	4.93	3.20	3.94	4.35
AP	3.88	4.14	3.19	3.68
JE	2.67	2.80	2.02	2.02
SS	3.86	3.97	3.38	4.23
JS	4.32	4.44	4.03	4.19
AC	3.47	2.75	2.49	2.65
LP	3.38	3.18	3.22	3.65
CJ	4.23	4.06	4.21	3.85
MV	3.63	2.67	2.93	3.45
KN	3.78	4.81	3.94	3.13
AT	2.78	2.96	3.20	3.61
KB	3.94	3.31	2.57	2.40