This is to certify that the

thesis entitled

A COMPARISON OF ANGULAR DISPLACEMENT, VELOCITY AND ACCELERATION OF THE ANKLE WITH AND WITHOUT AN ACHILLES TENDON TAPING TECHNIQUE

presented by

K. Danielle Henry

has been accepted towards fulfillment of the requirements for

M.S. degree in Kinesiology

[signature]

Major professor

Date May 12, 1998

A COMPARISON OF ANGULAR DISPLACEMENT, VELOCITY, AND ACCELERATION OF THE ANKLE WITH AND WITHOUT AN ACHILLES TENDON TAPING TECHNIQUE

By

Kerry Danielle Henry

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Kinesiology

1998

ABSTRACT

A COMPARISON OF ANGULAR DISPLACEMENT, VELOCITY, AND ACCELERATION OF THE ANKLE WITH AND WITHOUT AN ACHILLES TENDON TAPING TECHNIQUE

By

Kerry Danielle Henry

Achilles tendon taping techniques are routinely used in the athletic training profession for injury prevention and protection from further damage to the tendon. The aim of the study was to examine the effectiveness of a common Achilles tendon taping technique designed to limit excessive dorsiflexion of the ankle joint. The potential for injury exists during impacts encountered in sports , especially during landing phases. The landing of gymnastic skills have produced some of the largest peak reaction forces encountered in sport. This study utilized the landing from a single back tuck saltos, a basic skill for gymnasts at the collegiate level. Subjects were videotaped while executing the back tuck saltos with and without the Achilles tendon taping technique. This videotape was analyzed using the Aerial Performance Analysis System (APAS) to obtain the displacement and velocity of the ankle under the two conditions. The results of the study indicated that the taping technique was effective at restricting dorsiflexion of the ankle. There was no significant affect on the angular velocity of the taped ankle following initial contact with the ground.

ACKNOWLEDGMENTS

I would like to thank the members of my committee: Dr. Jeff Kovan, Sally Nogle, and Dr. Diane Ulibarri who have made this study possible. I want to extend a special thanks to the Department of Kinesiology at Michigan State University for the use of their Ariel Performance Analysis System (APAS). Dr. Ulibarri and Graduate Assistant Claudia Angeli had the troublesome task of educating me on the system and helping me transport and set up the materials needed to film and digitize.

I would also like to thank the Michigan State Women's Gymnastics coaching staff and team for their support and the use of their facilities during filming.

I want to give special thanks to Dr. Elsayed Abdel-Moty, from the University of Miami Ergonomics Department for his invaluable knowledge of statistical analysis.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

INTRODUCTION

The sports world today is characterized by intense competition, fractions of inches between winning and losing, multimillion dollar stakes, and grueling training regimens. There is intense pressure placed on athletes to continuously break records and push the human body to the maximum, often times with little regard for future well being. Despite the advancements in medicine and technology, it is often difficult for an athlete to physically maintain the highest level of performance. At some point the human body may become injured and simply need assistance to continue to perform at a competitive level. One important purpose of the athletic training profession is to maximize and prolong the efficiency of the body through the use of human biomechanics. This endeavor may be accomplished by utilizing both preventative and corrective devices (e.g., taping techniques) to provide support to tendons, ligaments, and/or muscles.

Gymnastics is one sport in which a wide range of injuries may occur, making athletic trainers a critical part of any gymnastic program. According to the National Collegiate Athletic Association, separate studies conducted in both 1986 and again in 1990 found that gymnastic injury rates were among the highest in collegiate sports. In addition, rates are even higher for gymnasts in the more advanced competition levels where skill complexity and practice hours tend to be the greatest. These injuries may be caused by fatigue, overuse, and especially, trauma (Mackie and Taunton, 1994).

Women's collegiate gymnastics is composed of four events: the parallel bars, the vault, the balance beam, and the floor exercise. The floor exercise event has been associated with the greatest number of injuries. According to McNitt-Gray, Munkasy, Welch, and Heino (1994) 37% of all injuries in women's gymnastics occurred on floor events. The landing skills performed during floor routines have produced some of the largest peak reaction forces encountered in sport. In addition, judges' scoring methods indirectly reward forceful landings by penalizing gymnasts for additional steps, excessive segment motion, or hand placements on the mat to control the desired outcome. These movements are natural reactions that would dissipate or reduce both the force and momentum of the landing. This pressure to "stick the landing" and absorb the shock of the impact directly increases the landing force on the body. Because of the large forces absorbed by the body, it is not surprising that the spine, knee, and foot are the most common sites of injury in the sport of gymnastics (Taunton, McKenzie, and Clement, 1988).

According to Mackie and Taunton's 1994 study of collegiate and nationally ranked gymnasts, 55% of acute injuries and 73% of overuse injuries involved the lower extremity. The Achilles tendon was one of these structures most commonly injured. The most common injury in the 1994 study was calcaneal traction apophysitis (Sever's disease). One major etiology of Sever's disease is a tight gastrocnemius/soleus complex. The second most common overuse injury was Achilles tendinitis. Strong dorsiflexion movements which are resisted by the plantar flexors or explosive stretching are often times the cause of an Achilles tendon strain or rupture (Årnheim, 1989). Athletic trainers often try to manage or protect both of these conditions through the use of Achilles tendon taping techniques. Some athletic trainers even take precautionary measures by using the taping technique on healthy gymnasts to prevent such conditions. The use of tape may provide the non symptomatic athlete mentally with a feeling of safety and stability in the ankle joint and encourage them to continue normal training conditions.

Protection for previous injury and supporting a body part to prevent additional insult are the two main reasons why athletic trainers utilize taping techniques. The two types of tape most commonly used in sports medicine are linen and elastic tape. Linen tape rigidly holds a body part in place, whereas elastic tape moves with the body while adding support to the area (Arnheim, 1985).

Scope And Objectives Of The Study

The following study was designed to test the effectiveness of a taping technique commonly used by athletic trainers to prevent injury to the Achilles tendon. The purpose of taping the ankle is to avoid hyper-stretching of the gastrocnemius and soleus muscles and the Achilles tendon by restricting dorsiflexion of the foot. Increased dorsiflexion (angular displacement), angular velocity, and angular acceleration are all contributing factors to Achilles tendon injuries and are the main focus of this study. Dorsiflexion can be determined by measuring the angular displacement and angular velocity can be computed from angular displacement using the equation V= change in speed/change in time. The effectiveness of external support devices, such as taping and bracing, has been documented in the literature. This information is limited to adhesive tape, rigid and semi-rigid orthosis. There have been no documented reports on elastic tape, specifically Achilles tendon taping techniques, although these taping techniques are used extensively

by athletic trainers in all sports. Objectively documenting the effectiveness of this specific taping technique can give the athlete and the sports medicine team a more informed basis on which to assess the merits of such taping techniques.

For this study elastic tape was used and the Achilles tendon taping technique as described in Modern Principles of Athletic Training (Arnheim, 1985, p. 482) with slight modifications was tested. These modifications are described in Chapter 3. The ankle movement during landing of a single back tuck saltos was analyzed for each gymnast. The single back tuck saltos is a common floor exercise event in which the gymnast propels their body backward in a tuck position and completes one full rotation of 360 degrees before landing. Two subjects, performing four trials each, were utilized to test the displacement, velocity and acceleration of the ankle with and without the Achilles taping procedure during the landing phase. The Aerial Performance Analysis System (APAS) was critical in the biomechanical analysis of the subjects' ankles during landings. High speed videography was used to record each landing, while the APAS was utilized to reduce the data, perform calculations of displacement, velocity and acceleration, and to graph the data. The landing was broken down into two phases, before contact with the ground and immediately following contact with the ground. Displacement, velocity and acceleration data was recorded at split second intervals during each phase of the landing. The portable APAS system was an invaluable tool in this study because it could be placed in a realistic environment (i.e., gymnasium) instead of a laboratory. Since gymnasts encounter a wide range of surfaces, velocities, segmental configurations and visual conditions prior to impact which may influence their ability to successfully execute the landing, it is very important to have them perform in their natural environment. A laboratory study would not have allowed subjects (i.e., gymnasts) to perform in their more familiar or comfortable surroundings (McNitt-Gray et al., 1994).

The Main Objectives Of This Study Were:

1. To compare the displacement of the ankle joint with and without the Achilles tendon taping technique during the landing phases.
2. To compare the angular velocity of the landing with and without the Achilles tendon taping technique.
3. To compare the angular acceleration of the landing with and without the Achilles tendon taping technique.

Chapter 2

LITERATURE REVIEW

A thorough literature review of topics pertaining to this study was conducted. The review will be presented in the following sections:

1. human musculoskeletal system overview.
2. the role of athletic trainers concerning injury prevention.
3. an overview of protective devices.
4. gymnastic studies.
5. biomechanical analysis of human motion

Human Musculoskeletal System Overview

In any movement, four body systems are involved. These systems are skeletal, muscular, neural and circulo-respiratory. The first two constitute the musculoskeletal system. The following is a brief review of these systems.

The skeletal system is composed of several kinds of bones, joints and connective tissues. Its main functions are: (1) to give form and structure to the body, (2) to protect internal organs, (3) to produce blood cells, (4) to store calcium and phosphorus, and (5) to serve as levers (bones) and axes (joints) in body movements. The skeletal system is composed of 206 bones (cranium, 8; face, 14: ear, 6; hyoid, 1; spine, 26; sternum and ribs, 25; upper extremities, 64; and lower extremities, 62). There are more than 200 joints (articulations) between these bones. Most of the bones are attached to each other by connective tissues and are classified as long, short, flat, or irregular bones.

A joint is a point in the skeletal system where two or more bones articulate. Joints vary in the amount of movement they allow and are classified as immovable, slightly moveable, or freely movable joints. Joint range of motion is usually expressed in degrees and is dependent upon the following factors: (1) bone structure of the joint itself, (2) amount of bulk near the joint, and (3) elasticity of the muscles, tendons, and ligaments around the joints (Anderson and Hall, 1997).

Soft tissue is an area of special concern to sports medicine because of its involvement in vigorous activity and exposure to trauma. Included in these tissues are ligaments, tendons, and muscles. A tendon attaches a muscle to a bone and channels tensile forces in a limited area. Tendons can maintain and produce a pull from 8,700 to 18,000 pounds per square inch. When the tension exerted on a tendon is released, the collagen fibers return to their original shape, however, the collagen fibers will rupture if their physiological limits have been reached. A breaking point usually occurs after a 6% to 8% increase in length. A tendon is usually double the strength of the muscle it serves, therefore, before the tendon would rupture tears commonly occur at the muscle belly, musculotendinous junction, or bony attachment. Ligaments attach bone to bone and are strongest in their middle and weakest at their ends. When a ligament is traumatically stretched, it often produces an avulsion-type fracture or tears at the ends. An avulsion fracture is a separation of a bone fragment from its cortex where the ligament or tendon attaches, and is seen when bone tissue is weaker than soft tissue (Arnheim, 1985). The muscular system constitutes 40% to 50% of the adult human body. The special characteristics of the muscle tissues are: (1) *irritability*, ability to receive and respond to a stimulus; (2) *contractility*, changing shape as a result of stimuli; (3) *extensibility*, ability to extend beyond normal length; (4) *elasticity*, ability to return to normal length when the stretching force is eliminated; (5) *amplitude,* differences between maximum elasticity and extensibility and (6) *viscosity,* internal resistance of the muscle itself. There are three kinds of muscle tissues responsible for body movements known as cardiac, smooth, and skeletal muscles. The skeletal muscles are the main cause of movement and are voluntarily controlled by nerve impulses transmitted from the central nervous system (Anderson and Hall, 1997).

The Lower Leg

The lower leg is part of the distal inferior extremity that lies between the knee and ankle joints. It is comprised of two bones, the tibia and the fibula. The tibia, located on the medial aspect of the leg, is considered the main weight bearing bone. The fibula, located on the lateral aspect of the lower leg, mainly provides for the attachment of musculature and helps the tibia distally to form the ankle joint. Between the tibia and fibula is a strong sheet of fibrous tissue called the interosseous membrane. There are four compartments that house the soft tissue of the lower leg. The anterior compartment encompasses the tibialis anterior, the extensor hallucis longus, the extensor digitorum longus, the tibial artery and the anterior tibial nerve. The lateral compartment encompasses the peroneus longus, the peroneus brevis, the peroneus tertius, and the superficial branch of the peroneal nerve. The superficial posterior compartment is made up of the gastrocnemius, the soleus, and the plantaris. The gastrocnemius and soleus unite distally and attach to the calcaneus by the Achilles tendon. The Achilles tendon becomes prominent from the lower one-third of the gastrocnemius to the calcaneus. The deep posterior compartment encompasses the tibialis posterior, flexor digitorum longus, the flexor hallucis longus, and the posterior tibial artery (Anderson and Hall, 1997).

The Ankle

Ankle injuries comprise 20% to 25% of all injuries associated with running and jumping sports (Anderson and Hall, 1997). The ankle is considered a freely movable hinge joint and is comprised of four bones: the tibia, the fibula, the talus and the calcaneus. The lower ends of the tibia and fibula form a mortise that houses the talus. The tibial section of the mortise is called the medial malleolus and the fibular section of the mortise is called the lateral malleolus. The talus sits on top of the calcaneus and only allows two movements: dorsiflexion (the act of pulling toes and foot toward the anterior aspect of the shank) and plantar flexion (the act of pushing the foot downward or pointing the toes away from the anterior aspect of the shank).

Lateral ankle stability is achieved mainly through the anterior talofibular ligament, the calcaneofibular ligament and the posterior talofibular ligament. Medial ankle stability is comprised of the anterior deltoid, medial deltoid, and posterior deltoid ligaments. The major muscles of the anterior aspect of the ankle are the extensor hallucis longus, and the extensor digitorum longus. The major muscles of the medial aspect are the posterior tibialis, the flexor hallucis longus, the tibialis anterior, and the flexor digitorum longus. The main lateral muscles are the peroneus longus and peroneus brevis. The main muscles for the posterior aspect are the gastrocnemius and soleus which form the Achilles tendon (Arnheim, 1985). The average range of motion starting from the neutral position for the ankle is 10 degrees in dorsiflexion and 23 degrees in plantar flexion. Bohannon, Tiberior, and Zito (1989) investigated ankle movement of eight volunteers. The results of the study revealed two distinct axes, one for plantar flexion and one for dorsiflexion. One axis ran close to the proximal tip of both malleoli, while the other axis ran close to the center of both malleoli during plantar and dorsiflexion. In some subjects there was an abrupt change between the axes during the range of motion, while in others there was a gradual change. The axes did tend to cross at one central point on the talus throughout the range of motion. The study also described and compared dorsiflexion range of motion measurements using the heel, fifth metatarsal, and plantar surface of the foot as distal landmarks, and the shaft of the fibula as the proximal landmark. Each distal landmark measurement differed significantly when the ankle was actively and passively dorsiflexed. Their conclusion was that, for measuring magnitude of movement, the information gained with one measurement method can not be interchanged with another technique.

The Foot

The foot is comprised of 26 bones: 14 phalangeal, 5 metatarsal, and 7 tarsal. The tarsal bones consist of the talus, the calcaneus, the navicular, and the first, second, and third cuneiform bones. The calcaneus, the bone that shapes the heel, is the largest tarsal bone. One of its main functions is to act as a lever attachment for the Achilles tendon. The navicular, cuboid, and cuneiform bones glide upon each other and permit rotation, inversion, and eversion of the foot. The metatarsals are five bones that lie between the tarsals and the phalanges (toes). These bones form semi-movable joints: the tarso-metatarsal and the metatarso-phalangeal joints. The 14 phalanges give a wider base for balance and help to propel the body forward (Arnheim, 1985).

The Achilles Tendon

The Achilles tendon is the strongest and thickest tendon in the body (Hoppenfeld, 1976). The tendon is comprised of two muscles, the gastrocnemius and the soleus. The gastrocnemius is a two joint muscle, being active in knee flexion and ankle plantar flexion. The tendon is known for having a poor vascular (blood) supply resulting from damage sustained during mid-gait when the foot moves from pronation to supination (Leach, Schepsis, and Takai, 1991).

Achilles Tendon Injuries

The two main injuries to the Achilles tendon are tendinitis and a rupture of the tendon. Achilles tendinitis is the most common form of tendinitis seen in athletes. Intermittent stresses produced during running is one etiology of Achilles tendinitis. As the athlete propels their body weight forward by anchoring the foot against the ground, the calf muscles are contracting to pull the foot down (Leach et al., 1991). Other risk factors may include: vascular insufficiency, tight heelcord, Achilles contractures, hyperpronation, repetitive heel running, a recent change in shoes or running surface, a sudden increase in distance or intensity of exercise, or excessive hill climbing. Pain increases with passive dorsiflexion and resisted plantar flexion. Symptoms may include: (1) point tenderness on the tendon, (2) swelling (diffuse or localized), and (3) crepitation in the middle of the tendon during movement that indicates friction between the tendon and its sheath (Anderson and Hall, 1997). Contracture of the tendon may occur as the result of prolonged shortening during ambulation. This shortening can be caused by several factors, including prolonged use of a heel lift or high-heeled shoes (Leach et al., 1991).

An Achilles tendon rupture is the most severe acute soft tissue problem in the lower leg. The two main reasons for an Achilles rupture are a sharp blow to the tendon or an abrupt strain from a sudden excess movement. A sharp blow may produce a transverse laceration, whereas a sudden strain may cause shredding of the tendon (Hoppenfeld, 1976). Due to the poor vasculature in the Achilles, ruptures usually occur 1 to 2 inches proximal to the distal attachment of the tendon on the calcaneus. The usual mechanism of injury is a push-off of the forefoot while the knee is extending (Anderson and Hall, 1997). The athlete usually hears or feels a "pop", followed by a sharp pain and the sensation that they have been kicked in the back of the leg. The symptoms include: (1) a visible defect, (2) swelling, (3) bruising, (4) excessive passive dorsiflexion, and (5) inability to stand on tiptoes or balance. To test for a rupture, the Thompson test is performed by squeezing the calf muscle while the leg is extended. A positive test is one in which the heel does not move (no plantar flexion is noted) (Arnheim, 1985).

Achilles Tendon Studies

It is critical to review a variety of studies that may contribute to the understanding of this tendon. Neurological assessment, EMG (electromyogram) reports and biomechanical assessments are all elements that may uncover predisposing factors as to why the Achilles tendon, the strongest tendon in the body, is so commonly prone to injury and even rupture.

Salmons (1975) introduced a design of a buckle transducer used to record tendon forces in animals. The buckle transducers were surgically implanted on select tendons, after appropriate healing and recovery, in vivo recordings were measured under several conditions. Many stages of development and trials on animals were needed before human experimentation. Salmon's experiments lead to the work of others, including Pavo Komi. According to Komi (1990) the Achilles tendon was chosen and most suitable for implantation of the transducer in humans for two main reasons: (1) there is a relatively large space between the tendon and the bone that would allow for the transducer to not touch the bone even in extreme dorsiflexion of the foot, and (2) running, walking and jumping are natural activities and are characterized with a stretch-shortening cycle.

In Komi's 1990 study, the transducer was implanted around the Achilles tendon by a surgical procedure performed under local anesthesia. After implantation, subjects were immediately able to perform motor activities (walk, run and hop). The transducers, force platform, cinematography and electromyograms (EMG) provided precise measures of EMG-velocity, and force-velocity relationships. The study showed that peak forces across the tendon were recorded up to 900 lbs (4,000 N). The study also showed that rates of force development were as high as 22,500 lbs (99,000 N) per second. The typical value for the rupture force of an Achilles tendon has been estimated to be 1,575 lbs (7,000 N) (Knuttgen, 1987).

If the suggested force of 1,575lbs (7,000 N) can cause an Achilles tendon to rupture, and the landing of a single back tuck saltos can cause forces up to eight times the body weight, the forces on the Achilles tendon upon execution of this skill by an 150 lbs gymnast may reach up to 1,200 lbs (5,280 N). This is only 375 lbs (1,650 N) away from a possible rupture according to Knuttgen (1987). Therefore, safe execution of landings during practice and competition contributes to the longevity of the gymnast.

Kyrolainen and Komi (1994) discussed the stretch reflex and its impact on the Achilles tendon. The researchers suggested that the stretch reflex response of the gastrocnemius and soleus may be dependent on the training background of their subjects. Endurance trained athletes and power trained athletes were tested using an ankle ergometer which created different dorsiflexion velocities around the ankle joint. EMG activity of the gastrocnemius, soleus and tibialis anterior were recorded and compared between the two groups. For both endurance and power-type athletes, it was found that the mechanical stimuli with higher velocity created higher stretch reflex responses. The endurance trained athlete's recovery time of the monosynaptic reflex was faster compared to the power trained athletes. This suggested faster recovery time by the endurance trained athlete, and that the endurance trained athletes were more sensitive to the stimuli than the power trained athletes. This study may correlate to the neural recruitment in gymnasts who are considered power trained athletes. It may be possible that high angular velocities on the Achilles tendon of a power trained athlete need longer recovery time in order to be effective in reflex recruitment. Reciprocal innervation may also need a recovery period; the study showed that EMG activity of the agonist (tibialis anterior) was irregular immediately following the stretching of its antagonist (gastrocnemius and soleus) in the power trained athlete (Kyrolainen and Komi, 1994).

The Role of Athletic Trainers Concerning Injury Prevention

Athletic trainers are a critical part of the medical community and the sport program. The athletic trainer serves as the liaison between the physician and athlete, and the physician and coach. Athletic trainers are educated in human anatomy and physiology, kinesiology, biomechanics, psychology, health and nutrition, exercise physiology, first aid and emergency care, injury prevention, injury assessment, therapeutic rehabilitation, use of modalities, and health care administration. This strong background is needed to be certified by the National Athletic Trainers Association (NATA) Board of Certification (Anderson and Hall, 1997).

One major goal of the athletic trainer is the prevention of injury. Therefore, the need to identify pre-existing conditions that may leave the athlete susceptible to further injury or insult is important. The athletic trainer may also need to construct and apply protective devices that support and/or limit body parts. These devices may include adhesive tape, orthotic devices, and braces (Anderson and Hall, 1997).

An Overview of Protective Devices

In an attempt to prevent injury to the lower extremity, various ankle orthosis are used to provide external support. These orthoses range from traditional adhesive tape to high tech commercial braces.

Tape As a Protective Device

Taping or wrapping a body part provides support and protection while allowing functional movement. Athletic trainers can use tape during rehabilitation to reduce risk or reinjury before the athlete has returned to baseline status. Taping an area is designed to control undesired movement that may impede the healing process. Tape may also be used as a prophylactic measure. Two types of tape are usually used in sports medicine:

Linen Tape

Linen adhesive tape is made to be immobile, only slightly giving in stretch. This tape is commonly used to hold a dressing, bandage, or body part in place. Linen tape is widely used in sports because of its adaptability, adhesive mass, adhering qualities, lightness, and material strength. It comes in a variety of widths (from 1/4 inch to 2+ inches), and grades (graded according to the number of longitudinal and vertical fibers per square inch of backing materials; 85 or more is heavier and costly, 65 or fewer is lighter and less expensive). Taping directly to the skin provides maximum support, but due to irritation and discomfort, underwrap material is often utilized. This material is fine and foam-like, extremely light, and often used in unison with a tape adherent (Arnheim, 1985).

Elastic Tape

Elastic tape is made to stretch and move as the body moves. It is also commonly used to compress dressings, bandages, or body parts in place. It is not as adaptable as linen tape in that it is bulkier, heavier, hard to tear with bare hands, and more expensive. It also comes in a variety of widths and grades. One unique quality of elastic tape is that after it is stretched, it returns to initial shape, although, it has the potential to lose its elastic qualities to some degree if it is over-stretch. It is also recommended to pre-stretch the tape so it does not impair circulation (Arnheim, 1985). The Achilles tendon taping technique is designed to prevent the Achilles tendon from over-stretching. The use of elastic tape allows movement about the joint without impeding circulation or neurological function. The review of protective devices so far has not touched upon elastic tape. A new wrap found in the literature review that is similar to elastic tape is 'Scotchwrap™'. Unlike adhesive tape or bandages, Scotchwrap™ consists of a knitted fiberglass fabric combined with a polyurethane resin. It must be soaked in water, similar to a plaster paris bandage, but unlike casting material, the finished bandage remains elastic in nature. After the bandage is applied, it allows normal dorsal and plantar-flexion while preventing inversion and eversion, pronation and supination. When the ankle is at rest, the bandage redresses the immobilized ankle into the neutral position. In a study by Johannes, Sukul, Spuit, and Putters (1993), Scotchwrap™ was compared to adhesive tape during the short term treatment of lateral ankle injuries. The study found no significant difference in the treatment between the two forms of support. The advantages to Scotchwrap™ application are that it can be worn throughout the course of treatment without replacement, it is less expensive than most braces, and it is ideal for patients who are allergic to adhesive tape. It is also currently being used for the after- treatment of surgically repaired Achilles tendon ruptures (Johannes et al., 1993).

There has been some debate in the past regarding the effectiveness of adhesive taping. Common arguments for and against taping, as presented in Modern Principles of Athletic training (Arnheim, 1985, p. 324) are listed below.

Arguments for routine ankle taping:

1) Wrapping or taping the ankle does not significantly hinder motor performance.
2) Properly applied wraps and tapings, even though they loosen during activity, provide critical support at the limits of ankle movement.
3) Because wraps and tapings do loosen in the initial period of activity, the midrange of ankle movement is allowed, thus moving adverse stress from the knee joint.
4) High-risk sports, such as football, basketball, and soccer, should use ankle prophylaxis.
5) Athletes having a history of recent ankle injury or chronically weak ankles should be given every possible protection against further insult.
6) Statistics show that athletes who wear tape as an ankle prophylaxis have fewer injuries.
7) Pressure of tape on the peroneus brevis muscle stimulates its action.

Arguments against routine ankle taping:

1) Tape is applied over movable skin.
2) Moisture collects under tape, increasing its looseness.
3) Constant taping for activity weakens supporting muscle tendons.
4) Tape support is reduced 40% after 10 minutes of vigorous activity.
5) Ankle wraps loosen 34% to 77% during exercise.
6) Taping often replaces the practice of thoroughly exercising the ankle joint.
7) The tradition of taping is based on folklore rather than on facts.
8) Taping gives the athlete false security and soon becomes a psychological crutch.
9) Because taping does not significantly reduce ankle torque it does not decrease the athlete's potential for lower leg injury.

Braces As a Protective Device

Various types of ankle braces have become more popular over the years as the controversy over adhesive tape has heightened. There has been documented evidence that adhesive taping techniques lose as much as 40% of range restrictiveness following 10 to 20 minutes of exercise. The controversy over adhesive tape's preventative value has increased the design and testing of various ankle stabilizers and orthoses as alternative means of support. These braces range from cloth lace-on types, to semi-rigid and rigid orthoses made from plastic polymers and thermo-plastic materials (Greene and Hillman, 1990). The three most common types of braces are:

Soft Braces

These braces are usually elastic in character. They are flexible and adjustable, sliding over the foot and ankle. They come in a variety of sizes, colors and amount of support.

Semi-Rigid Braces

These braces are similar to the soft braces in that they are elastic in nature, but they also incorporate a rigid lateral and/or medial structure to increase the external support of the surrounding ligaments.

Rigid Braces

This type of brace is often referred to as the 'spat type'. This brace is less resilient than the elastic or semi-rigid type. A common construction is an open front that permits it to be fitted directly over the ankle and then fitted snugly into the sport shoe. Like the semi-rigid brace, extra support (vertical ribs) may be added to reduce unwanted inversion or eversion of the ankle (Arnheim, 1985).

As presented in the literature, the athlete has a variety of protective ankle orthosis to choose from. Preference may be determined by what is aesthetically pleasing to the athlete, or by a specific individual need. According to Alves, Alday, Ketcham, and Lentell (1992) athletic tape is relatively expensive and time consuming, whereas ankle braces have an advantage in their ease of individual application, support and cost effectiveness. Regardless of choice, the researchers reviewed thus far suggest there would be obvious support in any external support device.

Effects of Protective Devices

There have been many studies on protective devices. The theoretical aim of taping or bracing is to stabilize externally the ligamentous structures of the ankle, without interfering with the normal joint mechanics. These studies have tested motor skill performances at all levels. The following is an overview of the effectiveness of protective devices.

Ankle Range of Motion

A study by Greene and Hillman (1990) examined passive inversion and eversion of the ankle. Range of motion was measured during five testing sessions: (1) before support, (2) before exercise with tape, (3) twenty minutes into a volleyball practice, (4) sixty minutes into a volleyball practice, and (5) after volleyball practice was completed (three hours). The study showed that maximum losses in taping restriction for both inversion and eversion occurred at twenty minutes into exercise. Initial range of motion restriction for adhesive tape was 41%. Following three hours of exercise it was reduced to 15%. Ankle braces were found to be more effective by restricting range of motion from 43% to 41% after three hours of exercise.

A study by Scheuffelen, Gollhofer, and Lohrer (1993) tested the effect of range of motion during applied inversion movements to an ankle taping technique and six different braces. The study found a significant reduction of the induced inversion displacement in all devices. These two more recent studies are in disagreement with the findings of Bunch, Bednarski, Holland, and Mancinati (1985) who stated that there was no significant difference in range of motion when comparing adhesive tape and lace-up braces after 20 minutes of repeated inversion movements in a laboratory setting.

Muscle-Tendon Strength

Paris and Sullivan (1992), reported that there were no differences seen in their study when comparing inversion and eversion isometric strength between nonsupported, taped and braced ankles. Therefore, they did not believe that protective devices cause restriction to the lower leg musculature. Abdenour, Saville, and White (1979) also reported no significant difference between taped and nontaped ankles when measuring dynamic strength of inversion and eversion.

Prevention of Ankle Injuries

A study done by Rovere, Clark, Yates, and Burley (1988) stated that ankle braces were associated with a lower incidence of ankle injury when compared to adhesive tape in collegiate football players. A key factor to take into consideration was that the administration of tape was applied up to four hours prior to games and practices. Later studies have demonstrated that tape tends to loosen over time (Greene and Hillman, 1990).

Functional Activity

Paris and Sullivan (1992) suggested that tape does not effect results on motor performance tests of speed, balance and agility, nor does it affect leg orientation (the body's awareness in space). Therefore, they agreed that functional activity is not compromised through the use of adhesive tape. In a more recent study by MacKean, Bell, and Burnham (1995) eleven female basketball players were tested on performance skills relating to basketball (vertical jump, jump shot, sprint drill and submaximal treadmill run), the study found their skill to be impaired by ankle support. The players were tested with ankle tape, three different kinds of ankle braces (Swede O-Universal, Active Ankle, and Aircast) and without any supportive device.

Paris and Sullivan (1992) discussed contradiction between their findings and a study done by Juvenal and Mayhew (1990) concerning vertical jump performance with adhesive taped ankles when compared to non-taped ankles. Juvenal and Mayhew reported significant lower performance in the vertical jump with adhesive taped ankles when compared to non-taped ankles. Later, Paris and Sullivan (1992) showed there was no significant difference in the vertical jump when comparing ankle braces, adhesive taped and non-taped ankles.

Proprioception

Tape has been shown to stimulate proprioceptive feedback. The external support of the tape increases the athlete's conscious awareness of the injured body part (Anderson and Hall, 1997). Research done by Paris and Sullivan (1992) reported that taping the ankle stimulated the peroneal brevis muscle during foot eversion which provided a counterforce resulting in a decrease of injury. Thus, the study showed a benefit to taping the ankle, not only as an external support but internally stimulating the main muscle that helps to support lateral ligamentous structures.

Muscular Fatigue

Paris and Sullivan (1992) also found that with taped restriction of plantar or dorsiflexion, leg musculature may have to contract harder to achieve the required output. It was noted that if prolonged activity continued, there is a chance that fatigue in leg musculature will develop, which may compromise both safety as well as performance.

Gymnastic Studies

As stated by McNitt-Gray et al. (1994), the United States gymnasts must continue to improve their landing and tumbling mechanics to remain at the elite, competitive international level, however, they must learn to master these tasks without compromising the health of their extremities during interaction with the landing surfaces.

The floor exercise event has been associated with the greatest number of injuries. According to McNitt-Gray et al. (1994), 37% of all injuries in women's gymnastics occurred during floor events. As the difficulty of aerial skills increases, larger impulses during the take-off phase are needed to produce the linear and angular momentum necessary for successful completion and landing. The single back tuck somersault has been shown to produce 55.9 kg-m^2/s of angular momentum. A double back tuck somersault can produce up to 72.5 kg-m^2/s, and a double back layout somersault up to 112.02 kg-m^2/s of angular momentum. The increased momentum during the take-off phase requires larger impulses to bring the total body momentum to zero with a single placement of the feet. Landings of aerial gymnastic skills have produced some of the largest peak reaction forces encountered in sport. These forces increase as the velocity of impact and skill complexity increase. A single back tuck saltos can create peak vertical reaction forces up to eight times the body weight, while a double back tuck saltos can create peak vertical reaction forces up to eighteen times the body weight. According to McNitt-Gray (1991), if landing is uncontrolled and the lower extremities are asymmetrically loaded, these forces can reach even higher magnitudes.

It is common to think that the lighter and leaner the gymnast is, the less work he or she must do against gravity, therefore attaining a higher performance potential (Sands, Irvin, and Major, 1992). Due to the high incidence of injury, the issue of weight relating to injury has been addressed. According to McNitt-Gray et al. (1994), there is no clear cause-effect relationship between high loads (weight) and injury during impact (landing), as compared to low loads and prevention of injury. Although the biomechanical and injury literature may suggest weight effect, the weight of the gymnast does not leave them prone to, or safe from injury during landings. McNitt-Gray et al. also suggested that landing with a higher degree of hip, knee and ankle flexion (e.g. "soft landings"), reduces the magnitude of impact (peak forces).

Biomechanical Analysis of Human Motion

Understanding the biomechanics of an activity is essential to understanding the mechanism of injury. It is important to study the performance demands of individual sports and the risk factors that the athlete is predisposed to in order to decrease the chance of injury. Biomechanical analysis may expose information which could lead to changes in current patterns of training and practice regimens, rules of competition, modification of equipment, as well as increasing performance (Taunton et al., 1988).

Factors of Analysis

Sports that involve landings from a jump or aerial gymnastic skills have a high incidence of injury to the ankle and foot complex. There are several variables that determine the type and severity of injury to this area, most of which are the biomechanics of the foot and ankle which may predispose an athlete to injury. Kannus's research (1992) has shown a closely related association between overuse injuries in the lower extremity and abnormal biomechanical factors. These biomechanical factors include hyperpronation and hypersupination of the foot, valgus and varus variations at the hip, knee, and tibia, leg length discrepancy, and position of the patella relative to the patellar groove. Taunton et al. (1988) are in agreement with Kannus (1992) when discussing anatomical factors associated with ankle injuries. Taunton et al. (1988) added femoral neck anteversion, knee recurvation, patella alta, excessive Q angle (greater than 15 degrees), tibial torsion, excessive tibial varum (greater than 5 degrees), forefoot valgus and forefoot varus. These are all important aspects to note when evaluating or preventing injury.

Gross and Nelson (1988) argued that during the landing phases of the vertical jump, injury prevention can be determined depending on the style of heel contacts. In their study, the nonheel contact landers (those who landed on the balls of their feet, not flat footed) greatly reduced the number of transients experienced on the lower extremity. Because forces at the Achilles tendon have been found to be greatest when the heel contacts the ground, they also concluded that landing without heel contact may be an important factor on long-term injury prevention.

The Aerial Performance Analysis System

The Aerial Performance Analysis System (APAS), is a computerized system for biomechanical analysis of human motion. The APAS integrates computer and video processing hardware with specialized software that allows data collection via cameras, reduction of data via digitization, analysis and presentation (APAS Manual, 1995).

The computer is the primary component of the APAS. It contains the central processing unit (CPU), the math co-processor, the computer memory and data storage, the graphics processor, and the video image processor. There are two monitors used. The monochrome monitor is the primary screen used with the APAS. Menus, instructions, and information are displayed on this monitor. The color graphic monitor displays results of digitization such as stick figures, and displacement, velocity, acceleration, and data smoothing graphs.

Besides the normal function of the cursor to make selections from menus, etc., it is used to identify and locate selected joints throughout the body during the video digitizing process. The cursor is used to enter positional information on the graphic display manually when prompted by the system.

The video playback system unit is used for playback of videotape recordings of performance. Most VHS cassettes, recorded from any video source may be used. The video playback allows high precision freeze-frame video imaging with single frame advance and reverse. It also contains variable speed search. When three dimensional movement analysis is desired, at least two cameras must be used. Filming does not require a link to the computer because the camera is used independently from the APAS hardware.

The usual movement analysis consists of four phases: Data collection (filming), digitization (data reduction), computation, and presentation of results.

In order to collect data, the image space (where the subjects are being recorded) must be calibrated, and the location of a fixed point defined. The Cartesian coordinate system is used to measure the control point locations. Each point location has an X, Y, and Z coordinate value. Normally the Z coordinate axis is chosen to coincide with the vertical direction, X for horizontal and Y for movement in the transverse plane. These are the control points when filming. For three dimensional analysis, at least six points must be available and they can not lie in the same plane. The points should be spread to cover the entire volume from side to side, front to back, and low to high. These control points must be visible to each of the cameras. The calibration structure, which holds the control points, is placed in the area that will be filmed and then removed after it is captured on all cameras. Removal of the calibration structure ensures that it will not interfere with the activity being filmed. The camera field of view is fixed for the duration of each performance. When the control points are filmed and the subject performance space is marked, the calibration structure can then be removed.

A single distinct event called the synchronizing event, must be recorded in order to combine simultaneous camera views. This event, whether it be timing lights or a running clock, must be visible in both camera views. Also, with every frame that is digitized, the fixed point must be digitized first. This point must be stationary throughout the filming and should be visible in every frame during the activity. The purpose of the fixed point is to provide a fixed reference against which all other points in the frame are aligned.

After the frames selected for the desired analysis are digitized (the grabbing process), the joint angles are plotted and saved. This is done for each view of each trial. To convert two dimensional digitized views into a three dimensional image, the data needs to be transformed. Direct linear transformation (D.L.T.) is a common transformation performed on the data. In this process, the image coordinates and the digitized coordinates of the control points are used to solve a set of simultaneous linear equations. This process relates one set of coordinates to the digitized points on the performer (calibration structure). The smoothing process is used to adjust small random digitizing errors from the transformed image sequence. The smoothing module is able to compute point velocities and point accelerations for each frame in the image sequence because the motion of each point is determined by a continuous smooth function. Smoothing is always performed following transformation.

After the performance has been digitized, transformed, and smoothed, the Viewing module displays the three dimensional image in a stick figure format. The stick figures are created by connecting the body joint locations with line segments. (APAS Manual, 1995).

Chapter 3

METHODS

The following study was designed to test the effectiveness of a taping technique commonly used to prevent and protect against injury to the Achilles tendon. The purpose of taping the Achilles tendon is to restrict dorsiflexion of the foot. Increased dorsiflexion which can be determined through the measurement of displacement, velocity and acceleration of movement, are all contributing factors to Achilles tendon injuries.

The procedures for the collection and analysis of the data obtained in this study are described in this chapter. Biomechanical sampling methods used in this study were consistent with current biomechanical research.

Equipment Description and Test Materials

In artistic gymnastics, the athlete can use the floor exercise area for various skills. An effective mat is one that provides a resilient, firm and non-slip surface that assists in amplifying the height of the athlete's acrobatic movements, while at the same time is able to absorb the shock of landings. Gymnastic mats are either primarily resilient, returning to their original position after compression or they are primarily shock absorbent. To create an authentic environment for the gymnasts, the subjects performed on an FIG (International Gymnastics Federation) regulated floor where they train daily.

The International Reflex Floor is constructed of multiple layers of rebound material, hardwood, and resilient matting. An example of the difference between resilient and shock-absorbing mats can be seen in the use of closed-cell foam as opposed to open-cell foam. The closed-cell foam does not allow the air trapped in each cell to escape. Therefore, its ability to be compressed is limited, and is quick to return to its original position, similar to the elasticity of a new tennis ball. The use of closed cell foam in basic mats creates a firm, resilient working surface.

In contrast to closed-cell foam, open-cell foam used in landing mats and skill cushions allows the air trapped in each cell to escape when compressed, similar to a sponge. Therefore, the use of the open-cell foam in these mats creates a softer, force absorbent working surface. Most mat materials will have characteristics of both resilience and shock absorbency. Materials vary to the degree that they are either resilient or shock absorbent.

The wood deck on which the floor is placed is 42 feet 8 inches, by 42 feet 8 inches (13 meters by 13 meters). A tapered foam border fits around the perimeter which forms a square of 46 feet 9 inches, by 46 feet 9 inches (14.25 meters by 14.25 meters). Four inch (10 centimeter) steel springs provide the suspension system below the wood deck. The deck is covered by rolls of two inch (50 millimeter) Cross-Link foam. This bottom section consists of a rebound platform that is absolutely even. A top cover of four rolls of continuous nylon carpet completes the floor system, resulting in an overall floor area of 49 feet, 4 and a half inches, by 49 feet, 4 and a half inches (15 meters by 15 meters). The top surface must also be even, level, and devoid of cracks, depressions, or hills.

Subject Selection

Initially, six female subjects ranging in age from 19 to 22 years of age volunteered to participate in this study. The subjects had been involved with club and collegiate gymnastics for at least ten years. The subjects were asked to complete a subjective medical history to insure that they had no previous Achilles tendon injuries. The subjects were informed of the confidentiality of the data and the purpose and procedures of the study. The consent form was completed and was in accordance with the policies established by the Michigan State University Committee for the Research Involving Human Subjects. After the filming was completed, data of two subjects (n=2) ages 19 and 21 were used. Subjects were excluded from the study if joint markers were hidden during any stage of analyzed flight and/or landing. Four subjects were eliminated from the study due to this problem. Subjects wore a gymnastic leotard or shorts with a tee-shirt; the lower leg was not covered in any way to allow joint markers to be placed directly on the skin or the taping procedure.

Excessive amounts of natural lighting can affect the reflective ability of the retroflective joint markers during filming. The first four subjects performed six trials each in a gymnasium before sunset. Although the gymnasium consisted of two full walls of smoked glass from ceiling to floor, the sunlight coming through the double pained glass created too much natural light causing a washout of the joint markers. The filmed data were not able to be digitized. Either lack of reflection, or over reflection minimized precision of location for markers on the lateral malleolus and the base of the fifth metatarsal. One subject was excluded because the joint marker at the fibular head was blocked by the subject's arm during flight. After exclusion of four subjects, two subjects with four trials each, remained to be analyzed.

Taping Procedure

The Achilles tendon tape job is one of many found in the literature. The taping procedure used in this study followed the tape procedure exhibited in Arnheim's Modern Principles of Athletic Training (1985), with slight modifications. The materials utilized during application of the tape job were: 3 inch (7.5cm) elastic tape, 1.5 inch (3.8cm) linen tape, and tape adherent. No pre-wrap was used for this study. The subjects were placed in a recumbant position with their knee in extension and their ankle relaxed over the edge of the taping table. Two anchors were applied with 1.5 inch linen tape, one circling the leg at the subject's muscle-tendon junction, and the other encircling the metatarsal heads at the ball of the foot. Two strips of 3 inch elastic tape were cut approximately 8 to 10 inches long (20 to 25 cm). Each strip of elastic tape was bisected at both ends, approximately 1.5 inches. One end of the elastic tape was placed at the distal anchor, with each of the bisected ends wrapping around the linen anchor towards the dorsal aspect of the foot. Once anchored, this strip was moderately stretched from the ball of the subject's foot along its plantar aspect up to the Achilles tendon junction. The proximal bisected ends reached the proximal linen anchor and wrapped around the lower leg towards the anterior aspect. The second elastic strip followed the course of the first, slightly staggering the placement of the bisected strips so the force of the tape was distributed across more surface area. The series was completed by placing two lock strips of linen tape around the arch and four around the subject's lower leg.

The modifications to Arnheim's (1985) procedure follow. Arnheim suggests that only the second elastic strip be bisected and only at the proximal end. He also suggests using two or three strips of elastic tape at the arch and five or six strips around the lower leg as the final locks instead of two strips of linen. No specific degree of plantar flexion was mentioned in Arnheim's procedure.

Data collection procedures

Testing took place in the gymnastics area, third floor of Jenison Fieldhouse at Michigan State University. Subjects were filmed on the floor exercise mat. The subjects were initially allotted as much time as needed to safely warm-up before either the data collection or taping procedure began. Once taping was completed, subjects were only allowed two back tuck saltos practice flips before they were filmed. The taping technique application took no longer than two minutes, and the subjects agreed that they were still warmed up when the taping was finished. After the subjects were warmed up and either taped or not taped, depending on the treatment, markers were placed on the subject and the subject was filmed.

Placement of the joint markers was performed by palpating the area, marking the point with a water soluble ink pen, and placing the marker either directly onto the skin, or onto the linen tape, with hypoallergenic tape. The subject was marked with three reflective markers at the following points: fibular head, lateral malleolus and the base of the fifth metatarsal. Four trials were recorded under both conditions of being taped, or without the taping technique, to insure that the subject remained in the calibrated space, and that all markers were seen by both cameras. After filming, the subject was thanked for participating and left the filming area. This procedure was repeated for all subjects.

Calibration structure

Prior to the subjects' arrival, a calibration structure (Figure 1) which surrounded the area in which the skill was to be performed was set up incorporating evenly distributed control points to improve accuracy in the D.L.T. calculations. The purpose of this calibration structure was to define the location of points in space in order that a volume of space be defined. The calibration structure consisted of 16 control points. Four sets of retroreflective tape covered balls were strung by surveyor's cord and tension was placed on the cords by surveyor's plumb bobs. The structure defined a calibration space of 65 cm wide by 65 cm long by 40.5 cm high. The control points were symmetrically distributed and placed 3.25 cm, 16.5 cm. 27.25 cm, and 40.5 cm from the floor. These control points were digitized in the order indicated on the calibration structure in Figure 1. The calibration structure was filmed, then removed from the filming area. Tape marks were left on the floor under the plumb bobs to mark the floor space of the calibration volume. Doing this, a volume in space was defined and a D.L.T. could be performed to take the two, two dimensional views of the movement and mathematically merge them into one, three dimensional view.

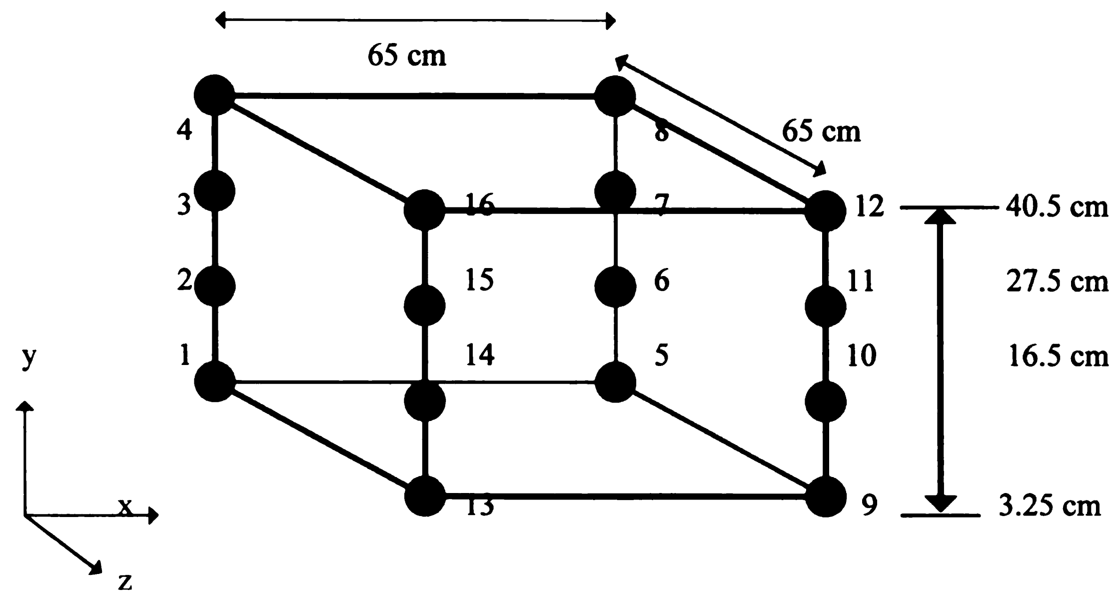

Figure 1. Calibration structure

Cameras and timing lights

Two S-VHS cameras (Panasonic S-VHS Reporter, AG-455) were used to record the trials. The cameras were set to film each trial at 60 frames per second (frame time equals .017 sec), and had a shutter speed of 1/100 second. Both cameras were equipped with zoom lenses and each camera was mounted on a tripod and were operated by trained assistants during the actual filming of subjects. Prior to subject filming, the zoom lenses were focused in on the calibration structure so that all control points were visible with the largest possible image in the frame. This allowed the largest object to frame size ratio which helped decrease error in digitization because the markers were as large as possible relative to the calibrated space. The cameras were placed at an angle of approximately 60 degrees to each other, in the sagittal plane, to the right side of the subject's back tuck saltos. Camera one was on the right and slightly to the rear of the calibration structure and camera two was located on the right and slightly forward of the calibration structure. The camera placement allowed for all targets to be in the field of view for each camera.

Timing lights were used to synchronize camera views of the skill. Two synchronized sets of timing lights were placed in the field of view for each camera. The timing lights consisted of four rows of ten lights. The first row changed lights every second, the second row every tenth of a second, the third row every one hundredth of a second, and the fourth row every one thousandth of a second. Finally, a fixed point needed to be identified so there would be a reference against which all other points in the frame were aligned. This reference point was placed in the calibrated volume in a position least likely to be a hazard to the gymnast. The fixed point for this study was a retroflective joint marker.

The subject was positioned so that their right side was toward the cameras. Filming began on an oral signal from the primary investigator before the subject began the stunt and the video was allowed to run continuously for all trials of that treatment.

Identification of subjects and trials

To identify the subjects and trials, a board was placed in view of each of the two cameras. The board contained a three digit numbering system. The first two digits represented the subject number, while the last number represented the trial number. The cameras were started and the gymnast performed the back tuck saltos within the calibrated space. If the joint markers moved or fell off the subject's body, the trial was re-filmed.

Data Analysis

The data were then reduced from the video tape via digitization. Two views of one good trial for each treatment were digitized. A good trial was defined as one in which all joint markers were visible to both cameras during the entire event. Fifteen frames before foot contact, and 15 frames following foot contact were digitized. Then, using D.L.T. the data points from two, two dimensional views were combined to obtain a three dimensional record of the sagittal plane movement.

The displacement data were smoothed using the cubic spline technique, and velocity and acceleration data were obtained. The analysis utilized seven frames before foot contact and three frames following contact. The extra frames were not used because the greatest amount of dorsiflexion had already occurred.

There has been controversy as to the location of the axis of the ankle joint. Some research has shown that there are two different axes for dorsiflexion and plantar flexion (Bohannon et al., 1989). While measuring dorsiflexion for this study, the center of the lateral malleolus was considered the axis of rotation. It was also recognized that a consensus has not been reached on how to measure ankle dorsiflexion range of motion. For the purpose of this study, the landmarks used were the head of the fibula, the lateral malleolus and the base of the fifth metatarsal. The researcher programed the APAS to define the measurements by determining the relative angle of the above landmarks. The joint angle that was plotted for each frame was the talocrural joint of the ankle. These measurements consisted of true joint location plus random error due to the inability to position the cursor on the exact center of the joint marker. A stick figure of the talocrural joint was created by connecting the joint locations with line segments. The line segments in this study connected the fibular head to the lateral malleolus, and the lateral malleolus to the base of the fifth metatarsal. For this study, the displacement, velocity and acceleration of the right ankle joint were measured in order to compare the relative differences in dorsiflexion at contact between the two treatments.

Experimental Design

The experimental design was a correlated, repeated measures t-test. Two trials for each of two treatments, taped and untaped, for two subjects were compared for differences in means at four points in the landing: one frame before contact, the contact frame, one frame following contact, and two frames after contact. Differences in means are interpreted relative to the standard error of the difference between means. The equation used was:

$$|t| = \frac{\bar{Y}_1 - \bar{Y}_2}{\sqrt{S^2 (2/n)}}$$

$$\text{where, } s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 - 1) + (n_2 - 1)}$$

The null hypothesis, H_0, of $\bar{Y}_1 = \bar{Y}_2$ would be rejected if:

$$|t| > t_{(2n-2),\alpha/2}$$

Figure 2. Experimental Design

Chapter 4

RESULTS, DISCUSSION AND SUMMARY

One major responsibility of athletic trainers is to be proactive in the prevention of injuries. Taping of joints is one method commonly used as a preventative measure for stabilizing joints.

Six female collegiate gymnasts were videotaped landing from a back tuck saltos under two conditions: 1) their ankles were not taped, and 2) their ankles were taped according to the procedure outlined earlier. Due to washout and hidden reflective markers, data from four of the subjects could not be used. Therefore, two trials for each treatment for the two subjects were used in this analysis.

This information was subsequently digitized, and using D.L.T., the two sets of two dimensional data were mathematically merged into one set of three dimensional data. Since the cameras were on the right side of the subject, the three dimensional view chosen for analysis was about the Z-axis in the X-Y plane, or the sagittal plane view. This plane gave information regarding dorsi and plantar flexion about the ankle joint.

From these sets of three dimensional data, four frames of information from each trial were analyzed using correlated, repeated measures t-tests. The four frames analyzed were: one frame before contact, the contact frame, one frame after contact and two frames following contact.

The purposes of this study were to determine if statistical differences existed between the taped and untaped conditions for: 1) range of motion (angular displacement), 2) angular velocity, and 3) angular acceleration, during the landing phase of a single back tuck saltos.

It was logical to assume that the two sets of data for each subject were positively correlated. In absence of evidence that refused this assumption, the analysis continued on the basis of correlated data. Therefore, a correlated, repeated measures t-test was performed with df = 6. No statistical differences were found for angular displacements, velocities, or accelerations at any of the discrete points chosen about landing.

The reader is cautioned at this point. These findings do not mean that taping joints to assist with stability is a worthless endeavor. Rather, additional inquiry needs to occur to examine the problem further.

There are two primary reasons for the caution surrounding the findings in the study. One reason is that such low power existed, that even if statistical differences had been found, those results also would have been suspect. Originally, six gymnasts were filmed with the intent of using the data from all the subjects. However, due to washout and hidden reflective markers, these six subjects became two.

Secondly, the speed at which the video captured data was only 1/60 second, or .017 second. Relatively speaking, .017 second is a long time in motion analysis. The problem with this frame rate, is that the data points captured are not all at the same point in time of the skill. For example, one subject may already be dorsiflexed during landing, and another subject just in contact with the mat. Both frames of information would be considered frame of contact, but are clearly at different points in their respective landings. In order for more discrete points to be captured along a continuous pattern, the video must be capable of shooting at higher speeds; at least 1/100 second, or .01 second.

Recommendations for further study

As a result of the findings of this study, this researcher suggests the following for future studies: 1) use cameras that have a higher frame rate than 1/60 sec., 2) compare landings on gymnastic mats with landings on the floor. Perhaps some of the qualities of the floor exercise mat masked some real differences in ankle movement, 3) examine the hip and/or knee joint(s) in combination with the ankle joints, and 4) increase the number of subjects analyzed.

REFERENCES

REFERENCES

Abdenour, T. E., Saville, W. A., White, R. C., & Abdenour, M. A. (1979). The effect of ankle taping upon torque and range of motion. Athletic Training, 14, 227-228.

Alves, J. W., Alday, R.V., Ketcham, D. L., & Lentell, G. L. (1992). A comparison of the passive support provided by various ankle braces. Journal of Orthopaedic and Sports Physical Therapy, 15, 10-14.

Anderson, M. K., & Hall, S. (1997). Fundamentals of Sports Injury Management. Baltimore: Williams and Wilkins.

Ariel Life Systems, Inc. Ariel Performance Analysis System (APAS) User's Manual.

Arnheim, D. (1985). Modern Principles of Athletic Training. St. Louis, MO: Times Mirror/Mosby College Publishing.

Bohannon, R. W., Tiberio, D., & Zito, M. (1989). Selected measures of ankle dorsiflexion range of motion: differences and intercorrelations. Foot and Ankle, 10(2), 99-103.

Bunch, R. P., Bednarski, K., Holland, D., & Mancinati, R. (1985). Ankle joint support: A comparison of reusable lace-on braces with taping and wrappings. The Physician and Sportsmedicine, 13(5), 59-62.

Greene, T. A., & Hillman, S. K. (1990). Comparison of support provided by a semirigid orthosis and adhesive ankle taping before, during, and after exercise. American Journal of Sports Medicine, 18(5), 498-506.

Gross, T., & Nelson, R. (1988). The shock attenuation role of the ankle during landing from a vertical jump. Medicine and Science in Sports and Exercise, 20(5), 506-514.

Hopenfeld, S. (1976) Physical Examination of the spine extremities. Hartford, CT: Appleton and Lange.

Johannes, E. J., Sukul, K., Spuit, P. J., & Putters, J. L. (1993). Controlled trial of a semi-rigid bandage (Scotchrap) in patients with ankle ligament lesions. Current Medical Research and Opinion, 13(3).

Kannus, V. P. (1992). Evaluation of abnormal biomechanics of the foot and ankle in athletes. Journal of Sports Medicine, 26(2), 83-89.

Knuttgen, H. G. (1987). Finns develop first in-vivo force measure. The Physician and Sportsmedicine, 15(1),

Komi, P. V. (1990). Relevance of in vivo force measurements to human biomechanics. Journal of Biomechanics, 23, 23-34.

Kyrolainen, H., Komi, P. V. (1994). Stretch reflex responses following mechanical stimulation in power and endurance trained athletes. International Journal of Sports Medicine, 15(6), 290-294.

Leach, Schepsis, & Takai. (1991) Achilles tendinitis, don't let it be an athlete's downfall. The Physician and Sportsmedicine, 19(8), 87-92.

Lundberg, A., Svensson, O. K., Nemeth, G., & Selvik, G. (1989). The axis of rotation of the ankle joint. Journal of Bone Joint Surgery, 71, 94-99.

MacKean, L. C., Bell, G., & Burnham, R. S. (1995). Prophylactic ankle bracing vs. taping: effects on functional performances in female basketball players. Journal of Orthopaedic and Sports Physical Therapy, 22(2), 77-81.

Mackie, S., & Taunton, J. (1994) Injuries in female gymnastics, trends suggest prevention tactics. The Physician and Sportsmedicine, 22(8), 40-45.

McKenzie, D. C., Clement, D. B., & Taunton, J. E. (1985). Running shoes, orthotics, and injuries. Sportsmedicine, 2(5), 334-347.

McNitt-Gray, J. (1991). The influence of joint flexion, impact velocity, rotation, and surface characteristics on the forces and torques experienced during gymnastic landings. FIG Medical/Scientific Symposium, 17-18.

McNitt-Gray, J., Munkasy, B., Welch, M., & Heino, J. (1994, August). Kinetics of successful and unsuccessful gymnastics landings. Technique, 27-30.

Paris, D., & Sullivan, J. (1992). Isometric strength of rearfoot inversion and eversion in nonsupported, taped, and braced ankles assessed by a hand-held dynamometer. Journal of Orthopaedic and Sports Physical Therapy, 15(5), 229-234.

Rovere, G. D., Clark, T. J., Yates, C. S., & Burley, K. (1988). Retrospective comparison of taping and ankle stabilizers in preventing ankle injuries. American Journal of Sports Medicine, 16(3), 228-233.

Salmons, S. (1975). Letter: in vivo tendon tension and bone strain measurement and correlation. Journal of Biomechanics, 8, 87-88.

Sands, W. A., Irvin, R. C., & Major, J. A. (1992). What the sport scientist can really tell about your percent fat and an alternative method for assessing body composition in female gymnasts. USGF Sport Science Congress, 54-60.

Scheuffelen, C., Gollhofer, A., & Lohrer, H. (1993). Novel functional studies of the stabilizing behavior of ankle joint ortheses. Sportverletzung Sportschaden, 7(1), 30-36.

Taunton, J. E., McKenzie, D. C., & Clement, D. B. (1988). The role of biomechanics in the epidemiology of injuries. Sportsmedicine, 6, 107-120.

USA Gymnastics Publications. USA Gymnastics Safety Handbook 25-27, 1994

Winer, B. J. (1971) Statistical Principles in Experimental Design. New York: McGraw-HillBook Company.