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Comparison of the Risk of Ankle Sprain for Braced, Taped and Unsupported Ankles in Intercollegiate Basketball

by

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ABSTRACT

This study compared the risk of ankle sprain in braced, taped and unsupported ankles in intercollegiate basketball. The ankles of male and female athletes were categorized into a brace, tape and no support group and followed for one season to determine the rate of ankle sprain.

The relative risks of injury, with 95% confidence intervals, were calculated for both the brace and tape groups relative to the no support group. Multivariate analysis was performed to assess the relationship between bracing and taping and the risk of injury after stratifying on each of severity of injury, gender, history of injury, type of injury, session, player position and shoe type separately.

No significant differences were found in the risk of ankle sprain for braced, taped and unsupported ankles. However, this study had low power to detect small differences. The data did suggest some interesting trends that may warrant further research.

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First, I would like to express my gratitude to my supervisor, Dr. W.H. Meeuwisse. Without his expertise and guidance this thesis would not have been possible.

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Finally, I would like to thank Brent Hagel for always being there to answer questions and offer assistance regardless if it involved the CISIR.

DEDICATION

This thesis is dedicated to my Mom, who has always supported and encouraged me in everything I've done, even if she didn't understand why, and to my husband, Greg, who managed to keep his and my spirits up even in the most stressful times.

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1. INTRODUCTION

1.1. Purpose

The primary purpose of this study was to determine if ankle bracing or taping reduce the risk of ankle sprain in intercollegiate basketball. Evaluation of injury prevention systems requires the control of confounding variables. Lack of control of these variables can lead to biased data collection and conclusions[1]. Therefore, the relationship between severity of injury, gender, injury history and the risk of ankle sprain in intercollegiate basketball were also examined. In addition, the relationship between type of injury, session, player position, shoe type and the risk of ankle sprain in intercollegiate basketball were also explored.

1.2. Significance

Ankle injuries are one of the most significant problems in athletics[2, 3, 4, 5, 6, 7, 8] accounting for 30 to 45% of all musculoskeletal sports injuries[9]. More than 75% of these injuries are sprains and more than 75% of these sprains involve the lateral ligaments[2, 4, 9]. Ankle sprains result in more lost time by athletes than any other injury; responsible for 20 to 25% of all time loss injuries in running and jumping sports[3, 7]. Ten years ago the average cost per person for diagnosis and rehabilitation of an ankle injury ranged from $400 to $1200 Canadian[10]. Most popular sports involve strenuous running, jumping and cutting maneuvers that put athletes at high risk for ankle injury[4]. Because they occur frequently, ankle sprains are often taken lightly[4, 10]. Many are not reported, suggesting the rate of ankle injury may be even greater than previously stated in the literature[3]. The high number of ankle injuries during athletic competition indicates the need for a prevention program to reduce the risk and severity of injury[5].

Ankle taping is the traditional method used in attempt to prevent ankle injuries. "Hundreds of thousands of rolls of tape are used each year in attempt to reduce the incidence of ankle sprains"[p. 388, 11]. Athletic programs frequently incur substantial costs through taping athlete's ankles. In 1988, Rovere et al.[11] estimated a cost of $US400 to tape both ankles of one university football athlete for an entire season. Some football teams spend as much as $50,000 per year taping ankles[12]. Is taping worth the cost? Previous research has indicated that tape loses its restrictive capabilities with exercise and thus perhaps its ability to prevent ankle injury[13, 14, 15]. Despite, the extensive literature on ankle taping, very little empirical evidence exists to support its use[16].

An alternative to ankle taping is the use of an ankle brace. Ankle braces have become increasingly popular as a means for the prevention of ankle injury. This increased use is due to the perceived restrictive capabilities of the brace, self application and relative cost effectiveness when compared to tape[7, 8, 17, 18, 19, 20]. However, there is little clinical evidence to support the use of ankle braces for the prevention of ankle sprains.

1.3. Specific Aims

1. To compare the risk of ankle sprain for braced, taped and unsupported ankles in intercollegiate basketball.
2. To determine if severity of injury, injury history or gender, modify or confound the relationship between bracing or taping and the risk of ankle sprain in intercollegiate basketball.
3. To explore the relationship between the type of injury, session, player position, shoe type and the risk of ankle sprain in intercollegiate basketball.

2. Background Information

2.1. Definition of Concepts

2.1.1. Athletic Injury Epidemiology

Epidemiology is defined as the medical science dealing with the occurrence, causes and prevention of disease. By identifying patterns of disease occurrence, epidemiologists seek to find factors associated with disease onset and make recommendations for its control and prevention[21, 22].

The application of epidemiological methodology is relatively new in athletic injury research[21, 22]. Athletic injury research has similarities with disease epidemiology, however several distinct differences do exist. First, most diseases have an insidious onset whereas most injuries have a sudden onset. For example, cancer develops over an extended period of time and is often difficult to diagnose whereas a fracture happens in an instant and is relatively easy to identify. Second, a disease may result from exposure to a specific set of factors that at first may be unknown and may have been present in many different situations. On the other hand, injuries occur under specific conditions and only when exposure to that situation is created. Sports injuries occur only when an athlete is exposed to sports (i.e. basketball injuries can only occur while an athlete is playing basketball). Despite these differences, epidemiological principles have been successfully applied to sports injury research[21].

2.1.2. Athletic Injury Definition

The most critical definition in athletic injury epidemiology is the injury definition[21]. In the past, a variety of definitions have been used to identify an injury. The two most commonly used methods for developing an injury definition are accurate medical diagnosis and time lost from participation. The use of a medical diagnosis requires a physician's intervention in the recording process and involves a great deal of subjectivity. Alternately, the time lost from participation definition is easily recorded and objective. However, the time-loss definition is not sensitive to the medical nature of the injury or the concept of returning to participation when not fully healed[22].

The stage at which the injury definition is applied is also an important consideration. An ideal injury definition is one that allows for data comparison at any point after data collection. This is accomplished by defining an injury at the data analysis stage rather than at the data collection phase[23]. A precise injury definition is not applied at the time of data collection instead an injury reporting threshold is defined. An injury reporting threshold may by defined as: any injury that requires treatment by an athletic therapist[23]. In this case, the athletic therapist collects information on all injuries not only those that require a medical diagnosis or result in time lost from participation. Injury definitions can by applied at the time of data analysis using essentially any parameter for which information was collected[23]. For example, only those injuries causing the athlete to miss the next practice or game could be included in the data analysis. This approach does require recording of individual injury outcome information but offers more options during data analysis[23].

2.1.3. Athletic Exposure

In athletic injury epidemiology, the definition of athletic exposure is more complex than in other areas. In sport, possessing a risk factor is not enough to constitute exposure; it must also be combined with playing sports[23]. If an individual possesses a risk factor but does not participate in sport they are consequently not at risk of sustaining an injury[21]. Athletic exposure, thus, is participating in the sport with or without the factor of interest. The amount of athletic participation provides a "dose" or amount of exposure to the factor of interest[23]. It is important to be able to account for variations in participation when assessing individual injury risk if it is to be associated with injury patterns[21, 23].

For instance, an individual cannot sustain a basketball injury unless he or she plays basketball. To examine the risk of developing a basketball injury while wearing an ankle brace, a group of individuals that wear a brace would be compared to a group of individuals who do not. The true risk of sustaining a basketball injury, in this situation, may be seen by comparing playing basketball while wearing an ankle brace versus playing basketball without wearing an ankle brace. The amount of basketball participation provides an amount of exposure to the ankle brace.

The dynamics of sport makes identifying exposure more difficult[22]. There are different conditions of sport exposure that may confound, bias or modify the effect seen with a given risk factor[23]. For example, if in basketball there were a difference in ankle injury risk with and without bracing, but the risk depended on whether the athlete was participating in a game or practice, the amount of practice and game exposure would also have to be measured.

In short, exposure in sport injury epidemiology can be defined as a combination of the presence of a risk factor and the participation in sport under a specified set of conditions[23].

2.1.4. Confounding

Confounding is the mixing of the effect of an exposure on the outcome with that of a third factor. With confounding an observed association between the exposure and outcome under study could be due, totally or in part, to the effects of a third factor, know as the confounder[24]. For confounding to occur, the third factor must be associated with the exposure and, independent of the exposure, be a risk factor for the outcome[24, 25].

Specifically, the following conditions must be met for confounding to occur. First, the third factor must be predictive of the outcome (but not necessarily causal).

Second, the third factor cannot be related to the outcome only through its association with the exposure. There must be an association between the outcome and the third factor even in non-exposed individuals. Finally, the third factor cannot be an intermediate link in the causal chain between the exposure and outcome[24].

When an association is observed between an exposure and an outcome it is important to determine whether it is a true association or a result of confounding by a third variable. The first question to ask, in addressing confounding, is whether a third factor is related to being in the exposed group or control group. Is the distribution of the third factor different among the groups [25]? The potential for a third factor to be a confounder, depends solely on whether it is distributed unevenly between the study groups. A factor can confound an association only if it differs in proportion between the study groups. Essentially confounding is the possibility that the observed association is due, totally or in part, to differences between the study groups, other than the exposure under study, that could affect the risk of developing the outcome of interest [24]. Therefore, confounding results in a distortion of the true relationship between the exposure and outcome due solely to the particular mix of subjects included in the study[24]. As a result, confounding may vary among studies depending on the distribution of the confounder between study groups[26].

For example, suppose one found that the risk of ankle injury was higher for athletes who taped their ankles compared to athletes who did not. This may not be a true association. There is concern that the association may be confounded by previous history of injury because it is associated with the use of tape and, independent of that association, may be a risk factor for injury. Athletes with a previous history of injury may be more likely to tape their ankles than athletes without a prior history. In a cohort study, this may result in the proportion of athletes with a previous history of injury being higher in the tape group than the no support group, thus satisfying the conditions for confounding. If previous history of injury were a confounder, the relative risk of ankle injury in taped ankles compared to untaped ankle injuries would be overestimated if injury history were not taken into consideration.

Confounding can be addressed either in the design of the study or in the data analysis. Controlling for confounding in the design of the study can be done using restriction or randomization. Matching can be used to control for confounding both in the design and analysis. Lastly, confounding can be controlled and assessed in the data analysis stage through stratification or mathematical modeling[21, 25, 26].

It is important not only to evaluate the presence or absence of a confounder but also to identify its direction and quantify its magnitude. The benefit of using stratification or mathematical modeling is that the direction and extent of confounding can be assessed[24, 26]. However, in order to use stratification or mathematical modeling to control for confounding, it is necessary in the design stage to select variables that will be considered potential confounders. This will ensure that adequate data is collected, as it is impossible to control for the effects of a variable on which information is not obtained. Uncontrolled confounding is a threat to the validity of study results; therefore it is imperative that the design of the study allows for the collection of adequate data to address it[24].

Confounding is not an error in the study but is a true phenomenon that is identified by a study (due to the particular mix of subjects included in the study) and must be understood. The aim is to control confounding and eliminate its affects[24, 25].

2.1.5. *Effect Modification*

Effect modification occurs when the association between the exposure and the outcome varies by levels of a third factor[24, 27]. Effect modifiers are factors that affect the relationship between the exposure and outcome[21]. With effect modification, the outcome in the presence of both the exposure of interest and the effect modifier differs from that expected to result from their individual effects[25].

For example, previous history of injury is an effect modifier if a different association exists between ankle brace use and rate of ankle injury for those individuals with a previous history of injury and for those without a previous history.

Effect modification is assessed by determining whether the magnitude or direction of the association being studied varies according to the level of a third factor[24]. Stratification is used to evaluate and describe effect modification. If the association is equally strong in all strata (formed on the basis of the third factor), effect modification is not present. However, if the association is of different strengths in different strata the third factor is actually modifying the effect of the exposure on the outcome[24, 25]. In this case, data should be reported separately for each stratum and the emphasis of the data analysis and the presentation of the study results should be on describing how the association of interest is modified by the third factor[24].

Effect modification is a result of the underlying nature of the outcome and exists independently of any particular study design or group of subjects. It is to be described and reported, not controlled[24].

2.1.6. Injury Reporting Systems

In the past a variety of approaches have been used for athletic injury reporting. The key difference among these approaches is the method used to collect data (design)[23]. Initially, injury-reporting systems were designed to provide descriptive information on the frequency of injury in specific sport settings. More recently, focus has been shifted to the importance of collecting injury data necessary to develop injury reduction strategies including assessing the effectiveness of interventions aimed at injury prevention[28].

The ability to predict or prevent injury is based on the concept of risk factor assessment. If potential risk factors can be changed then injuries may be prevented. To determine an individual's risk for injury, his or her individual characteristics, injury and participation (exposure) must be measured. To effectively predict future injury and evaluate the impact of preventative measures, a reporting system must enable an athlete's injury to be directly related to his or her participation[28].

A cohort-based injury reporting system allows the researcher to measure injury rates and estimate injury risk[23]. This type of system enrolls a group of athletes (a cohort) at the beginning of the study and then follows them for a period of time. This procedure allows for the examination of characteristics that differ between injured and uninjured athletes. The cohort is defined by their participation in sport; therefore the amount of participation must be measured. Injury rates can be determined as the ratio of the number of injuries in a group divided by the number of exposures in that group. Examining differences between groups exposed to different conditions can assess injury risk[23].

The Canadian Intercollegiate Sport Injury Registry (CISIR) is a cohort-based injury reporting system with exposure measurement. The goal of the CISIR is to determine which factors predispose an athlete to injury by measuring rates of injury and individual athlete risk. Athletes are enrolled at the time of their preseason medicals. At this time, a standardized form is used to collect baseline data including injury history. Throughout the season the team's athletic therapist documents participation and all injuries requiring assessment and treatment[28].

2.2. Current Knowledge – Ankle Injuries

2.2.1. Anatomy of the Ankle

Knowledge of ankle anatomy is essential to understanding the treatment and prevention of ankle injuries[29]. The ankle is comprised of two joints, the talocrural joint and the subtalar joint. The talus, tibia and fibula form the talocrural joint. The dome of the talus fits into a mortise formed by the inferior surface of the tibia and the medial (tibial) malleolus and lateral (fibular) malleolus[5, 6, 29, 30]. The malleoli prevent lateral displacement of the talus and help stabilize the ankle joint. The lateral malleolus projects down to the level of the subtalar joint. This is considerably further than the medial malleolus thus providing greater bony stability on the lateral side[5, 6, 29].

The talocrural joint is responsible for plantar flexion and dorsiflexion of the foot. The anterior portion of the talus is wider than the posterior portion. In addition, the tibial portion of the joint is also wider anteriorly than posteriorly. With dorsiflexion the wider anterior portion of the talus is positioned in the narrower posterior portion of the joint. As the ankle goes into plantar flexion, the narrower posterior portion of the talus is brought into the wider anterior portion of the joint resulting in a relatively unstable joint[5, 6].

The subtalar joint is the articulation between the talus and the calcaneus[5, 6, 29, 30]. The subtalar joint is responsible for inversion and eversion of the foot. As a result of the relative lengths of the medial and lateral malleoli, the amount of eversion is limited while a greater amount of inversion is permitted

Both the talocrural and subtalar joints are synovial joints, which means they are surrounded by a capsule and supported by ligaments[5]. A fibrous capsule surrounds the ankle joint, which is weakest anteriorly and posteriorly, allowing for dorsiflexion and plantar flexion[5]. The joint is strengthened by three groups of ligaments: the deltoid ligament, the tibiofibular syndesmosis and the lateral ligament complex.

The deltoid ligament supports the medial aspect of the joint and limits eversion. It is a strong, broad ligament made up of superficial and deep fibers. Although, it is anatomically divisible it is generally considered a single functional unit[5, 6, 29, 30].

The tibiofibular syndesmosis is comprised of the anterior tibiofibular ligament, the posterior tibiofibular ligament and the interossesous membrane. These structures connect the distal tibia and fibula and maintain the mortise of the ankle joint[29, 30].

Three ligaments make up the lateral ligament complex of the ankle: the anterior talofibular ligament, the calcaneofibular ligament and the posterior talofibular ligament. Together these ligaments provide lateral stability and help limit inversion of the foot depending on the position of the talus. The anterior talofibular ligament is the most anterior structure. It lies in a horizontal plane from the anterior surface of the fibula to the body of the talus. When the foot is plantarflexed, the anterior talofibular ligament is perpendicular to the talus providing stability against excessive inversion. The calcaneofibular ligament lies in a vertical plane from the distal fibula to the calcaneus and spans both the talocrural and the subtalar joints. The calcaneofibular ligament is perpendicular and taut in slight dorsiflexion, providing stability against inversion in this position. The posterior talofibular ligament runs posteriorly from the posterior surface of the fibula to the posterior talus. It is the strongest of the lateral ligaments and the least likely to be injured. The posterior talofibular ligament helps resist forward dislocation of the leg on the fcot[5, 6, 29, 30, 31].

The muscles that cross the ankle support the ligaments in maintaining the stability of the talocrural and subtalar joints[5, 6]. The peroneus longus and peroneus brevis muscles aid in lateral support of the ankle. These muscles make up the lateral compartment of the leg and pass posteriorly and inferiorly to the lateral malleolus. The peroneus brevis attaches to the base of fifth metatarsal and the peroneus longus passes under the cuboid and inserts on the base of the first metatarsal. Both tendons cover the posterior talofibular ligament and part of the calcaneofibular ligament. Because of their relationship with the lateral ligaments, the peroneal muscles are capable of absorbing stress and protecting these ligaments from injury[5, 6]. The muscles that are important for medial stabilization of the ankle are the tibialis posterior, the flexor hallucis longus and the flexor digitorum longus. These muscles originate in the deep posterior compartment of the leg and pass posteriorly and inferiorly to the medial malleolus.

2.2.2. Mechanisms of Ankle Injury

The most common ankle injury is the sprain. The relative weakness of the lateral ligaments and the bony characteristics of the joint predispose the ankle to lateral injuries[6, 29]. The typical injury mechanism for lateral ankle injury is inversion combined with plantar flexion. With plantar flexion the stability of the ankle is reduced as the narrow posterior portion of the talus is brought into the wider anterior portion of the talocrural joint. Furthermore, plantar flexion stresses the anterior talofibular ligament. As the foot moves into plantar flexion, the anterior talofibular ligament tightens and becomes perpendicular to the movement of the talus while the calcaneofibular ligament relaxes. For this reason, the anterior talofibular ligament is the ligament most commonly injured with lateral ankle injuries. As the injury progresses the calcaneofibular ligament and, rarely, the posterior talofibular ligament may be injured[5, 29, 30].

Any sport that involves running and jumping provides the opportunity for an inversion injury. Poorly executed cutting maneuvers, enhanced by unintentional foot fixation, increase the frequency of inversion sprains. Push off during a cut forces the ankle into inversion, external rotation and ultimately plantar flexion. These are the same motions that are involved in a typical lateral ankle sprain. If the foot does not release after the initiation of the cut, an injury may result. Uneven playing surfaces may also contribute to an increase in ankle sprains. One of the most common mechanisms of ankle injury in basketball is coming down from a jump and landing on another player's foot. Uneven surfaces accentuate the ankle's normal tendency to go into inversion and may result in an inversion ankle sprain[2].

Eversion ankle sprains occur less frequently than inversion ankle sprains. Eversion is limited due to the length of the lateral malleolus and the relative strength of the deltoid ligament[5]. Because of the strength of the deltoid ligament and the bony block of the lateral malleolus, eversion sprains are generally more severe than inversion sprains. Eversion sprains are usually associated with fractures and disruption of the ankle mortise[5, 29].

Syndesmotic injuries account for approximately 10% of all ankle sprains. The distal tibiofibular ligaments may be injured during an inversion or eversion injury. However, these ligaments are most likely to be injured in forced dorsiflexion or forced external rotation of the foot[30].

2.2.3. Ankle Injury Risk Factors

Those elements that contribute to the occurrence of an event are called risk factors[32]. Risk factors are classified as either intrinsic or extrinsic. Intrinsic risk factors are those factors which are a part of the athlete themselves and come from within the body. Extrinsic factors are those factors that have an impact on the athlete due to athletic participation and come from outside the body[32, 33].

Most proposed risk factors for ankle injuries are controversial. Proposed intrinsic risk factors for ankle injury include: somatotype, gender, previous sprain, foot type and size, ankle instability, generalized joint laxity, lower limb strength, anatomic alignment and limb dominance[33]. Proposed extrinsic factors for ankle injury include: sport, equipment, length and intensity of play (i.e. game versus practice), playing surface and player position[33].

The most studied of all proposed ankle injury risk factors is previous history of ankle sprain. An increased risk of ankle injury has been reported for soccer players with a previous history of ankle injury[34, 35, 36]. However, the difference in the risk of ankle sprain between athletes with and without previous history of injury has not been established for basketball players[1, 37]. In addition, history of a first-degree sprain does not appear to increase the risk for a subsequent sprain. Baumhauer et al.[38] reported that soccer players with a previous Grade I sprain did not have an increased risk of ankle injury compared to those players with no history of injury.

Extrinsic risk factors that have been studied include shoe type, player position and length and intensity of play. In the National Basketball Association, athletes wearing three-quarter top shoes were almost twice as likely to sustain an ankle injury compared to those players wearing high top shoes[39]. However, a recent study, involving college intramural basketball players, reported no relationship between shoe type and the risk of ankle sprain. Barrett et al.[37] suggested no difference in ankle sprain rate (injury per player-minute) among those athletes wearing high top shoes, low top shoes and high top shoes with inflatable chambers.

Another proposed extrinsic risk factor for ankle injury is player position. Ekstrand and Gillquist[34] reported no differences in ankle injury risk between player positions in soccer. However, in the National Basketball Association the ankle injury rate was found to be highest for forwards, followed by guards and then centers[39].

The length and intensity of play is also a proposed risk factor for ankle injury. In soccer, twice as many injuries occur during games as during practices[34]. The ankle injury rate in elite volleyball is four times greater during games than during practices[40].

2.2.4. Sport Specific Ankle Injuries

Ankle injuries are the most common sports-related injury, accounting for 10 to 45% of all sport related injuries and 5% to 20% of all time-loss injuries. Ankle injuries are unique in that almost all are of a single type; a sprain (85%) and an equally high proportion involve the lateral ligaments[41]. Athletes involved in popular sports, such as football, soccer, basketball and volleyball, are especially at risk for ankle injury. These sports involve running, jumping and cutting maneuvers that put athletes at a high risk for ankle injury[4].

Although, ankle injuries are a threat to participants in nearly all sports ankle sprains are most prevalent in basketball[41]. The unpredictability of landing from jumps and large ground reaction forces on landing contribute to the high frequency of ankle sprains in basketball[39]. Ankle injuries account for 20% to 45% of all injuries in basketball[2, 39, 41, 42, 43, 44]. By the time a competitive athlete reaches the elite level, he or she usually has a history of several ankle injuries to both ankles[45]. In 1986, Smith and

Reischl[46] reported that 70% of basketball players had a history of ankle sprain and 80% of these players had a history of multiple sprains.

2.3. Current Knowledge - External Support

2.3.1. Bracing versus Taping

Ankle taping is the traditional method used to prevent ankle injuries. It has been used to support ankles for more than a hundred years[47]. However, taping has been criticized for its expense. In addition, tape loses its restrictive capabilities with exercise. Studies have reported an 18% to 50% loss of support for taped ankles after exercise[47]. Taping also requires application by a skilled person. If an untrained individual applies ankle tape its effectiveness may be lost[47].

An alternative to ankle taping is the use of an ankle brace. Ankle braces have become increasingly popular as a means for the prevention of ankle injury. Bracing is more cost effective over time, maintains its restriction with exercise and can be applied more consistently by athletes themselves[51].

2.3.2. Types of Ankle Braces Studied

2.3.2.1. Aircast® Sport Stirrup

The Aircast® Sport Stirrup (Aircast® Inc., Summit, NJ) consists of two thermoplastic molded sides (stirrups) that cover the medial and lateral aspects of the ankle and extend approximately five inches above the malleoli. Inflatable air cells, which conform to the bony contours of the ankle joint, are positioned on the interior aspect of each stirrup. These cells can be adjusted to the wearer's ankle and are used to protect the malleoli from pressure injury and to improve stability. This brace also has an adjustable heel pad and two Velcro straps that encircle the lower leg just above the maleoli[13, 14, 17, 18, 19, 52] (**Figure 1**).

Figure 1. The Aircast® Sport Stirrup

2.3.2.2. Ankle Ligament Protector (ALP)

The ALP (DonJoy® Orthopedic, Carlsbad, CA) consists of a single hard plastic posterior strut, which is positioned directly along the posterior aspect of the tibia. The strut connects a heel cup (fastened to the wearer's shoe with Velcro) and a spring loaded tibial cuff. This feature enables the strut to move up in to the cuff during plantar flexion allowing for unrestricted motion in the saggital plane. The theoretical aim of the brace is to transfer stress loads from the calcaneus to the tibia thereby reducing strain on the ankle ligaments[13, 17, 18, 19] (**Figure 2**).

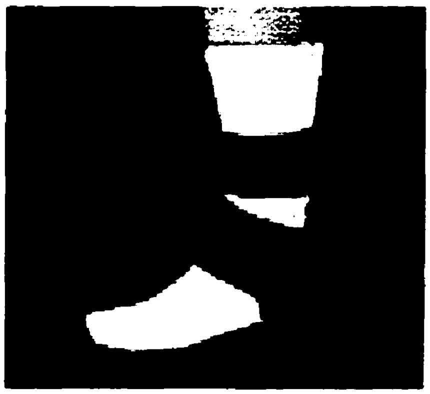

Figure 2. The Ankle Ligament Protector

2.3.2.3. Sure Step Ankle Brace

The Sure Step (Joint Solutions Inc. Tustin, CA) ankle brace consists of two thermoplastic sides and a footplate. The footplate is connected to the sides using two posts and screws. With both screws in place (fixed position option), the ankle is stabilized in a neutral position. This position is used for immobilization of unstable sprains and simple fractures. The fixed position is converted to a functional position, allowing free plantar and dorsiflexion, using a screwdriver to remove the bottom post and screw[48] (**Figure 3**).

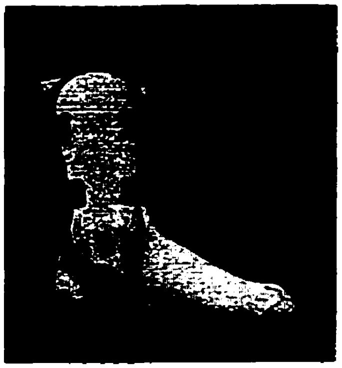

Figure 3. The Sure Step Ankle Brace

2.3.2.4. Malleoloc® Ankle Brace

The Malleoloc® (Baurerfeind, Germany) ankle brace is designed to prevent inversion and eversion without restricting plantar and dorsiflexion. It consists of thermoplastic material and figure eight Velcro strapping that is color-coded for easy application. The Velcro straps are individually adjustable to allow for comfort and fit. The thermoplastic portion fits anteriorly to the lateral malleolus and posteriorly to the medial malleolus to prevent the outward rolling of the ankle joint. The heel and front of the foot are left free for natural stabilization and to allow for plantar and dorsiflexion[49] (**Figure 4**).

Figure 4. The Malleoloc® Ankle Brace

2.3.2.5. Strong Ankle Brace

The Strong (Pi-medical, Uppsala, Sweden) ankle brace was initially a custom made support but is now is available commercially. The custom made brace is shaped using an individually made mold, whereas the commercial brace is available in three sizes that can be adjusted to give good comfort and fit. It is made of polypropylene and has an adjustable strap on the lateral side and a hinge on the medial side. The hinge permits plantar and dorsiflexion while the lateral strap is designed to counteract ankle inversion[50].

2.3.2.6. Swede-O-Universal® Ankle Brace

The Swede-O-Universal® (Swede-O-Universal®, North Branch, MN) ankle brace is a lace up support consisting of a double layer of cloth material that encompasses the ankle and subtarsal joints. Extra medial and lateral plastic inserts, which are placed between the fabric layers, are available[17, 19].

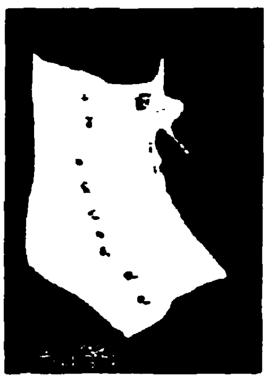

Figure 5. The Swede-O-Universal® Ankle Brace

2.3.2.7. Kallassy Ankle Support™

The Kallassy Ankle Support™ (Sports Supports®, Dallas, TX) is a nylon lined neoprene sleeve that extends from the lower leg to the subtarsal joint. Two non-stretch lateral Velcro straps are attached to the sleeve laterally. These are designed to resist inversion forces when wrapped around the ankle complex. In addition, there is a medial Velcro strap that wraps around the ankle to secure the lateral straps[17].

Figure 6. The Kallasay Ankle Support™

2.3.3. Types of Tape Studied

The majority of previous research have studied one of three types of zinc oxide tape: Zonas (Johnson and Johnson) [12, 13, 20, 81], Coach (Johnson and Johnson)[56, 67, 73] or Leukotape (Beirsdorf Medical) [54, 55]. For most studies, the tape was applied over prewrap[12, 13, 14, 20, 52, 67, 73, 81] or directly to skin[12, 56, 57, 58] starting with anchor strips, followed by alternating stirrups and horseshoes (basketweave), and continuous figure eights and heel locks.

2.3.4. Mechanical Stability

2.3.4.1. Effect of External Support on Mechanical Stability

Traditionally, the function of external ankle support has been regarded as mechanical prevention of extreme joint range of motion and reduction of abnormal movement of the ankle[35]. The rationale for the use of ankle bracing and taping has been based on the assumption that, with the use of external support, ankle stability will be increased through reinforcement of the ankle ligaments and restriction of inversion/eversion range of motion[8, 19, 36].

Rearfoot range of motion, subtalar joint inversion angle, talar tilt and ankle joint range of motion are all terms used to describe the mechanical stability of the ankle joint complex. These parameters have been measured in an attempt to determine the effects of external support on the mechanical stability of the ankle joint[51].

The majority of studies, to date, have examined the effectiveness of ankle bracing and taping in limiting passive joint range of motion [12, 13, 14, 17, 19, 48, 50, 49, 52, 53, 54, 55], with several others measuring active motion restriction[18, 49, 55, 56, 57] or dynamic motion restriction[20, 58].

A large number of studies have examined the ability of different external supports to restrict inversion/eversion range of motion in stable ankles before and after exercise. Most recently, Lohrer et al.[55] investigated the effect of tape on ankle inversion range of motion. Active inversion range of motion was reduced 50% with the application of leukotape (Group 1) and 52% with the application of 3M tape (Group 2). After 20 minutes of exercise inversion restriction decreased to 36% and 34% in Groups 1 and 2 respectively. Although the tape lost restriction with exercise, the amount of restriction was still significantly greater compared to the unprotected condition[55].

Alves et al.[17] compared the restriction provided by the Kallassy Ankle Support, ALP brace, Swede-O-Universal brace and Aircast Sport-Stirrup brace before and after exercise. The Sport-Stirrup limited the most passive inversion pre-exercise (29%) and post-exercise (27%). All braces restricted at least 19% of total range of motion, with the Sport-Stirrup and ALP restricting more than the Swede-O and Kallassy. There was a significant decrease in the restriction of total range of motion after exercise for the Swede-O and Kallassy, however all braces still restricted total range of motion after exercise[17].

Similarly, Greene and Wight[19] also compared the inversion and eversion restriction provided by the Aircast Sport-Stirrup, Swede-O and ALP braces, however before and after 20, 40 and 90 minutes of softball. All the braces restricted pre-exercise passive range of motion, however the Sport-Stirrup and ALP provided more restriction than the Swede-O. At the end of the 90-minute softball practice the Swede-O, Sport Stirrup and ALP lost 35%, 12% and 8% of initial inversion restriction respectively[19].

Gross et al.[52] compared the effectiveness of the Swede-O and Aircast Sport-Stirrup ankle braces and ankle tape in restricting passive inversion/eversion range of motion before and after exercise. It was reported that the Sport-Stirrup and Swede-O provided equal restriction of passive inversion and were less restrictive than tape before exercise. After exercise the tape and Sport-Stirrup provided equal restriction and were more restrictive than the Swede-O[52]. An earlier study by Gross et al.[14] compared the effectiveness of the Aircast Sport Stirrup brace to that of tape in limiting ankle motion before and after exercise. Before exercise, the Sport-Stirrup and ankle tape both significantly restricted passive inversion/eversion range of motion. After exercise, both conditions still significantly restricted total range of motion, compared to the no support condition, however the tape showed a significant degree of loosening[14].

Green and Hillman[13] compared the restriction of inversion provided by the ALP brace and ankle taping before and after 10, 60 and 180 minutes of volleyball practice. The ALP and tape provided similar restriction of passive ankle inversion before exercise however, after exercise the ALP provided considerably more restriction than tape. The brace had an initial restriction of 42%, which was reduced to 37% with exercise. Initially, the tape restricted inversion by 41% however after exercise, restriction was reduced to 15%. Maximal loss of restriction was observed after 20 minutes of exercise[13].

Green and Roland[18] examined active inversion and eversion under three different test conditions: no external support, after application of the ALP brace and after exercise. The brace significantly restricted active inversion and eversion and did not lose its restriction after 20 minutes of exercise[18].

Similarly, Fumich et al.[56] and Myburg et al.[57] tested the effectiveness of tape in restricting active inversion/eversion range of motion before and after exercise. Immediately after application taped caused a 30% decrease in active inversion/eversion range of motion. Fumich et al. [56] reported the restriction was reduced to 15% after a three-hour football practice, whereas Myburg et al. [57] reported the restriction was reduced to 10% after a one-hour squash match. In both cases, resistance decreased by at least 50% after exercise.

A few researchers have studied the effect of external support on ankle range of motion and talar tilt for individuals with unstable ankles. Wiley and Nigg[49]examined the effect of the Malleoloc brace on active and passive inversion/eversion range of motion before and after exercise in subjects with a history of inversion sprain and an increased translation in an anterior drawer test. Active inversion was reduced by 44% before exercise and by 35% after exercise with brace use. Passive inversion was reduced by 45%, 50%, 50% and 46% in 20° dorsiflexion, neutral and 20° and 40° plantar flexion respectively with brace application. After exercise, the brace reduced passive inversion by 42%, 45%, 50% and 39% in 20° dorsiflexion, neutral and 20° and 40° plantar flexion respectively. For both the passive and active tests, the difference in restriction pre and post exercise was minimal and statistically insignificant[49].

Vaes et al.[54] tested the ability of tape to reduce the talar tilt angle in unstable ankle joints before and after exercise. Initially, the talar tilt angle was decreased 63% with the application of tape. After 30 minutes of exercise, the talar tilt angle was increased to 48% of the initial angle. However, this was still significantly lower than compared to the unsupported condition.

Lofvenberg & Karrholm[50] measured the three dimensional motion of the talus and calcaneus with and without the Strong brace in ankles with symptoms of chronic lateral instability. The ankle brace significantly reduced talar and calcaneal plantar flexion, internal rotation and varus angulation[50].

Harstell et al.[48] compared the passive range of motion for individuals with chronic ankle instability and with no history of ankle injury in three brace conditions (no brace, Swede-O and Sure-step brace). The increase in passive resistive torque and decreased range of motion were related to the type of brace worn and to the presence or absence of a history of ankle instability. Passive range of motion was reduced with brace application, however range of motion restriction was greatest with application of the Sure-step brace. After brace application, the chronically unstable ankles resisted higher inversion moments than braced stable ankles[48].

The above studies all evaluated the restriction of range of motion in a non-weightbearing position. However, measurement of inversion resistance during weightbearing may be a more relevant measure for evaluating the restriction provided by external support[12]. For this reason, several researchers have attempted to examine the effect of external support on inversion in a weightbearing position.

Lohrer et al.[55] studied the effect of tape on ankle inversion angle in a standardized sprain simulation on a tilt platform. After tape application, the inversion angle was reduced 44% for all ankles. After ten minutes of exercise, the inversion restriction was reduced to 34% for ankles taped with leukotape and to 28% for ankles taped with 3M tape. After 20 minutes of exercise, there was no further reduction in inversion restriction. Although, the tape lost some of its restriction with exercise, inversion angles were still significantly less than in the untaped condition[55].

Manfroy et al.[12] measured the maximal ankle resistance to inversion under unipedal weightbearing conditions before and after exercise. Before exercise, taped ankles resisted a significantly larger inversion moment than ankles without tape. The maximal inversion resistance increased 11.5% for the ankles taped over prewrap and 8.7% for ankles taped directly on the skin compared to no tape. After 40 minutes of exercise, the maximal inversion resisted in both conditions was reduced so that it was not significantly different than the untaped condition[12].

Kimura et al.[53] examined the ability of the Sport Stirrup to restrict ankle inversion range of motion of stable ankles using a tilt platform. The Air Stirrup reduced passive inversion range of motion by 33%[53].

In attempt to better simulate an actual sports situation, a few studies have assessed the effect of external support in limiting inversion under dynamic loads. Martin and Harter[20] compared the ability of ankle tape, Swede-O brace and Sport Stirrup brace to restrict the inversion angle. The restriction of inversion during footfall for both running and walking on a laterally tilted treadmill were measured. The Sport Stirrup significantly restricted inversion compared to all test conditions during both walking and running. The Swede-O significantly restricted inversion compared to the unsupported condition during walking only. Inversion restraint during dynamic loading was greatest for the Sport Stirrup followed by the Swede-O brace, tape and no support[20].

Similarly, Laughman et al.[58] measured three-dimensional range of motion during walking along a flat and then a slanted surface, in untaped and taped ankles both before and after exercise. All motions showed an average reduction of 26.7% with the application of tape. The post exercise evaluation indicated a general loosening of the tape, with an average 12.1% increase in joint motion. Nonetheless, after exercise 18.6% restriction remained. This was significantly greater than the untaped condition[58].

2.3.4.2. Summary

Both ankle bracing and taping significantly limit inversion before and after exercise[12, 13, 14, 17, 18, 19, 20, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58], however tape loses considerable amounts of restriction after exercise compared to before exercise[12, 13, 14, 52, 54, 55, 56, 57, 58]. Nevertheless, the amount of support available may be more than without any tape at all[14, 52, 54, 55, 58].

The majority of researchers further suggested that, since external support is effective in limiting inversion/eversion range of motion, it is also effective in preventing ankle injury. However, controversy exists over whether physiological range restriction is a reliable indicator of a support system's ability to prevent ankle injury. It has been assumed that if the support restricts range of motion in a non-injurious range, the movement available outside this range will also be limited[5]. It is argued that, if a brace or tape sufficiently restricts range of motion within the non-injurious range, it is of little concern how the external support will perform outside of the normal physiological range, as the joint should be prevented from reaching the point where injury occurs. However, it is doubtful whether an external support could withstand the forces required to rupture a ligament. Laboratory range of motion studies do not simulate the forces involved in ankle sprain, therefore they may overestimate the ability of taping and bracing to limit ankle range of motion. When considering the forces associated with ankle injury, the mechanical role of external support may be insignificant[35, 59].

2.3.5. Functional Stability

Functional instability was a term first introduced by Freeman et al.[60] to describe an individual's subjective complaint for the tendency of the ankle joint to "give way". It was suggested that functional instability may be attributed to impaired ankle proprioception. Proprioception is the cumulative neural input to the central nervous system from mechanoreceptors in joint capsules, ligaments, muscle, tendons and skin[61]. There is controversy in the literature regarding the relative contribution of these different mechanoreceptors in ankle joint proprioception. In the past, joint capsule, ligament and tendon receptors were believed to be the greatest contributors to ankle joint proprioception[60]. However, recently muscle and skin receptors have been suggested to have larger role in ankle joint proprioception[61, 62, 63, 64].

In the literature, the concept of proprioception is often confused with the closely related concepts of kinesthesia and postural balance[61]. Kinesthesia is itself a part of proprioception. It is defined as the conscious awareness of joint position and movement resulting from proprioceptive input to the central nervous system[61, 65]. It involves the gathering and processing of neural input by the higher brain centers, resulting in the conscious awareness of joint position and movement[65].

Postural balance is also associated with proprioception. It is the ability to maintain the body's center of gravity within the area of support provided by the feet[61]. Postural balance is a complex function of brain, spinal and peripheral nerve signals along with muscle actions working together to keep the center of gravity within the area of support[66]. Proprioceptive input is integrated with input from the visual and vestibular systems to monitor the center of gravity. The brain stem processes information from proprioceptive, visual and vestibular systems to maintain balance. Postural balance is achieved with appropriate muscle activation patterns, which are coordinated by complex interactions between the brain, spinal and peripheral signals[61, 65].

2.3.5.1. Functional Stability Assessment

Several methods have been used in attempt to assess functional stability, including detection of joint movement, joint position reproduction, ability to balance on the injured ankle and electromyographic muscle analysis[63, 65, 67, 68, 69, 76].

2.3.5.2. Effect of Injury on Functional Stability

Ankle proprioception is regarded as an important factor that affects susceptibility to ankle injury[61]. Ankle injury has been reported to affect the functional stability of the ankle. It is suggested that proprioceptive defects occur, after an ankle sprain, due to a disruption of the afferent nerve fibers coming from the mechanoreceptors associated with the ankle joint [60, 63, 66]. Decreases in sensory input from receptors may lead to faulty joint position and a diminished postural reflex [60, 67]. Many individuals who sustain an ankle injury consequently demonstrate functional instability in the injured ankle[60, 63, 68, 69, 70, 71, 72]. Ankle injury has been reported to decrease the ability for detecting joint motion[63], reduce the accuracy in reproducing joint postion[69], impair one-leg balance stability[60, 63, 71, 72] and affect the response of the peroneal muscles[68, 70].

Garn and Newton[63] examined the ability of 30 US Naval Academy athletes, with a history of two or more ankle sprains, to detect plantar flexion of the ankle and to balance one-legged, with eyes closed, on the injured limb. The subjects' ability to detect movement when movement occurred and to detect no movement when movement did not occur was poorer on the injured side. In addition, balance deficits occurred more frequently while standing on the side of the ankle sprain than on the uninjured side[63].

Injury has also been shown to adversely affect the ability to match a reference position. Boyle and Negus[69] compared the ability of an uninjured group and an injured group, consisting of individuals with two or more sprains of the lateral ligament complex, to actively and passively match three different positions of inversion (30, 60 and 90 percent of the subjects total inversion range of motion). With passive testing, the injured group was considerably less accurate than the uninjured group in matching all inversion positions.

Several researchers have documented the detrimental effect of injury on postural balance. Freeman et al.[60] and Forkin et al.[71] reported an increase in postural sway in single leg standing on the injured leg compared to the uninjured limb. Freeman et al.[60] reported decreased stability in one-legged balance when subjects stood on the leg with the sprained ankle as compared to standing on the uninjured leg. Only 16% of the injured ankle joints did not show a deficit in stability. Forkin et al.[71] reported that 63% of subjects with recurrently sprain ankles had impaired balance. Leanderson et al.[72] prospectively studied the effect of ankle sprains on the postural sway of 53 ballet dancers. Postural sway was recorded before and after the injuries. Postural stability was impaired after the ankle injury compared to before the injury. However, postural stability improved during the healing process[72].

The response of the peroneal muscles to stress has been indicated to decrease after injury. Nawoczenski et al.[68] and Konradsen and Bohsen-Ravn[70] reported that injured ankles showed a delay in the motor response of the peroneal muscles to inversion stress. Nawoczenski et al.[68] compared the time to onset of the peroneus longus motor response, to induced inversion stress, in injured and uninjured ankles. Within the same subject, 14 of 15 injured ankles responded more slowly than the uninjured ankle. In addition, 12 of 15 injured ankles were further into inversion at the onset of motor response than the uninjured ankle[68]. Konradsen and Bohsen-Ravn[70] also reported a delay in the response of the peroneus longus muscle when the ankle was suddenly inverted.

Previous research has shown that ankle injury adversely affects the functional stability of the ankle[60, 63, 68, 69, 70, 71, 72]. However, proprioception may play a role in the initial injury itself. Most inversion injuries occur during foot contact on landing from a jump or during movements associated with unanticipated foot movement or inappropriate foot positioning. It is suggested that in these situations, individuals perceive the magnitude of inversion to be less than it actually is and induce muscle support adequate for the perceived stress but inadequate for the actual stress thus resulting in an ankle sprain[59].

2.3.5.3. Effect of External Support on Functional Stability

It is thought that external support may prevent ankle injury by enhancing proprioception and stimulating muscular control associated with the ankle joint. Surve et al.[35] suggested that the effect of an ankle brace may be to improve proprioceptive function of the previously injured ankle rather than providing mechanical support alone.

It is suggested that an ankle brace or ankle tape may provide enough stimulation of the tissue surrounding the ankle joint to stimulate mechanoreceptors associated with the joint[73]. Many researchers support this theory, however the scientific basis of it is not well established[4, 62, 64, 73, 74, 75, 76, 77, 78].

Feuerbach et al. [64] reported that subjects, without a recent history of ankle injury, showed an increased ability to match a reference position without visual feedback while wearing an Aircast Sport Stirrup brace. It was suggested that brace application may increase the afferent feedback from skin receptors which may lead to improved ankle joint position sense. The investigators concluded that ankle brace application does increase ankle joint proprioception, however research on the mechanism needs to be conducted[64].

The ability to reproduce joint position may, in part, be dependent upon the direction of joint motion. Twenty-six college-aged individuals, with stable ankles, were measured on their ability to actively reproduce a joint position (30° plantar flexion or 15° inversion) while wearing an ankle brace, ankle tape or no support[73]. For a plantar flexion test, both the ankle brace and ankle tape increased the ability of the subject to match the joint position. However, for an inversion test, only the ankle tape significantly enhanced joint position sense[73]. It was suggested that either the application of an ankle brace or tape may be sufficient to stimulate mechanoreceptors associated with the ankle joint. The researchers also speculated that taping may be more effective than bracing in improving ankle joint proprioception. However, because the common mechanism of ankle injury involves both plantar flexion and inversion, bracing may increase joint position awareness enough to prevent or lessen the severity of a lateral ankle sprain[73].

Robbins et al.[62] examined the kinesthetic sense (perceived slope angles when blindfolded) in taped and untaped stable ankles before and after exercise. Taping positively influenced foot position awareness and showed the greatest benefit after exercise. Although the error for taped ankles increased 7% following exercise, the error in untaped ankles increased 39%[62].

Postural balance testing has also been used to measure the effect of an external support on ankle joint functional stability. Friden et al.[66] examined the effect the Aircast Sport Stirrup brace had on postural sway, in subjects with and without a previous history of ankle injury. The standard deviation for the mean center of pressure was higher in the injured ankles relative to the reference group, uninjured ankle group and injured ankle brace group. When the brace was used, the effect was obvious and none of the parameters showed any significant difference compared to the uninjured leg. However, the different parameters did discriminate between the injured and the uninjured leg[66].

Kinzey et al[75] compared the change in the center of pressure resulting from wearing an ankle brace and wearing no brace during a one-legged standing test combined with the elimination or confusion of visual and proprioceptive inputs. Wearing a brace caused the subject's average center of pressure to increase both laterally and anteriorly when all other sensory modalities were unaffected. However, when the other sensory systems were challenged, no effect due to ankle bracing was found[75]. It was concluded that ankle bracing does not affect proprioception but may be a successful way to reduce injuries by providing a sufficient amount of mechanical stability[75].

Jerosh et al.[76] studied the functional capabilities of external ankle support (Mikros, Aircast Sports Stirrup and tape) in both stable and unstable ankles during a single-leg jumping course, a single-leg stance position test and an angle reproduction test. The scores for the single-leg-jumping course were higher when wearing any external support. In all tests there was a significant reduction in scores with brace use compared to the unsupported condition. Time in the jumping course and angle reproduction was better with the application of tape, however,. the error rate in the single-leg stance test was higher for the taped ankle than the unsupported condition[76]. The injured ankle showed the greatest improvement in all tests, however there was also an improvement in stable ankles. The researchers concluded that the close contact of an ankle brace to the skin may provide additional feedback regarding joint position[76]. Taking this into consideration, the poor results of the tape were not explainable as tape has a more intensive skin contact than a brace[76].

The effect of ankle taping on peroneal muscle functioning has also been investigated. Glick et al.[4] studied the muscle actions of the prime movers for eversion and inversion, in taped ankles during running, for both stable and unstable ankles. In stable ankles, the tape had no effect on muscle activity. However, in three of four individuals with unstable ankles, the peroneus brevis, a primary evertor of the foot, starter to contract earlier and functioned for a longer period of time, just before foot strike in the taped ankle[4]. The researchers suggested that the application of tape might have had a stimulating effect on this muscle. This is important because if the ankle is kept out of inversion, due to contraction of ankle evertors, the likelihood of inversion trauma is reduced[4].

Karlsson and Andreasson[74] measured the reaction time of the peroneal muscles after a simulated ankle sprain on a tilted trap door. Reaction time was significantly slower in the previously injured ankles compared with the stable ankles. With tape, the reaction time was significantly shortened. The greatest improvement in reaction time was achieved in ankles with the highest degree of instability[74]. It was concluded that ankle tape may shorten the reaction time of the peroneal muscles by affecting proprioceptive function of the ankle[74].

2.3.5.4. Summary

Functional instability is a consequence of ankle injury[60, 63, 68, 69, 70, 71, 72]. External ankle support may help to reduce this ankle instability through proprioceptive stimulation[4, 62, 64, 73, 74, 76]. Ankle bracing and taping may function by improving the judgement of position of the plantar surface with respect to the leg[62, 64, 73] or by stimulating muscular control[4, 74]. Skin traction on the foot or leg by ankle tape or pressure of an ankle brace on the leg may stimulate the mechanoreceptors associated with the ankle joint[62, 64, 76]. The sensory feedback from these mechanoreceptors may be used to anticipate foot contact and position the plantar surface of the foot to reduce forces causing inversion and/or command muscles to sustain these forces, thus preventing ligament loading and ultimately injury[59].

2.3.6. *Injury Prevention*

2.3.6.1. *Effect of External Support on Ankle Injury Rates*

The effectiveness of external support in preventing ankle injury is best indicated by epidemiological evidence that shows an external support reduced the incidence of ankle injury. This type of research requires the collection of baseline information before the application of the external support and monitoring of a wide variety of variables during external support use[51]. Epidemiological studies determining the effectiveness of external support in preventing ankle injuries are limited.

Quigley et al.[79] and Thorndike[80] were the earliest researchers to show a reduction in the number of ankle injuries with the use of ankle tape. However, neither used a control group of untaped players. In addition, a study by Garrick and Requa[81] is often cited as evidence that ankle taping reduces ankle injury[1, 11, 47, 51, 56, 57, 59, 82]. Recreational basketball players were randomly assigned to a taped or untaped group and followed for two intramural seasons. During the first year, participants were assigned to groups prior to each game. During the second year, individuals were randomly assigned to either the tape or no tape group for the entire season. Players used their usual high or low topped shoes and were questioned about ankle injuries at the end of each game[81]. During the two seasons, 55 ankle sprains occurred in a total of 2562 games. There was a significant reduction in the ankle sprain rate in the taped ankle group compared to the untaped ankle group. Thirty-six injuries occurred in 1107 games for the untaped group resulting in an injury rate of 32.8 injuries/1000 player games. Seventeen injuries were sustained in 1163 games for the taped group (14.7 injuries/1000 player games). In addition, shoe type had an influence on the injury rate. Those athletes wearing high top shoes and tape exhibited the lowest incidence of ankle sprains (6.5 injuries/1000 player games). At the opposite end of the spectrum, those players wearing low top shoes and no tape had the highest injury rate (33.4 injuries/1000 player games).

Previous history of injury also affected the injury rates. Players with a history of previous injury were twice as likely to be injured compared to those players without a history of previous injury (27.7 and 13.9 injuries per 1000 player games respectively). The application of ankle tape reduced the injury rate for players both with and without a history of ankle injury, however for those previously uninjured players this effect was only observed in combination with high-top shoes. Garrick and Requa[81] concluded that the use of both high-top shoes and ankle taping appeared to decrease frequency of ankle sprains. This decrease was particularly marked in those individuals who had suffered a previous ankle sprain. However, injury rates were expressed by player and not by ankle. This distinction is important, as a previously injured player may sustain a new injury in either the previously injured ankle or the ankle not previously injured[35]. It is possible that an injury occurring in the left ankle of a player with a previous right ankle injury was misclassified into the previous history group. This differential misclassification bias may have led to an overestimation of the rate of injury in the previous history group and an underestimation in the no history group. The resulting estimate of risk of injury comparing the previous history group to the no history group would be away from the null, with the risk appearing to be greater in the previous history group.

The effectiveness of wearing a laced brace (specific brace not identified) and taping in preventing ankle injures has been studied retrospectively over 6 collegiate football seasons[11]. For the first year of the study all players were taped and for the remainder of the study the players wore the support of their choice. Two hundred and thirty three athletes sustained 248 ankle injuries in 51,931 exposures (46,789 practice exposures and 5,142 game exposures). The players with taped ankles sustained 182 injuries during 38,658 exposures whereas the players wearing a brace sustained 38 injuries during 13,273 exposures. After stratifying for position, Rovere et al[11] reported that players wearing the lace-up brace had half the risk of injury to those wearing tape regardless of shoe type. Also, 23 out of 24 re-injuries occurred in players wearing tape. It was concluded that ankle tape was less effective in preventing ankle injury and reinjury during football practices and games than a laced ankle brace. The researchers further suggested that this may reflect that fact that the ankles were often taped long before the actual exposure to injury, therefore loosening of the tape with time and mechanical stress may have resulted in its ineffectiveness.

The investigators did not account for previous history of injury. The higher injury rate in the tape group may have resulted because those athletes with a previous history of injury may be more likely to tape their ankles than those athletes without a past history of injury. Furthermore, athletes with a previous history of injury may be at a greater risk for reinjury. Therefore, previous history of injury may have confounded the relationship leading to an overestimation of the risk of injury in the tape compared to the brace group. In addition, the researchers did not compare the injury rates for braced or taped ankles to unsupported ankles.

Tropp et al.[36] were the first to study the effectiveness of a semirigid ankle brace in reducing the incidence of ankle sprains. Soccer teams were randomly assigned to either a control group, brace group or coordination training program group. Those players assigned to the brace group were then given the choice of whether or not to use the brace. Approximately half chose to wear it. Players were then divided into previous or no history of ankle injury groups within the three study groups. Among the control group, 75 men with a previous history of ankle problems sustained 19 sprains (25%) compared to one of 45 (2%) in the brace group and three of 65 (5%) in the coordination training group. For players without a history of ankle problems, there was no difference in the frequency of ankle injuries among the three groups. Tropp et al.[36] reported that the ankle brace and coordination training were equally effective in reducing the number of ankle sprains in players with a previous history of injury only. However, differences in exposure to injury were not taken into account. All injuries were treated equally regardless of chance of sustaining a particular injury. This may have resulted in unreliable estimates that may have under or over estimated the true risk of injury.

A more recent study by Sharpe et al.[82] of female collegiate soccer players, with a previous history of ankle injury, also indicated that ankle bracing was effective in reducing the incidence of ankle sprains in soccer players. This is the only known study to report on the relationship between ankle bracing and injury rates in female athletes. Medical records, over a five-year period, were retrospectively reviewed and athletes with a previous ankle sprain were considered as subjects for this study. Thirty-eight players, with 56 previously sprained ankles, were followed for one soccer season after the previous sprain. Each previously sprained ankle was classified into a tape, Swede-O ankle brace, tape and brace or no external support group. Among the four groups, a total of 1717 practice exposures and 650 game exposures were recorded. There were no ankle sprain recurrences in the brace group (0%), three recurrences occurred in the tape group (25%), two in the combination group (25%) and six in the no support group (35%). The recurrence frequency was significantly lower in the brace group compared to all other groups. Neither the tape group nor the combination group differed, in recurrence frequency, from the no support group[82]. However, these results may be limited due to the low number of injuries. In addition, exposure was estimated from practice and game schedules. Variability in individual participation was not taken into account. Athletes who participated on a regular basis were considered at the same risk of injury as those who did not. This would result in unreliable estimates that may have under or over estimated the true risk of injury.

Surve et al.[35] conducted a prospective, randomized clinical study to examine the effectiveness of the Aircast Sports Stirrup in reducing the incidence of ankle sprains in 629 male senior level soccer players during one playing season. The players were divided into two groups, those with previously injured ankles (258 players) and those with no history of injury (246 players). Brace assignment was then randomized within the injury groups. For players with a previous history of ankle injury, the incidence of ankle sprains was significantly lower for the braced ankles (0.14 injuries/1000 playing hour) compared to unbraced ankles (0.86 injuries/1000 playing hours). However, for players with no previous history of ankle injury, the ankle sprain rate was similar in the braced and unbraced conditions (0.97 and 0.92 injuries/ 1000 playing hours respectively). It was concluded that semirigid ankle braces significantly reduced the incidence of sprains in soccer players with previously injured ankles but did not reduce the incidence of ankle sprains in uninjured ankles[35].

The generalizability of this study, outside of soccer, is arguable. The different movement patterns of different sports may result in different injury risk factors. The effectiveness of an external support system may be altered by the injury risk factors present. For this reason, it is debatable whether the results of the Surve et al.[35] study can be generalized to intercollegiate basketball.

In a similar study, Sitler et al.[1], evaluated the efficacy of the Aircast Sports Stirrup in reducing the incidence of ankle injuries in 1601 recreational basketball players. Players were divided into uninjured and previously injured ankle groups. Braces were then randomly assigned within the injury groups. Subjects who sustained an ankle injury during the study were required to wear the brace regardless of original group assignment. Subjects participated in a total of 13,430 athlete exposures (game or practice) during the two years of the study. Forty-six ankle injuries were sustained during the study period. The ankle injury rate was 1.4 times greater for the previous history group compared to the uninjured group. However, this difference was not statistically significant so the two groups were collapsed together. Eleven ankle injuries were sustained in 6682 athlete exposures (1.6 injuries per 1000 athlete exposures) for the brace group. For the unsupported group, 35 injuries occurred in 6748 athlete exposures (5.2 injuries per 1000 athlete exposures). Thus, the risk of sustaining an ankle injury was approximately 3 times greater for the unbraced individuals as for the individuals wearing the ankle brace. Sitler et al.[1] concluded that semirigid ankle braces are effective in reducing the incidence of ankle injuries in basketball, regardless of injury history.

Although this study was randomized and controlled for confounding variables, it is arguable whether the results can be generalized to intercollegiate sport. This is due to the differences in player stature, playing experience, exposure to injury and level of play between the study subjects and intercollegiate basketball athletes. The subjects in the Sitler et al.[1] study were not typical of the average intercollegiate basketball player. The average height of the players in this study was 5'8''; much shorter than that of the average intercollegiate basketball player. In addition, the study was conducted in an intramural league. The level of play in an intramural league is recreational while that in an intercollegiate league is competitive. Furthermore, the exposure to injury in the Sitler et al.[1] study was considerably less than that of an intercollegiate athlete. Games consisted of two 15-minute halves and practices lasted approximately 75 minutes. At the intercollegiate level, games consist of two 20-minute halves and practices last approximately 90 to 180 minutes. This difference is important considering Sitler et al.[1] based athlete-exposure on the number of games or practices in which a player participated and not the total number of participation hours.

2.3.6.2. Summary

Although the cited studies have some limitations, there is a general agreement that external support is effective in preventing ankle injuries. However, the effect may vary with type of support (i.e. brace or tape) and sport. Rovere et al.[11] concluded that, in football, ankle tape was less effective in preventing ankle injury and reinjury than a laced ankle brace. Sharpe et al.[82] indicated that, in soccer, taped ankles had the same frequency of recurrent ankle sprains as unsupported ankles. However, Garrick and Requa[81] reported that ankle tape is effective in reducing the incidence of ankle injury in basketball (especially when combined with a high top shoe). It is possible that the differences among these studies were due to the different sports studied. The effect of previous history of injury on the ability of an external support to prevent injury also seems to depend on sport. Surve et al.[35] and Tropp et al.[36] suggested that semirigid ankle braces reduced the incidence of sprains in soccer players with previously injured ankles only. However, Sitler et al.[1] reported that semirigid ankle braces are effective in reducing the incidence of ankle injuries in basketball, regardless of injury history.

2.4. Summary

The mechanism of external ankle support function is arguable. Two theories exist regarding how ankle bracing and taping may effect the rate and severity of ankle injury. The first suggests that external ankle devices add mechanical support to the joint, thereby limiting extreme ranges of motion. The second suggests that a brace or tape may prevent injury by enhancing proprioception and stimulating muscular control[73]. The majority of studies, in the past, have examined the effectiveness of ankle bracing and taping in limiting the ankle's inversion/eversion range of motion in a laboratory setting[12, 13, 14, 17, 18, 19, 20, 48, 49, 50, 52, 53, 54, 55, 56, 57, 58]. The majority of researchers suggested that ankle braces and ankle tape are effective in limiting extreme range of motion, however tape looses some of it restriction with exercise. Fewer studies have examined the effect of external support on ankle joint proprioception and muscular control[4, 62, 64, 66, 73, 75, 76, 77, 78]. The majority of these studies indicated that external support improves proprioception or stimulates muscular control[4, 62, 64, 66, 73, 76, 77, 78].

The effectiveness of external support in preventing ankle injury is supported by epidemiological evidence. Epidemiological studies tend to indicate that bracing or taping may be effective for reducing the incidence of ankle injuries[1,35,36,81,82], especially in those athletes with a history of injury[1, 35, 36, 81]. However, the effect may vary with type of support (i.e. brace or tape) and sport.

3. METHODS

3.1. Study Design

The varsity athletic population constitutes and ideal "epidemiological laboratory" as it provides a controlled environment in which to observe the effects of preventative measures. Therefore, a prospective cohort study was conducted. The use of external support by Canada West University Athletic Association (CWUAA) and Great Plains Athletic Conference (GPAC) basketball players was documented. The ankles of all athlete were classified into brace, tape, or no support groups and were followed for one season to determine the risk of ankle sprains.

3.2. Subjects

The study population consisted of male and female varsity basketball players from the University of Victoria (UVic), University of British Columbia (UBC), University of Lethbridge (U of L), University of Calgary (U of C), University of Alberta (U of A), University of Saskatchewan (U of S), University of Winnipeg (U of W), University of Manitoba (U of M) and Brandon University.

3.2.1. Subject Enrollment

CWUAA and GPAC male and female varsity basketball players were recruited for participation in the study at the start of the 1998/99-basketball season. Consent to participate in the study was obtained through the following procedure, approved by the Office of Medical Bioethics, Faculty of Medicine, University of Calgary.

At the preseason team meeting/ briefing each team's athletic therapist was instructed to inform the players of the existence of the Canadian Intercollegiate Sport Injury Registry (CISIR) and the nature of the study. Specifically the therapists were instructed to tell the players:

> *"For the past five years, an injury registry has been used in the Canadian Inter-University Athletic Union (CIAU) to track injury rates and risks with the purpose*

*of predicting and preventing injury. As part of this, I (the team therapist) will send your medical and injury information to the registry in Calgary where it will remain **strictly confidential**. If you have any objection to this, please talk to me after the meeting."*

Any player that objected to sending his/her medical and injury information to the CISIR was excluded from the study.

3.3. Data Collection - Procedure

3.3.1. Reporting

Baseline information, daily athletic participation (including external support use) and injuries were documented using a validated reporting system; the Canadian Intercollegiate Sport Injury Registry (CISIR)[28]. Three separate data collection forms were used to capture baseline, exposure (participation) and injury information. The instruments used to collect this information were a preseason medical form, a weekly exposure sheet (WES) and an individual injury report form (IIRF) [28].

These forms were used by each team's athletic therapist to collect information. Because the athletic therapists are involved with the teams on a daily basis, they were in an optimal position to document detailed participation and injury information consistently[28]. The athletic therapists were familiar with the CISIR from previous years and were provided with a handbook detailing all aspects of the data collection procedure.

In addition, the head athletic therapist for each university was contacted at the start of the season to ensure his or her willingness to participate with the data collection. The nature of the study was also explained, at this time. All therapists willing to participate in the data collection signed an agreement (Appendix A).

3.3.1.1. Baseline Information

Baseline information, including injury history, was collected at the time of the athlete's preseason medical. This information was collected using standardized forms. For those athletes new to the CISIR (i.e. Rookies), a standardized Injury History Questionnaire was completed (Appendix B). Returning athletes, with a previously documented detailed medical history, completed the CWUAA Reassessment Form (Appendix C). This form was designed to capture interval changes in injuries since the initial baseline evaluation of the athlete. Any injuries that had occurred since the last season were noted. The preseason medical forms were used to document demographic characteristics and to obtain information regarding potential risk factors such as player position. In particular, the preseason medical forms were used to establish a history of previous injury at the outset of the study[28].

3.3.1.2. Daily Athletic Participation

Throughout the 1998/99 season each team's athletic therapist completed a Weekly Exposure Sheet (WES) to document participation for each athlete every day of the season (Appendix D). The WES was completed on a daily basis, by an athletic therapist, for each practice or game. Data was collected from the first practice session to the end of the season, including play offs[28]. The therapist documented the individual participation for every athlete, including shoe type and external support information, in a tabular format. The columns of the WES designated one game or practice while rows were used to represent each player. At the top of each column the type, duration and playing conditions for each session were documented. The level of athlete participation (full, partial or no participation) was recorded in the cells of the table. The cells were coded with full (F), partial (P) or no participation (O) codes for each athlete. In addition, an explanatory code was recorded if partial (P) or no participation (O) was recorded for one of the following reasons: injury (I), sickness (S) or absence for any other reason than injury or sickness (A). If an explanatory code was recorded for injury (i.e. a PI or OI code) the injury ID# from the corresponding individual injury report form was also recorded[28]. In previous years, shoe type and brace and tape use were recorded on a weekly basis rather than on a session by session basis. The Weekly Exposure Sheet was revised, for the 1998/99 season, to allow the entering of brace and tape use on a session by session basis. In the cells beneath the participation information, shoe and external support information were entered for every practice or game.

3.3.1.3. Injury

Throughout the season the athletic therapists collected detailed information on all injuries[28]. A one page Individual Injury Report Form (IIRF) was developed, as part of the CISIR, to make the collection of injury information as simple and as time-efficient as possible (Appendix E). Each team's athletic therapist completed an IIRF, at the time of the injury, for all injuries that occurred during the 1998/99 season and required assessment or treatment by the team therapist or a physician. This form consisted of a series of fixed and open-ended responses. Fixed responses were used to document player position, injury zone, injury status, session type, contact, return to play, external support use, illegal play and treatment. These fixed response items included lists with check boxes and were used to eliminate errors and increase consistency. In addition, the last response for some of the fixed responses was other. This choice allowed for the recording of unanticipated circumstances. Open-ended responses consisted of space for recording injury events, physical findings, assessment and additional treatment plans. If a physician saw an athlete for the same injury, he or she also recorded his or her diagnosis and treatment plan in the space provided on the IIRF. The IIRF was produced in triplicate to provide one copy for the therapist, one for the physician and one for the CISIR[28].

3.4. Data Collection - Outcome

3.4.1. Injury Definition

The injury reporting definition adopted by the CISIR is: "any event requiring assessment and treatment by a team therapist or physician"[28]. However, differences in injury reporting among therapists may create a potential bias. For example, some therapists may report all injuries and others may only report time loss injuries. Therefore, for this study, an injury was defined as “any ankle sprain that occurred during a scheduled game or practice and caused the athlete to miss at least part of one game or practice following the injury”. This time loss definition was validated through cross checking with the time loss noted on the Weekly Exposure Sheet[28].

3.4.1.1. Severity of Injury

Severity of injury was based on the amount of time lost from participation due to injury (i.e. the number of sessions a player missed due to an injury). The number of sessions affected or missed due to an injury for each group were measured using the participation and explanatory codes recorded on the Weekly Exposure Sheet.

3.4.1.2. Type of Injury

To determine if the injury involved contact or no contact, check box number five of the IIRF was used. If the check box was left blank, the "Events Surrounding Injury" open-ended section was used to determine if contact was involved.

3.4.2. Athlete Exposure Measurement

The Weekly Exposure Sheet was used to calculate the total athlete exposure for each group. Using participation and explanatory codes along with external support information, a precise measure of the number of sessions for each study group was calculated.

3.5. Data Checking

Weekly Exposure Sheets and Individual Injury Report Forms were sent to the central registry in Calgary every two weeks where they were entered into the CISIR. Before forwarding the forms to Calgary, the head therapists from each university checked all forms for completeness (missing information). When the forms arrived in Calgary they were checked for any missing or unclear information. Any missing information or discrepancies were clarified by contacting the head therapist. Also, at this time, each Individual Injury Report Form was checked against the Weekly Exposure Sheet to determine time loss for the injury. This was accomplished through cross validation of the Injury ID#.

3.6. Data Entry

Information collected using the preseason medical forms, Weekly Exposure Sheets and Individual Injury Report Forms were entered into the CISIR. The CISIR is a single entry database constructed using Microsoft® Visual FoxPro (Microsoft Corporation, Redmond, WA). For data entry, computer input screens were developed as an electronic counterpart to the paper forms[28]. Fixed response items were entered using scrolling lists or radio buttons. This sped up data entry and eliminated typing errors. For open-ended responses, the text recorded by the therapist was typed into the appropriate screen. In addition, each injury was recorded in text format as well as being coded. This allowed the exact text to be viewed during data analysis and allowed for verification of the coding.

A check for default or blank values was developed to minimize data entry error. The system was programmed to check for default/ blank values before moving on to the next data entry screen. Following this check, a list of fields that contained blank or default values were given and the user was prompted to check the entries presented in the list. In addition, the data entry screens also had a limited range of responses for certain fields. These "validation checks" prohibited the entry of inappropriate responses for certain fields (e.g. dates)[28].

3.7. Data Analysis Strategy

The data from the CISIR was imported into Microsoft® Excel (Microsoft Corporation, Redmond, WA) and Stata™ (Stata Corporation, College Station, TX) for analysis. Once imported into Excel the data was checked to ensure that the recorded values were plausible.

3.7.1. Descriptive Analysis

The study population was described in terms of total number of injuries and total amount of athlete exposure. The ankles of the subjects were classified into a brace, tape or no support group based on the type of support used. The total number of ankle exposures was then calculated for each support group. Based on the total amount of ankle exposure, a comparison of the distribution of support use was made for university, gender, previous history of injury, session type, player position and shoe type.

Using the total number of injuries and ankle exposures, ankle sprain rates were determined for each support group.

3.7.2. Severity of Injury

The amount of time lost for each injury, by support group, was summarized in a frequency table. Based on this table, injuries were categorized into mild (at least half a session lost), moderate (one to seven sessions lost) and severe (more than seven sessions lost) ankle sprains. Injury rates for mild, moderate and severe sprains were then calculated.

3.7.3. Univariate Risk Analysis

The relationship between external support and the rate of ankle injury was summarized and displayed using contingency tables. This allowed the injury rate per thousand ankle exposures to be determined for each support group. Using injury rates, the relative risk of injury, with 95% confidence interval, was calculated for the brace group compared to the no support group. A similar comparison was made between the tape and no support groups.

3.7.4. Multivariate Risk Analysis

Because subjects were not randomly assigned to groups it was imperative that the influence of extraneous factors be minimized. Stratified analysis was performed to assess the relationship between bracing and taping and the risk of injury after stratifying on each of severity of injury, gender, history of injury, type of injury, session, player position and shoe type separately. The relative risks for each stratum were compared to each other, and the combined estimate, to identify the presence of confounding or effect modification. The presence of effect modification was observed if the stratified estimates were different from each other. Mantel-Haenszel adjusted relative risk estimates, with 95% confidence interval, were also calculated. Confounding was observed when this adjusted estimate differed from the overall unadjusted estimate.

4. Results

4.1. Study Population

4.1.1. Subjects

Data was collected on 250 (136 male and 114 female) basketball athletes from nine universities. The age of the subjects ranged from 18 to 27 years with a mean (standard deviation) of 20.51 (2.00) years. **Figure 7** illustrates the distribution of subjects among the nine universities.

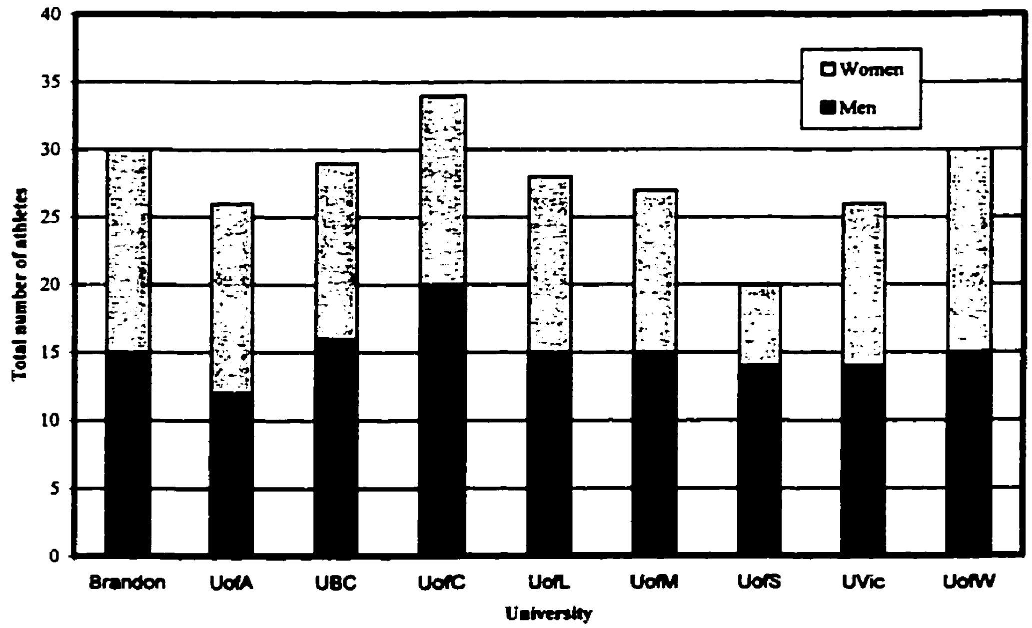

Figure 7. Distribution of Subjects among the Universities

Nine female athletes from the University of Saskatchewan declined participation in the study. In addition, 23 athletes were cut or quit before the end of the 1998/99 season. The exposure for these athletes was included up to the time they left. No athletes discontinued participation due to an ankle injury.

4.1.2. Athlete Exposure

Total exposure was determined from the Weekly Exposure Sheets (WES). Ninety-nine percent of the total WES's were received. The total exposure is a count of all sessions for which there was a possibility of ankle injury. To calculate exposure, full participation codes were weighted 1.0 and partial participation codes were weighted 0.5. The 250 subjects participated in a total of 23,091 sessions. Of these, 6583.5 were game exposures and 16,507.5 were practice exposures.

The frequency of practice and game exposures among the nine universities is illustrated in **Figure 8.**

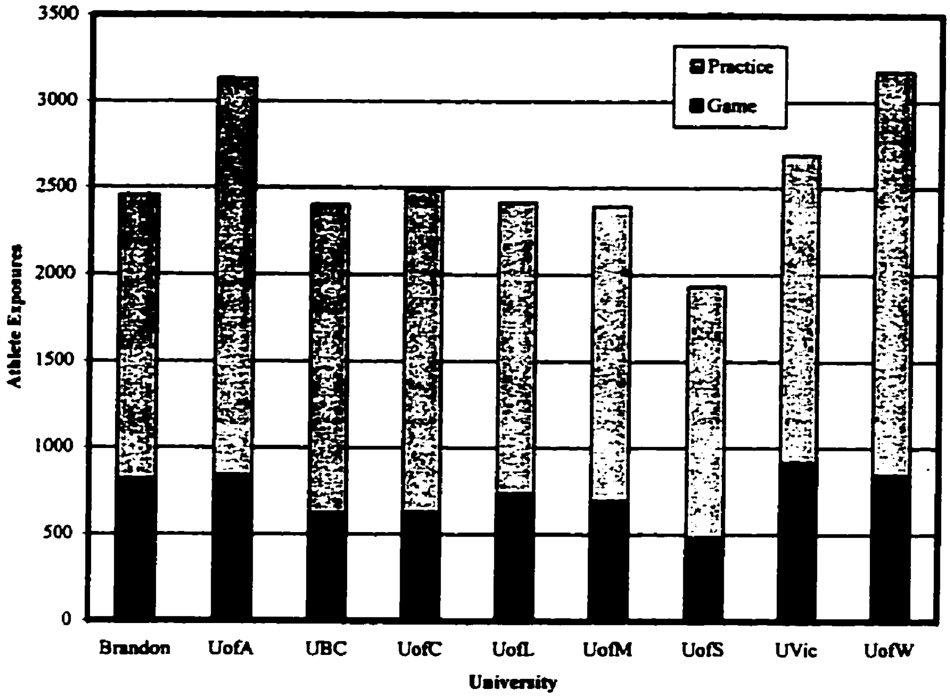

Figure 8. Comparison of Total Athlete Exposure among the Universities

4.1.3. Total Number of Injuries

Ankle injuries were determined from the Individual Injury Report Forms (IIRF). One hundred percent of all IIRF's corresponding to Injury Identification Numbers on the WES's were received.

A total of 50 subjects or, 20% of the study population, sustained 57 ankle sprains. Of these, 53 were initial injuries and four were a second sprain to the same ankle during the study period. Three subjects sustained sprains to both ankles. The distribution of injuries among the nine universities is illustrated in **Figure 9.**

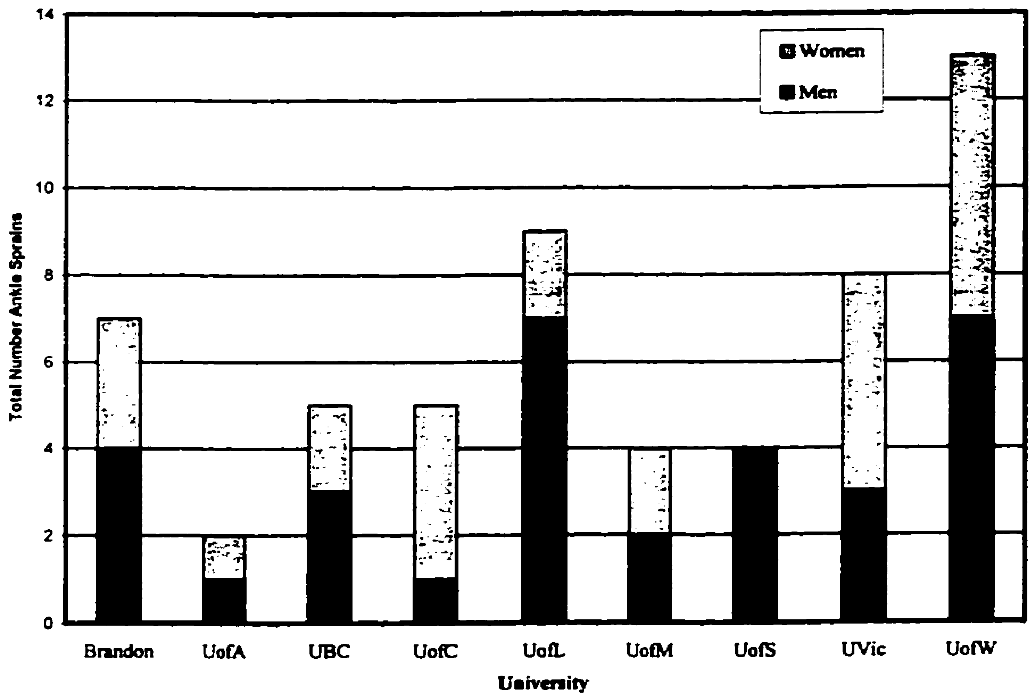

Figure 9. Comparison of Total Number of Ankle Sprains among the Universities

4.2. Group Characteristics

4.2.1. Study Groups

The WES was designed to capture support use on a session by session basis. However, 11% of the WES's reported support usage on a weekly basis.

Subjects could not be categorized discretely into support groups because athletes tended to change their support condition on a session to session basis. One hundred and fifty one subjects (60%) changed their support condition at least once.

In addition, for 16% of all exposures, subjects did not wear the same support on both right and left ankles. Therefore, ankles, not subjects, were categorized into study groups. Each athlete exposure became two ankle exposures, each of which was then categorized into its corresponding study group. Ankles were classified into brace, tape and no support groups. A small number of subjects wore both a brace and tape on the same ankle. Of these, the majority of exposure was limited to one female athlete who wore both a brace and tape on both ankles for the entire study period. The remainder of the exposure for this group, was comprised of athletes who used both brace and tape for a short time after an injury. It was felt that analysis of this data would not be valid, thus it was excluded from the rest of the analysis.

4.2.2. Ankle Exposure

Figure 10 illustrates the total ankle exposure for each support group.

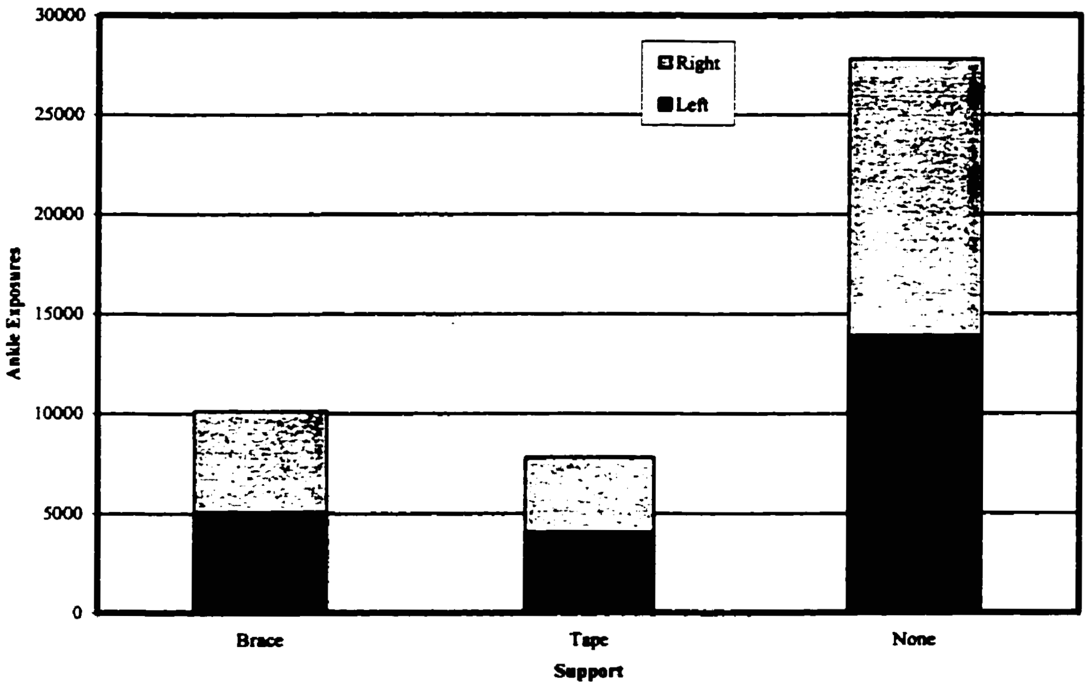

Figure 10. Comparison of Total Ankle Exposure among the Support Groups

The majority of braces used were seimirigid, however the specific model was only available for three schools. All athletes at the U of S and female athletes at the U of L wore an Active Ankle™ (Active Ankle Systems Inc., Louisville, KY) brace whereas female athletes at the U of A wore an Aircast® Sport Stirrup (Aircast Inc., Summit, NJ) brace.

The use of external ankle support varied by university. Ankle bracing and ankle taping were used at all schools, however there was not an equal distribution of support use at each university. Athletes at the U of A, U of L and U of S tended to brace their ankles whereas athletes at UBC and UVic rarely braced their ankles. However, athletes at UVic tended to tape their ankles more frequently than athletes at other universities. Athletes at U of C, UBC, Brandon, U of M and U of W tended to not wear external ankle support. The frequency of external support usage by athletes at each university is illustrated in **Figure 11**.

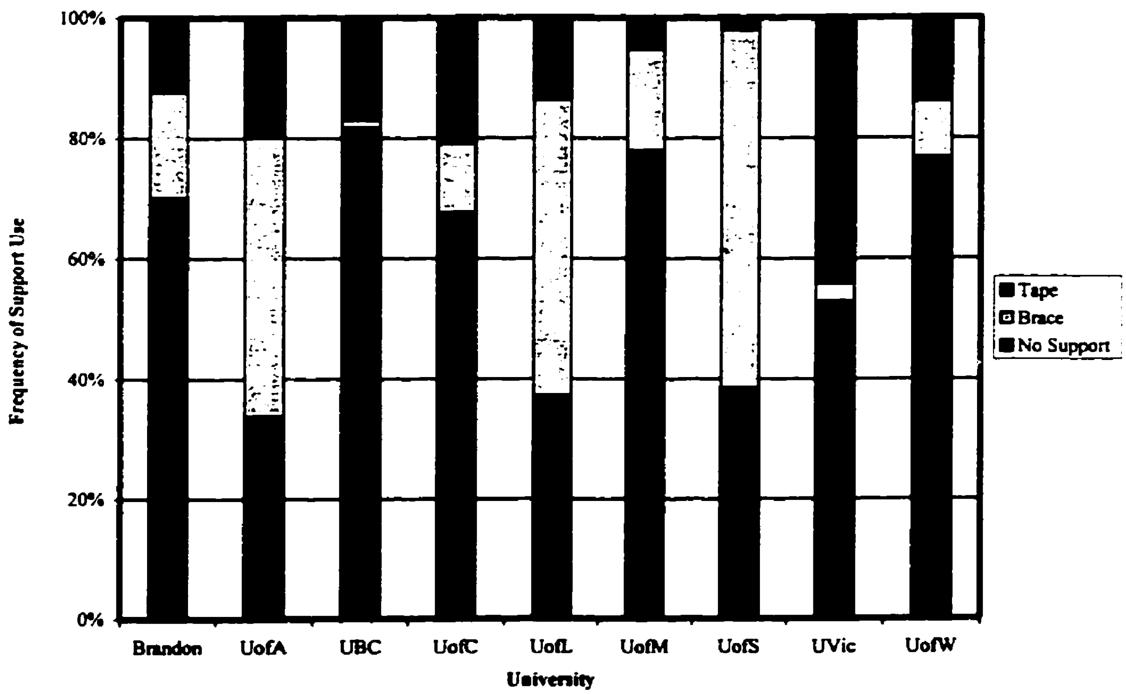

Figure 11. Comparison of the Frequency of Support Use by University

External support use varied between male and female athletes. In approximately 50% of the sessions female athletes wore an external support. The external support most frequently used by female athletes was the brace. On the other hand, male athletes wore an external support for only 30% of the sessions. The support most commonly used by males was ankle tape. The difference in support use between male and female athletes is illustrated in **Figure 12**.

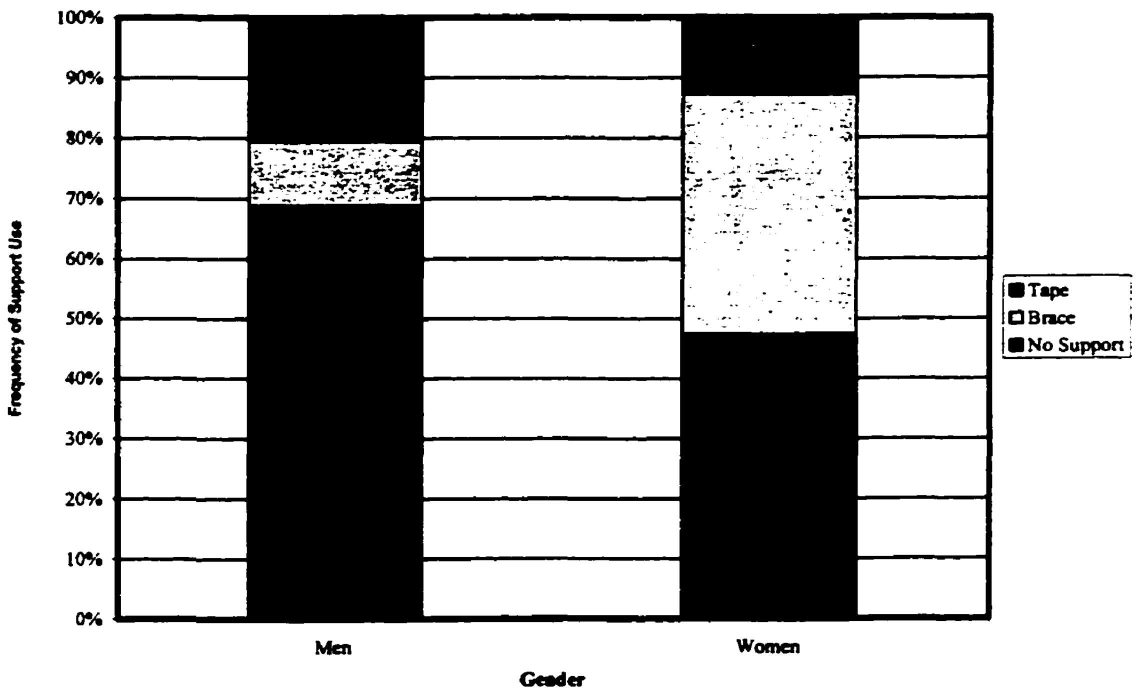

Figure 12. Comparison of the Frequency of Support Use by Gender

External support use was also different for previously injured ankles compared to ankles without a previous history of injury. Approximately 50% of previously injured ankles were either braced or taped. The use of ankle bracing was about the same for previously injured ankles compared to ankles without a previous history of ankle sprain. However, taping was more commonly used in previously sprained ankles. The difference in support use between previously sprained ankles and ankles without a history of ankle sprain is depicted in **Figure 13**.

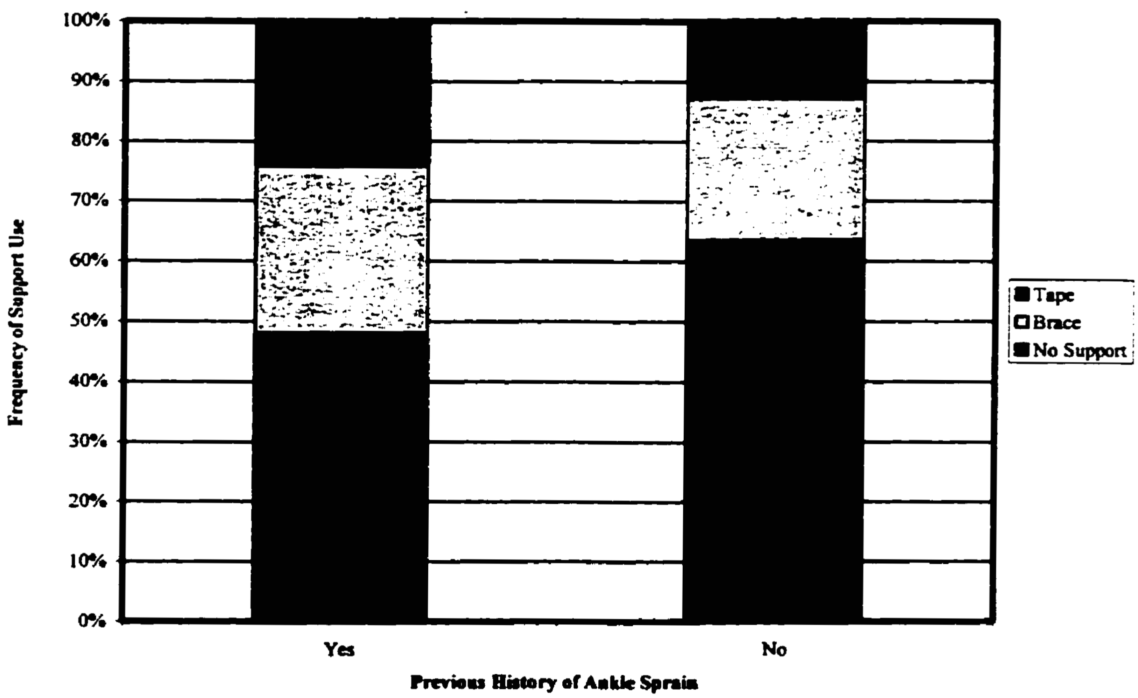

Figure 13. Comparison of the Frequency of External Support Use by Previous History of Injury

Figure 14 illustrates the frequency of support use for games and practices. The use of ankle bracing was approximately the same for games and practices. However, taping was more commonly used during games than during practices.

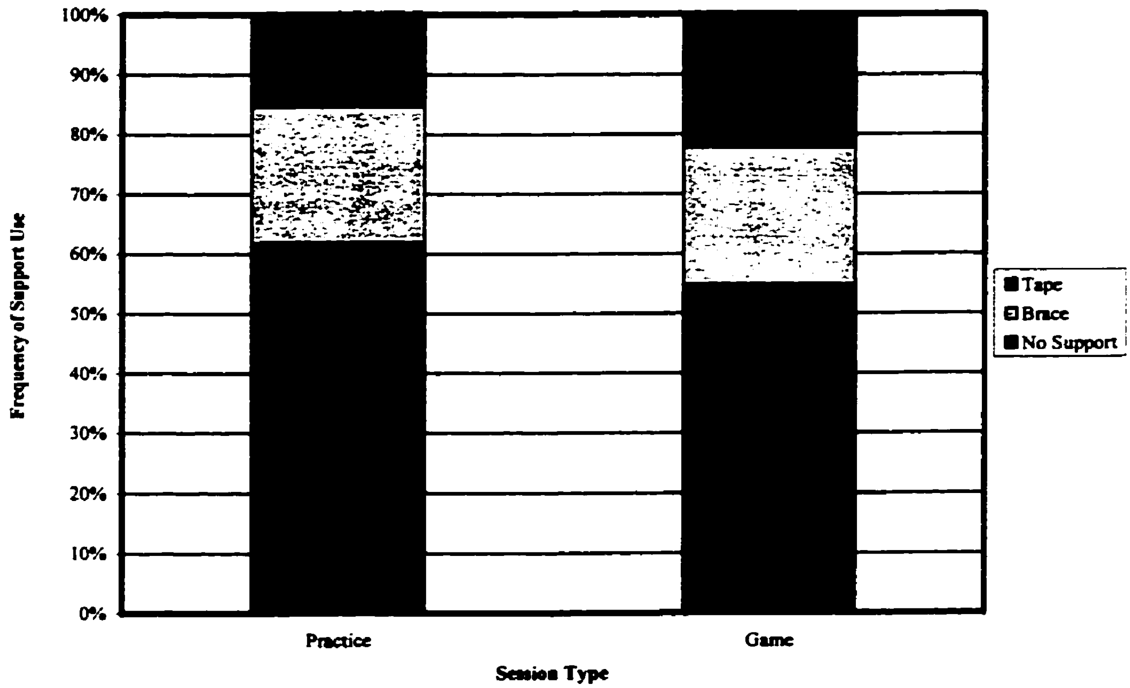

Figure 14 Comparison of the Frequency of External Support Use for Games and Practices

A comparison of the frequency of support use by player positions is depicted in Figure 15. The use of ankle bracing and taping was approximately the same for point guard, guards and centres whereas forwards tended to brace their ankles less frequently than the other positions. Tape usage was approximately the same for forwards, centres and point guards whereas guards used tape less frequently than the other positions.

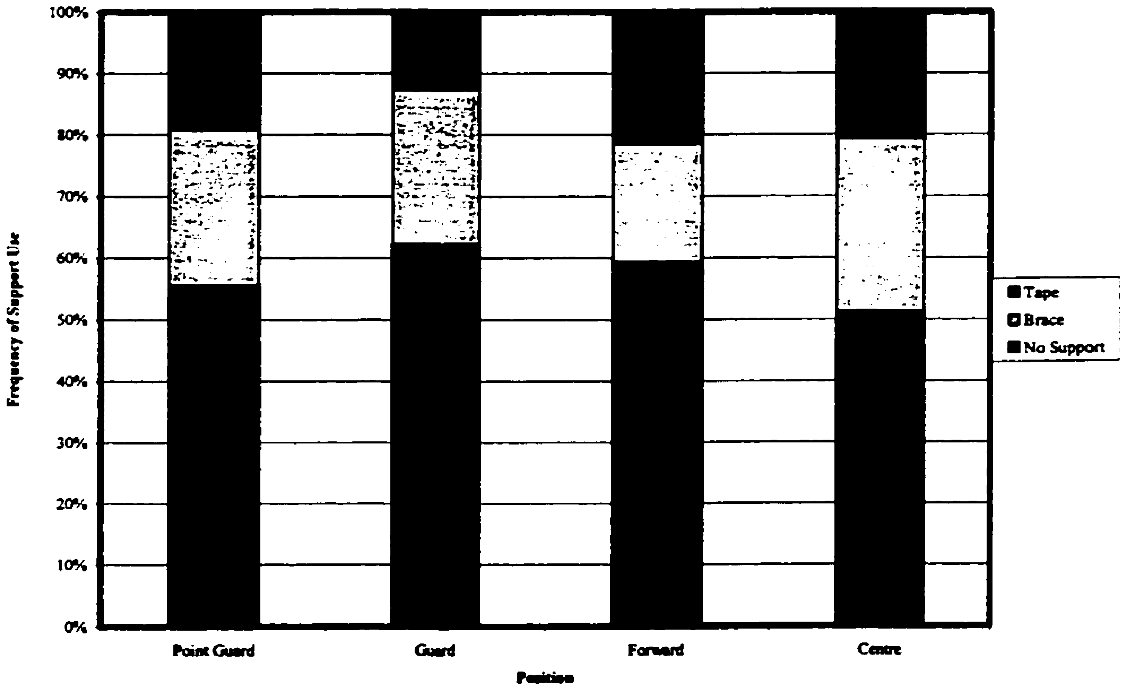

Figure 15. Comparison of the Frequency of External Support Use by Player Position

Figure 16 depicts the frequency of the different support and shoe type combinations used during the study. Adidas and Nike shoes were combined with either an ankle brace or ankle tape for approximately the same number of ankle exposures. Reebok shoes were most commonly combined with an ankle brace. Converse shoes were rarely combined with either an ankle brace or ankle tape

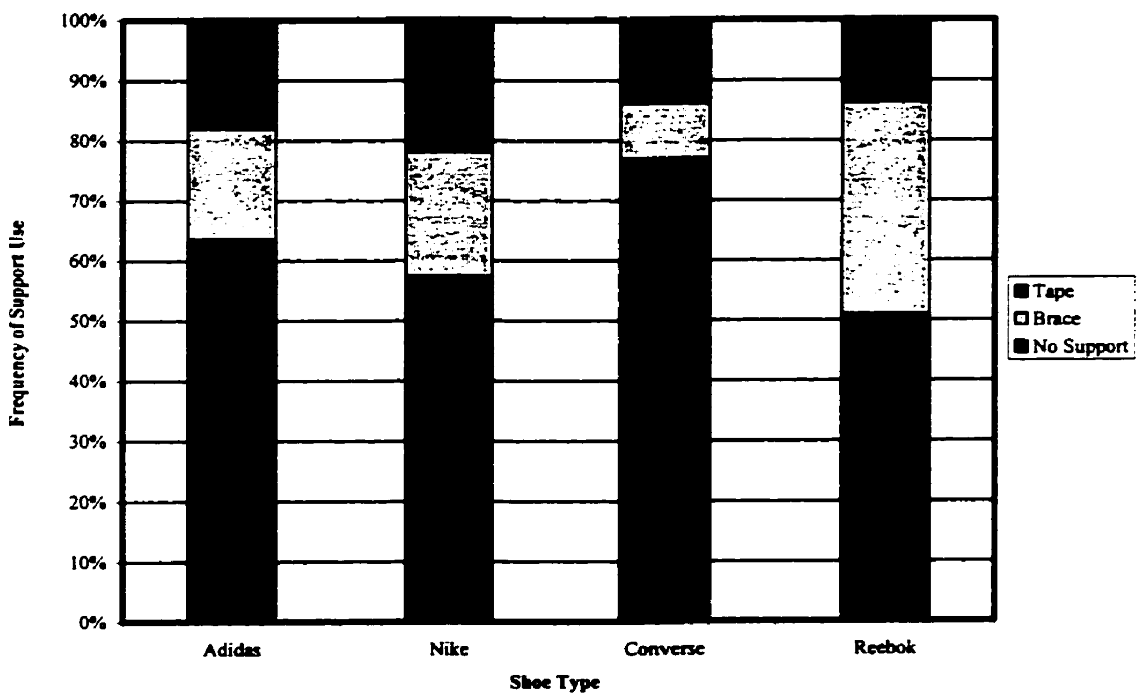

Figure 16. Comparison of the Frequency of External Support Use and Shoe Type Combination

4.3. Univariate Analysis

4.3.1. Injury Rates

Ankle sprain rates for the brace, tape and no support groups are illustrated in. Figure 17.

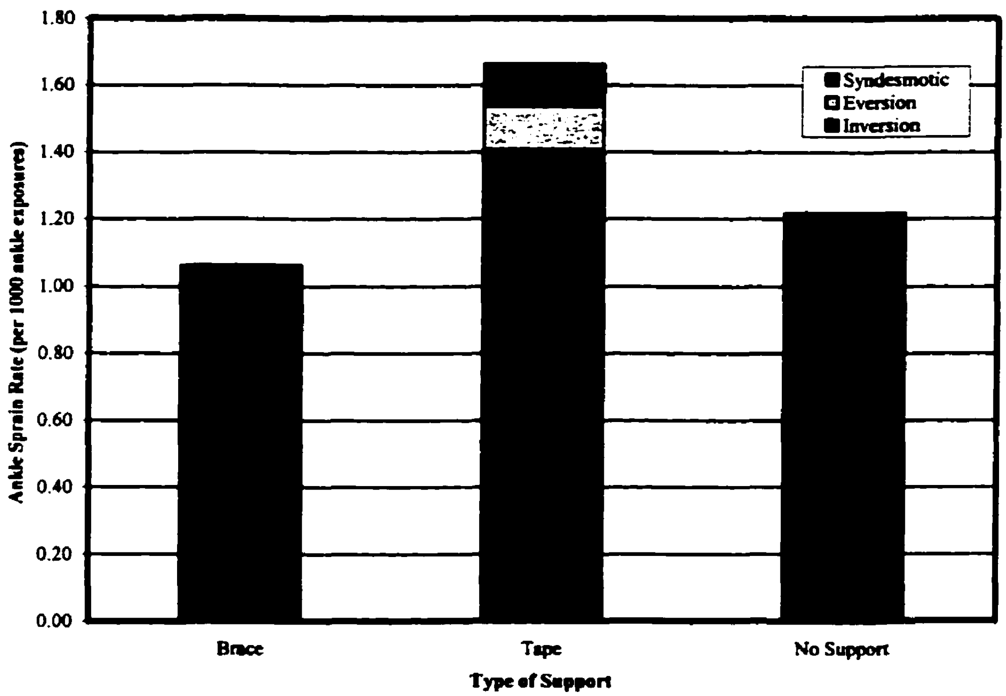

Figure 17. Comparison of the Rate of Ankle Sprain for Braced, Taped and Unsupported Ankles

Of the 57 ankle sprains, 11, 13 and 33 occurred in braced, taped and unsupported ankles respectively. Overall injury rates (per 1000 ankle exposures) of 1.06, 1.66 and 1.21 were calculated for the brace, tape and no support group respectively. The majority of injuries were inversion sprains; however, a taped ankle sustained one eversion injury. One taped ankle and two unsupported ankles sustained syndesmotic injuries.

4.3.2. Univariate Risk Analysis

The relative risk estimates for braced and taped ankles compared to unsupported ankles are summarized in **Table 1.**

Table 1. Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles

	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Brace	11	10350	1.06	0.87	(0.40, 1.77)
Tape	13	7809	1.66	1.37	(0.66, 2.67)
No Support	33	27080	1.21		

* per 1000 ankle exposures
** CI, confidence interval

The risk of ankle sprain was 1.14 times lower for braced ankles and 1.37 times higher for taped ankles relative to the risk of ankle sprain for unsupported ankles. However, as seen in **Table 1**, the 95% confidence intervals for both estimates included the null value.

4.4. Multivariate Risk Analysis

4.4.1. Severity

The amount of time lost for each ankle sprain is shown in **Table 2**.

Table 2. Amount of Time Lost for Each Ankle Sprain by Support Group

Time Loss (Sessions)	Brace	Tape	No Support	Total
0.5	3	4	8	15
1	1	0	3	4
1.5	2	2	2	6
2	2	0	1	3
2.5	0	2	3	5
3	0	1	0	1
3.5	1	0	0	1
4.5	0	0	2	2
5	0	0	3	3
5.5	1	1	0	2
6.5	0	0	2	2
7	0	0	1	1
7.5	0	0	1	1
8.5	0	0	1	1
9.5	0	1	0	1
10	0	0	3	3
12	0	0	1	1
13	0	1	1	2
14	1	0	0	1
15.5	0	1	0	1
33.5	0	0	1	1
Total	11	13	33	57

Twenty-one ankle sprains resulting in no time loss were reported. However, in terms of the CISIR this is not a validated category, therefore these injuries were not included in the analysis.

Based on time loss, ankle injuries were categorized, post hoc, into three levels of severity, mild, moderate and severe. A mild injury was defined as a sprain that restricted participation in part of a session. Sprains that caused the athlete to miss at least one session but no more than seven sessions were considered to be of moderate severity. Severe sprains were those that caused the athlete to miss more than seven sessions.

Figure 18 illustrates the rate of mild, moderate and severe ankle sprains for each support group.

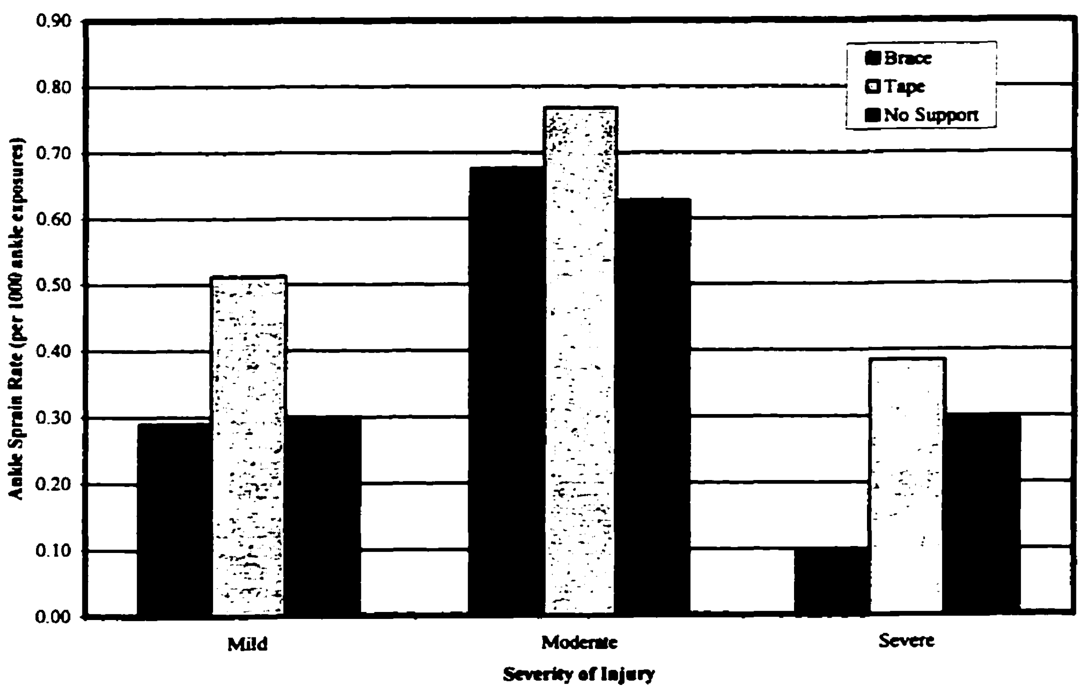

Figure 18. Comparison of the Rate of Mild, Moderate and Severe Injuries for Each Support Group

There was indication of different severity specific relative risk estimates for braced ankles relative to unsupported ankles. There was no difference in the risk of ankle sprain for braced ankles compared to unsupported ankles for both mild and moderate sprains. However, for severe sprains, the risk of injury was three times lower for braced ankles compared to unsupported ankles. For taped ankles, the risks of injury for mild, moderate and severe sprains were all higher than the risk for unsupported ankles. The risk of injury for taped ankles relative to unsupported ankles was 1.73, 1.22 and 1.30 times higher, respectively. However, as is shown in **Table 3,** the 95% confidence intervals for all relative risk estimates overlapped and included the null value.

Table 3. **Severity Specific Relative Risk of Ankle Sprain for Taped Ankles Compared to Unsupported Ankles**

Severity	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Mild					
Brace	3	10350	0.29	0.98	(0.14, 4.09)
Tape	4	7809	0.51	1.73	(0.38, 6.47)
No Support	8	27080	0.30		
Moderate					
Brace	7	10350	0.68	1.06	(0.38, 2.73)
Tape	6	7809	0.77	1.22	(0.40, 3.25)
No Support	17	27080	0.63		
Moderate					
Brace	1	10350	0.10	0.33	(0.007, 2.44)
Tape	3	7809	0.38	1.30	(0.22, 5.41)
No Support	8	27080	0.30		

* per 1000 ankle exposures

** CI, confidence interval

Severity of injury did not confound the overall relative risks of ankle sprain for either braced or taped ankles compared to unsupported ankles. The overall relative risk estimate for both braced and taped ankles compared to unsupported ankles was the same as its respective, Mantel-Haenszel relative risk estimate. **Table 4** compares the overall relative risks with the Mantel-Haenszel adjusted relative risks for braced and taped ankles compared to unsupported ankles.

Table 4. Comparison of Overall and Severity Adjusted Mantel Haenszel Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.87	(0.40, 1.77)
Mantel-Haenzsel	0.87	(0.44, 1.73)
Tape vs. No Support		
Overall	1.37	(0.66, 2.67)
Mantel Haenzsel	1.37	(0.71, 2.60)

*CI, confidence interval

4.4.2. Gender

Gender specific rates of ankle sprain for braced, taped and unsupported ankles are depicted in **Figure 19**.

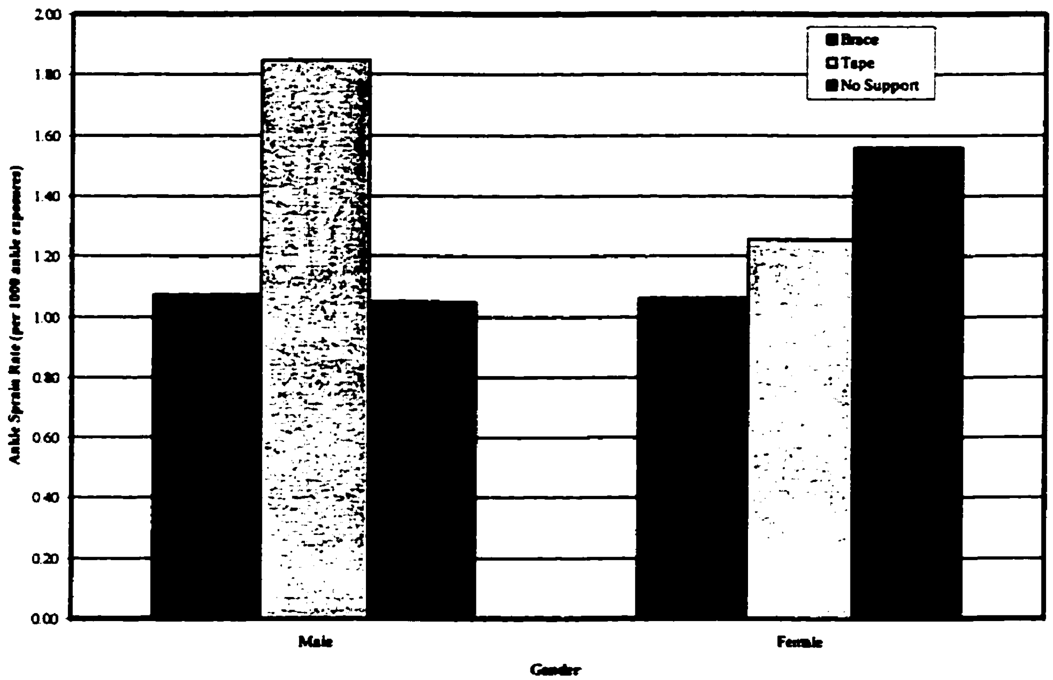

Figure 19. Comparison of the Gender Specific Rates of Ankle Sprain for Braced, Taped and Unsupported Ankles

For female subjects, the rate of ankle sprain was lowest for braced ankles, followed by taped and unsupported ankles. For male subjects, the rate of ankle sprain was similar for braced and unsupported ankles, but higher for taped ankles. In addition, the rate of sprain was approximately the same for the braced ankles of men and women.

There was indication of different gender specific relative risk estimates for both braced and taped ankles relative to no support. For men, there was no difference in the risk of ankle sprain for braced ankles compared to unsupported ankles. However, for women, the risk of ankle sprain was 1.47 times lower for braced ankles compared to unsupported ankles.

The risk of ankle sprain for the taped ankles of women was 1.25 times lower than the risk for the unsupported ankles of women. For men, the risk of ankle sprain was 1.76 times higher for taped ankles than the risk for unsupported ankles.

However, as in shown in **Table 5**, the 95% confidence intervals for all relative risk estimates overlapped and included the null value.

Table 5. Gender Specific Relative Risk of Ankle Sprain for Taped Ankles Compared to Unsupported Ankles

Gender	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Male					
Brace	3	2795	1.07	1.02	(0.19, 3.48)
Tape	10	5416.5	1.84	1.76	(0.73, 3.98)
No Support	19	18133	1.04		
Female					
Brace	8	7555	1.06	0.68	(0.25, 1.73)
Tape	3	2392.5	1.26	0.80	(0.15, 2.88)
No Support	14	8967	1.56		

* per 1000 ankle exposures
** CI, confidence interval

In addition, the relative risk of ankle sprain for braced ankles compared to unsupported ankles may have been confounded by gender. The overall relative risk estimate and the Mantel-Haenszel gender adjusted relative risk estimate appeared to be different from each other. However, the 95% confidence intervals for these estimates overlapped considerably. The relative risk of injury for taped ankles compared to the risk for unsupported ankles was not confounded by gender. For taped ankles, the overall relative risk estimate was the same as the Mantel-Haenszel adjusted relative risk estimate. **Table 6** compares the overall relative risks with the Mantel-Haenszel relative risks for braced and taped ankles compared to unsupported ankles.

Table 6. **Comparison of Overall and Gender Adjusted Mantel Haenszel Relative Risk Estimates for Braced and Taped Ankles Compared to Unsupported Ankles**

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.87	(0.40, 1.77)
Mantel-Haenszel	0.78	(0.38, 1.57)
Tape vs. No Support		
Overall	1.37	(0.66, 2.67)
Mantel Haenzsel	1.38	(0.72, 2.62)

*CI, confidence interval

4.4.3. Injury History

Injury specific exposure was not available for 30 subjects. The 128 brace exposures, 604 tape exposures and 2577.5 no support exposures effected were removed from this part of the analysis

The injury history specific rates of ankle sprain for braced, taped and unsupported ankles are illustrated in **Figure 20.**

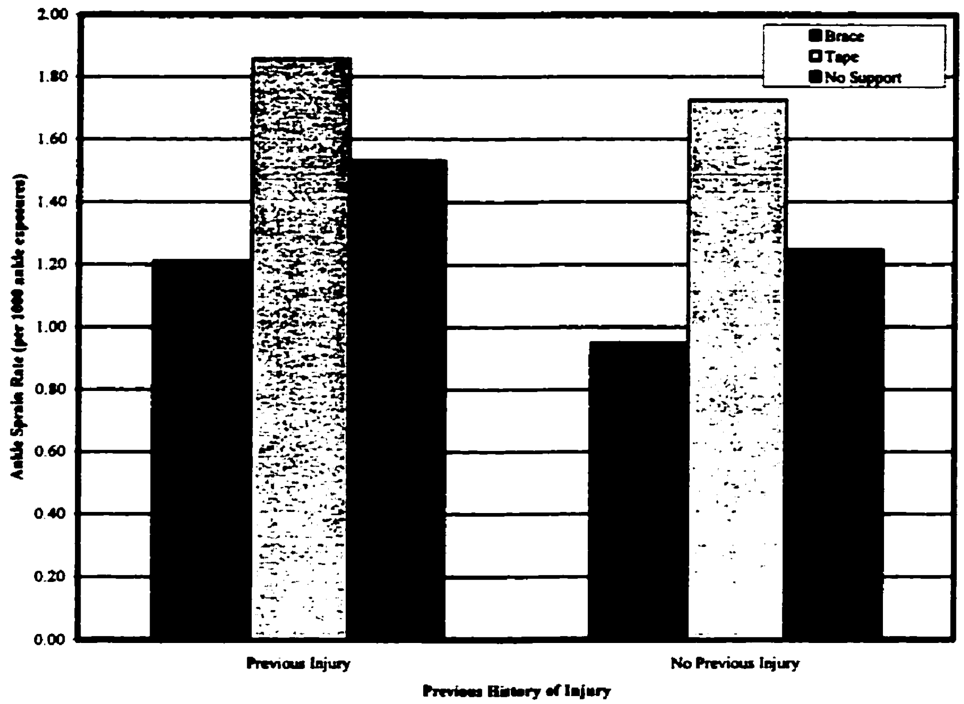

Figure 20. Comparison of the Injury History Specific Rates of Ankle Sprain for Braced, Taped and Unsupported Ankles

The rate of ankle sprain was highest for taped ankles both with and without a previous history of ankle injury, followed by unsupported and braced ankles. For all support conditions, ankles without a past history of injury had a lower rate of ankle sprain than previously injured ankles.

The relative risks of ankle sprain for both braced and taped ankles compared to unsupported ankles were not significantly different for previously sprained ankles compared to ankles without a past history of injury. The relative risk for each stratum was within the 95% confidence interval of the other indicating that each was a plausible estimate for the other. Regardless of injury history, there was an indication of a reduction in the risk of ankle sprain for braced ankles and an increase in the risk of ankle injury for taped ankles relative to unsupported ankles. However, the 95% confidence intervals for all estimates included the null value. **Table 7** is a summary of the injury specific relative risks for braced and taped ankles compared to unsupported ankles.

Table 7. Injury Specific Relative Risk for Braced and Taped Ankles Compared to Unsupported Ankles

History of Injury	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Previous History					
Brace	6	4957	1.21	0.79	(0.24, 2.21)
Tape	8	4307.5	1.85	1.21	(0.44, 3.15)
No Support	13	8481	1.53		
No History					
Brace	5	5265	0.96	0.76	(0.22, 2.09)
Tape	5	2897.5	1.72	1.38	(0.41, 3.80)
No Support	20	16021.5	1.25		

* per 1000 ankle exposures
** CI, confidence interval

In addition to being similar to each other, the stratum specific risks for both braced and taped ankles relative to unsupported ankles were not significantly different from the overall risk. This indicated the overall relative risk estimate comparing either braced or taped ankles to unsupported ankles was not confounded by injury history. In addition, the overall relative risk estimates, for both braced and taped ankles compared to unsupported ankles, did not differ from its respective injury adjusted, Mantel-Haenszel relative risk estimate. **Table 8** compares the overall relative risks with the Mantel-Haenszel relative risks for braced and taped ankles compared to unsupported ankles.

Table 8. **Comparison of Overall and Injury Adjusted Mantel Haenszel Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles**

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.79	(0.36, 1.61)
Mantel-Haenzsel	0.77	(0.38, 1.49)
Tape vs. No Support		
Overall	1.34	(0.64, 2.59)
Mantel Haenzsel	1.27	(0.66, 2.45)

*CI, confidence interval

4.4.4. Injury Type

The rates of contact and non-contact ankle sprains for braced, taped and unsupported ankles are illustrated in **Figure 21**.

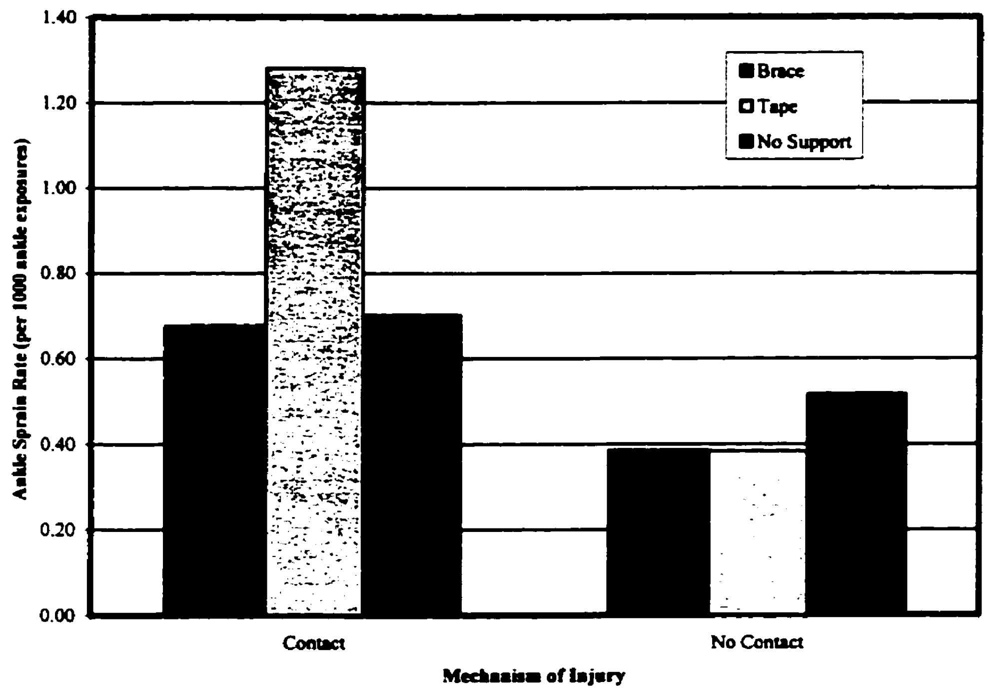

Figure 21. Comparison of the Rate of Contact and Non-contact Ankle Sprains for Braced, Taped and Unsupported Ankles

There was an indication of a different risk for sustaining a contact or non-contact injury for both braced and taped ankles relative to no support. For braced ankles, there was no difference in the risk of ankle sprain involving contact compared to unsupported ankles. However, the risk of ankle sprain not involving contact was 1.33 times lower for braced ankles than for unsupported ankles. For taped ankles, the risk of non-contact ankle sprain was also 1.35 times lower compared to the risk for unsupported ankles. The risk of contact ankle sprain was 1.83 times higher for taped ankles than the risk for unsupported ankles. However, as depicted in **Table 9,** the 95% confidence intervals for all relative risk estimates overlapped and included the null value.

Table 9. **Relative Risk of Contact and Non-contact Ankle Sprains for Braced and Taped Ankles Compared to Unsupported Ankles**

Contact	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Yes					
Brace	7	10350	0.68	0.96	(0.34, 2.39)
Tape	10	7809	1.28	1.83	(0.76, 4.13)
No Support	19	27080	0.70		
No					
Brace	4	10350	0.39	0.75	(0.18, 2.38)
Tape	3	7809	0.38	0.74	(0.14, 2.66)
No Support	14	27080	0.52		

*per 1000 ankle exposures
** CI, confidence interval

Type of injury did not confound the overall relative risks of ankle sprain for either braced or taped ankles compared to unsupported ankles. The overall relative risk estimate for both braced and taped ankles compared to unsupported ankles was the same as its respective, Mantel-Haenszel relative risk estimate.

Table 10 compares the overall relative risks with the Mantel-Haenszel adjusted relative risks for braced and taped ankles compared to unsupported ankles.

Table 10. Comparison of Overall and Mantel Haenszel Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.87	(0.40, 1.77)
Mantel-Haenzsel	0.87	(0.44, 1.73)
Tape vs. No Support		
Overall	1.37	(0.66, 2.67)
Mantel Haenzsel	1.37	(0.71, 2.60)

*CI, confidence interval

4.4.5. Session

Session specific ankle sprain rates for braced, taped and unsupported ankles are illustrated in **Figure 22.**

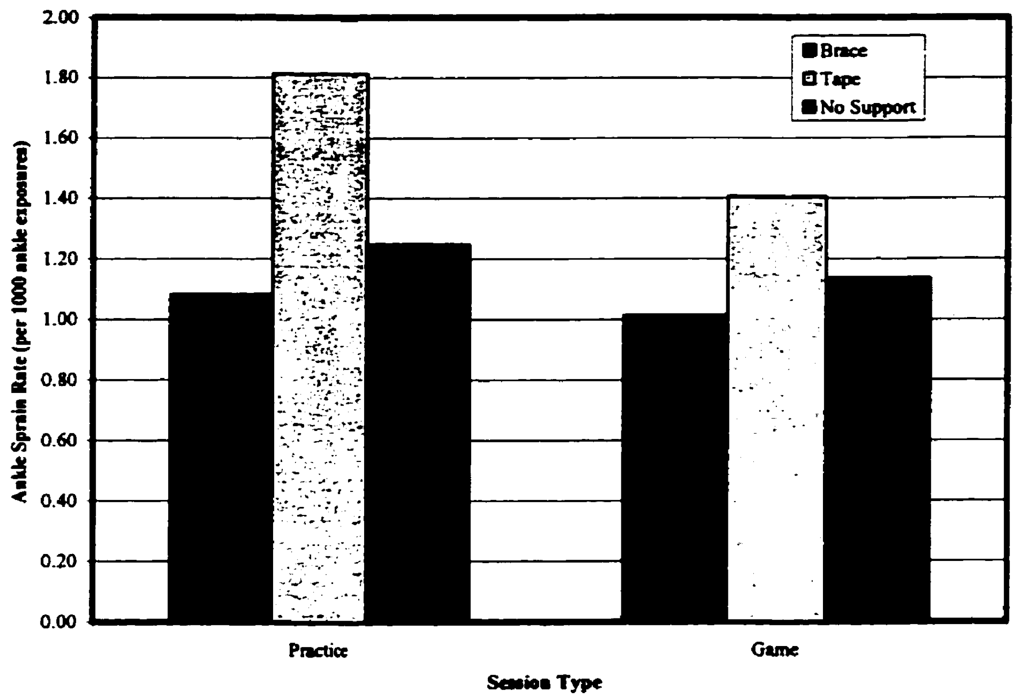

Figure 22. Comparison of Session Specific Rates of Ankle Sprain for Braced, Taped and Unsupported Ankles

The relative risks of ankle sprain, for both braced and taped ankles compared to unsupported ankles, were not significantly different for games or practices. Regardless of session type, there was an indication of a reduction in the risk of ankle sprain for braced ankles and an increase in the risk of ankle injury for taped ankles relative to unsupported ankles. However, the 95% confidence intervals for all relative risk estimates overlapped and included the null value. **Table 11** is a summary of the session specific relative risks for braced and taped ankles compared to unsupported ankles.

Table 11. Session Specific Relative Risk of Ankle Sprain for Braced and Taped Ankles Compared to Unsupported Ankles

Session	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Game					
Brace	3	2956.5	1.01	0.89	(0.15, 3.72)
Tape	4	2847.5	1.40	1.24	(0.27, 4.62)
No Support	8	7045	1.14		
Practice					
Brace	8	7393.5	1.08	0.87	(0.34, 1.98)
Tape	9	4961.5	1.81	1.45	(0.60, 3.22)
No Support	25	20035	1.25		

* per 1000 ankle exposures
** CI, confidence interval

In addition to being similar to each other, the stratum specific session risks for both braced and taped ankles relative to unsupported ankles were not significantly different from the overall risk. This indicated that neither the overall relative risk estimate comparing braced and unsupported ankles nor the overall relative risk estimate comparing taped and unsupported ankles was confounded by session type. In addition, the overall relative risk estimate for both braced and taped ankles relative to unsupported ankles did not differ from its respective, Mantel-Haenszel adjusted relative risk estimate.

Table 12 compares the overall relative risk estimates with the Mantel-Haenszel relative risk estimates for braced and taped ankles compared to unsupported ankles.

Table 12. Comparison of Overall and Session Adjusted Mantel Haenszel Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.87	(0.40, 1.77)
Mantel-Haenzsel	0.87	(0.44, 1.73)
Tape vs. No Support		
Overall	1.37	(0.64, 2.67)
Mantel-Haenzsel	1.38	(0.73, 2.63)

*CI, confidence interval

4.4.6. Player Position

Position specific exposure was not available for 26 subjects. The 305.5 brace exposures, 283 tape exposures and 2512.5 no support exposures effected were removed from this part of the analysis.

The rates of ankle sprain for braced, taped and unsupported ankles for point guards, guards, forwards and centres are illustrated in **Figure 23**.

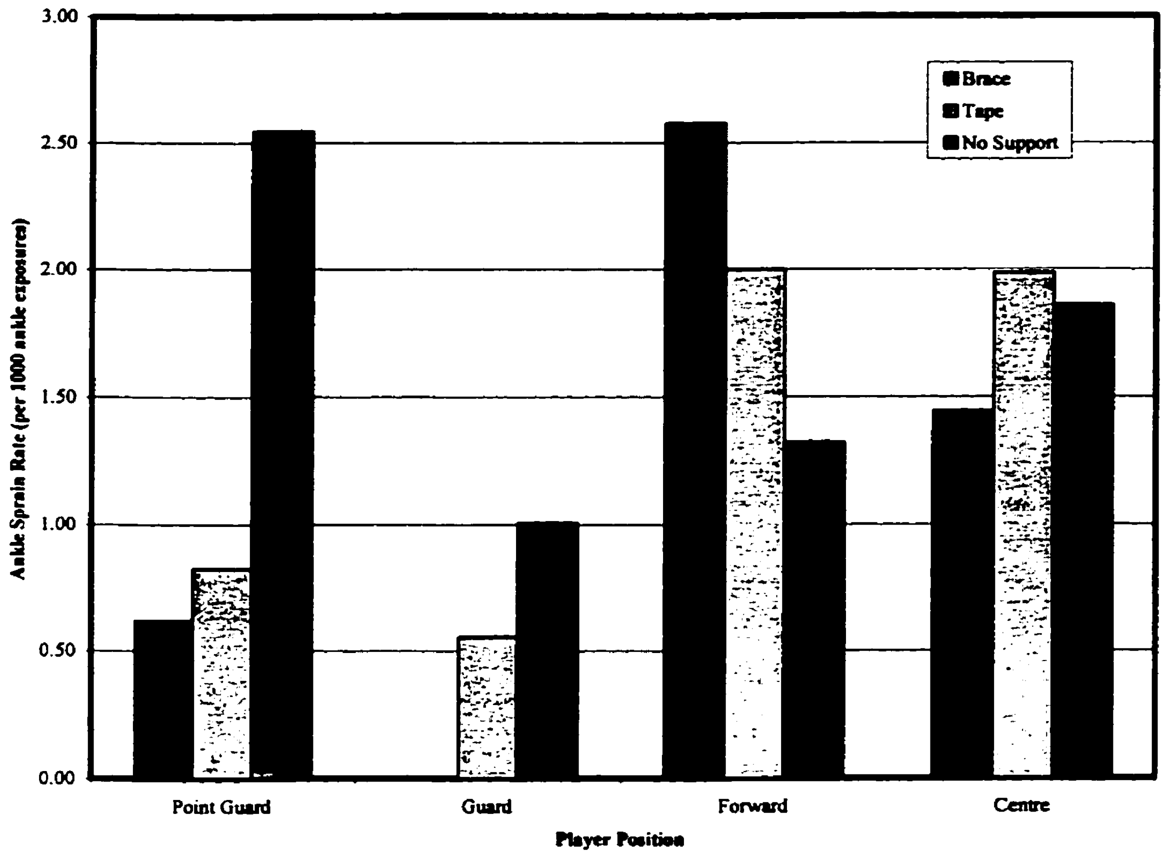

Figure 23. Comparison of Player Position Specific Rates of Ankle Sprain for Braced, Taped and Unsupported Ankles

There was indication that relative risk estimates for both braced and taped ankles relative to no support were different for different player positions. For point guards, the risk of ankle sprain was 4.17 times and 3.13 times lower for braced and taped ankles compared to unsupported ankles, respectively. The taped ankles of guards had a 1.82 times lower risk of injury compared to unsupported ankles at this position. The braced ankles of guards sustained no injuries, therefore, a relative risk estimated could not be calculated for this stratum. For forwards, braced and taped ankles had a 1.95 and 1.51 times greater risk of ankle sprain than unsupported ankles, respectively. For centres, the risk of ankle sprain was about 1.28 times lower for braced ankles, but the risk was the same for taped ankles compared to unsupported ankles. However, as shown in **Table 13**, the 95% confidence intervals for all relative risk estimates overlapped and included the null value.

Table 13. Player Position Specific Relative Risks of Ankle Sprain for Braced and Taped Ankles Compared to Unsupported Ankles

Position	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Point Guard					
Brace	1	1616	0.62	0.24	(0.006, 1.75)
Tape	1	1213	0.82	0.32	(0.007, 2.34)
None	9	3534	2.55		
Guard					
Brace	0	3636	0	-	-
Tape	1	1803	0.55	0.55	(0.01, 3.98)
None	9	8948.5	1.01		
Forward					
Brace	7	2716	2.58	1.95	(0.64, 5.51)
Tape	6	3000	2.00	1.51	(0.46, 4.46)
None	11	8319	1.32		
Centre					
Brace	3	2076.5	1.44	0.78	(0.13, 3.40)
Tape	3	1510	1.99	1.07	(0.18, 4.68)
None	7	3766	1.86		

* per 1000 ankle exposures
** CI, confidence interval

Player position did not confound the overall relative risks of ankle sprain for either braced or taped ankles compared to unsupported ankles. The overall relative risk estimate for both braced and taped ankles compared to unsupported ankles did not differ from its respective, Mantel-Haenszel relative risk estimate. **Table 14** compares the overall relative risks with the Mantel-Haenszel position adjusted relative risks for braced and taped ankles compared to unsupported ankles.

Table 14. **Comparison of Overall and Position Adjusted Mantel Haenszel Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles**

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.75	(0.34, 1.50)
Mantel-Haenzsel	0.75	(0.38, 1.44)
Tape vs. No Support		
Overall	1.00	(0.64, 2.67)
Mantel Haenzsel	0.93	(0.47, 1.84)

*CI, confidence interval

4.4.7. Shoe Type

The rates of ankle sprain for braced, taped and unsupported ankles combined with different shoe types are illustrated in **Figure 24**.

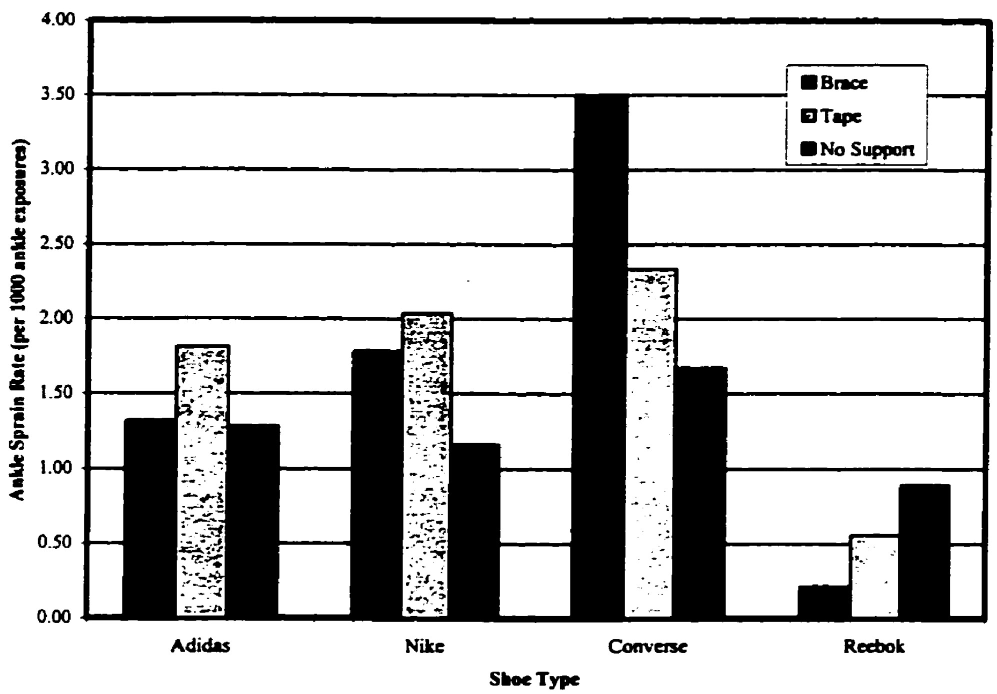

Figure 24. Comparison of Shoe Specific Rates of Ankle Sprain for Braced, Taped and Unsupported Ankles

There was an indication of different shoe specific relative risk estimates for both braced and taped ankles relative to unsupported ankles. When combined with a Reebok shoe, the risk of ankle sprain was 4.17 times lower for braced ankles relative to unsupported ankles. The risk of injury was also lower (1.61 times) for taped ankles compared to unsupported ankles when combined with a Reebok shoe. However, when combined with Nike or Converse shoe, the risk of injury was higher for braced and taped ankles relative to unsupported ankles. For taped ankles, the risk of injury, relative to unsupported ankles, was 1.75 and 1.40 times higher when combined with Nike and Converse shoes respectively. For braced ankles, the increase in ankle injury risk relative to unsupported ankles was 1.54 and 2.09 times higher when combined with Nike and Converse shoes respectively. For Adidas shoes, the risk of ankle sprain was 1.41 times higher for taped ankles compared to unsupported ankles whereas the risk for braced ankles and unsupported ankles was the same.

However, as depicted in **Table 15**, none of the 95% confidence intervals for all relative risk estimates overlapped and included the null value.

Table 15. Shoe Specific Relative Risk of Ankle Sprain for Braced and Taped Ankles Compared to Unsupported Ankles

Shoe Type	Injuries	Exposure	Injury Rate*	Relative Risk	95% CI**
Adidas					
Brace	3	2275	1.32	1.03	(0.18, 4.00)
Tape	4	2208	1.81	1.41	(0.323, 4.90)
No Support	10	7806.5	1.28		
Nike					
Brace	5	2805	1.78	1.54	(0.40, 5.10)
Tape	6	2946.5	2.04	1.75	(0.51, 5.52)
No Support	9	7751.5	1.16		
Converse					
Brace	2	572	3.50	2.09	(0.22, 10.48)
Tape	2	856.5	2.34	1.40	(0.14, 7.00)
No Support	8	4786.5	1.67		
Reebok					
Brace	1	4692	0.21	0.24	(0.005, 1.97)
Tape	1	1798	0.57	0.62	(0.01, 5.15)
No Support	6	6735.5	0.89		

* per 1000 ankle exposures
** CI, confidence interval

In addition, the relative risk of ankle sprain for braced ankles compared to unsupported ankles may have been confounded by shoe type. The overall relative risk estimate and the Mantel-Haenszel gender adjusted relative risk estimate appeared to be different from each other. However, each estimate was contained in the 95% confidence interval of the other and the confidence intervals overlapped. The relative risk of injury for taped ankles compared to the risk for unsupported ankles was not confounded by shoe type. The overall relative risk estimate was similar to the Mantel-Haenszel adjusted relative risk estimate. **Table 16** compares the overall relative risks with the Mantel-Haenszel relative risks for braced and taped ankles relative to unsupported ankles.

Table 16. Comparison of Overall and Shoe Type Adjusted Mantel Haenszel Relative Risks for Braced and Taped Ankles Compared to Unsupported Ankles

	Relative Risk	95% CI*
Brace vs. No Support		
Overall	0.87	(0.40, 1.77)
Mantel-Haenzsel	1.05	(0.54, 2.04)
Tape vs. No Support		
Overall	1.37	(0.66, 2.67)
Mantel Haenzsel	1.39	(0.72, 2.66)

*CI, confidence interval

4.5. Statistical Considerations

The observed number of injuries was lower than the number expected at the planning stages of this study. After reviewing prior CISIR data for men's basketball, and assuming the number of injuries and amount of exposure for women's basketball would be similar to men's basketball, approximately 40% more ankle injuries were expected than reported by this study. This may have affected the ability of this study to detect a significant difference in the risk of ankle sprain between braced, taped and unsupported ankles.

Power calculations were performed using a one-sided, two sample Poisson distribution calculation available on UCLA's Statistical Power Calculation web page[83]. Overall observed injury rates for braced ankles, taped ankles and unsupported ankles plus the number of observed exposures for each group were input into the web-based statistical calculator to determine power. The calculation for braced ankles relative to unsupported ankles yielded a statistical power of 0.11. Estimation of the amount of exposure needed to detect the observed effect size of 0.87 with a power of 0.80 was approximately 45 times greater than the amount of exposure reported in this study. However, after stratification, greater effect sizes were observed for braced ankles relative to unsupported ankles for severe injuries, female athletes and point guards. The observed relative risks of injury, for braced ankles relative to unsupported ankles, were 0.33, 0.68 and 0.24 for severe injuries, female athletes and point guards respectively. To detect these observed effects with a power of 0.80, after stratifying on each of injury severity, gender and player position separately, the exposure reported by this study would need to be increased approximately six, eight and four times respectively.

One purpose of this study was to determine if ankle taping reduced the risk of ankle sprain. However, the observed risk of ankle sprain for taped ankles was actually higher than the observed risk of ankle sprain for unsupported ankles. Therefore, a one-sided power calculation, based on the observed risks and the hypothesis that ankle tape reduces the risk of ankle sprain, would yield a power of zero. For this reason, a power calculation based on the hypothesis that tape increases the risk of ankle sprain was performed. This calculation provided a statistical power of 0.23. Estimation of the amount of exposure needed to detect the observed effect size of 1.37 with a power of 0.80 was approximately seven times greater than the amount of exposure reported in this study.

5. Discussion

5.1. Main Findings

A significant difference was not found between the risk of ankle sprain for either braced or taped ankles and unsupported ankles. The 95% confidence interval for both the relative risk comparing ankle sprains for braced ankles relative to unsupported ankles and for comparing taped ankles relative to unsupported ankles included the null value. In addition, the 95% confidence intervals for each point estimate overlapped considerably. The confidence interval for the point estimate reflects the range of plausible estimates for that estimate. When this range of plausible values includes the null it suggests that a significant difference between the groups would not be found had a statistical test been performed. This suggests that, even though the point estimates of relative risk differed for braced, taped and unsupported ankles, these differences were not significant. However, it is possible that the sample size of this study was not large enough to detect differences in risk of this magnitude.

Sample size is an important part of epidemiological research. Statistical power is the ability of a study to find an effect when an effect actually exists and depends on, among other factors, sample size. When power is low, the probability of rejecting the null hypothesis (of no difference) is also low. In this study, the number of injuries reported was lower than expected. A review of prior CISIR data indicated approximately 40% more reported ankle injuries compared to this study period. This may have affected the ability to detect a significant difference in the risk of ankle sprain between braced, taped and unsupported ankles.

A power calculation for the overall relative risk estimate comparing braced and unsupported ankles revealed a low statistical power of 0.11. In order to detect an effect size of 0.87 with a power of 0.80, 45 times more exposure than that reported by this study would be required. In other words, to detect an effect of this magnitude, it would be necessary to follow the same individuals included in this study for 45 seasons or the number of individuals followed for one season would need be increased 45 times. Research involving this length of time or this number of individuals may not be warranted. The overall risk of injury for braced ankles was only 1.14 times lower than the risk of unsupported ankles. This decrease in risk may not be a clinically significant, given the additional cost of bracing and possible comfort or performance deficits. However, strata specific relative risks comparing braced and unsupported ankles, particularly for severe injuries, female athletes and point guards, were 0.33, 0.68 and 0.24 respectively. These are clinically significant reductions, therefore future research involving additional teams or seasons, may be warranted. A larger sample size may decrease the range of the strata specific confidence intervals, and yield statistically significant results.

For taped ankles compared to unsupported ankles, a power calculation based on the hypothesis that taping increases the risk of injury also revealed a low statistical power of 0.23. In order to detect an effect size of 1.37 with a power of 0.80 the amount of exposures would need to be by approximately seven times greater than that reported by this study. However clinically, no difference in risk and an increased risk have are essentially the same. The cost of ankle tape does not justify its use unless the risk of ankle injury with the application of tape is reduced considerably. Therefore, even if additional research did yield a significant increase in risk for taped ankles relative to unsupported ankles, the new information would yield essentially the same clinical recommendation as finding no significant difference in the risk of ankle sprain for taped and unsupported ankles.

Although there was not a significant difference in the risk of ankle sprain for braced, taped and unsupported ankles, for the sake of discussion it would be interesting to review how the point estimates differed.

The difference in the point estimates for the risk of ankle sprain for braced ankles relative to unsupported ankles suggests there may be a protective effect of ankle bracing regardless of injury history or session type. This suggests that ankle braces may be equally effective in reducing the risk of recurrent as well as initial injuries. However, this protective effect may be limited to severe injuries. The risks of mild and moderate ankle sprain were the same for both braced and unsupported ankles whereas the risk for severe injury was three times less for braced ankles than for unsupported ankles. However, the 95% confidence intervals for all point estimates had considerable overlap and included the null value.

Differences in point estimates comparing the risk of ankle sprain for taped and unsupported ankles suggest an opposite effect of taping compared to bracing. The difference in the risk of sprain for taped and unsupported ankle suggests that taping does not decrease the risk of ankle sprain and may even increase it, regardless of severity, history or session type. However, the 95% confidence intervals for the point estimates contained the null value.

Previous research suggests that ankle braces are effective in reducing the risk of ankle sprain. In one study evaluating the effectiveness of ankle bracing in reducing the risk of ankle injuries for recreational male basketball players, there was evidence to suggest that ankle braces significantly reduced the risk of ankle injury regardless of injury history. Overall, this study reported a three-fold increase in the risk of ankle injury for non-braced players[1].

Other studies have documented a similar decrease in the risk of ankle sprain with the application of the brace, however, this reduction depended on injury history[35, 36]. Surve et al.[35] reported a two and half times decrease in the incidence of ankle sprains with the application of a brace. However, this protective effect was limited to previously injured ankles only. In addition, these researchers reported that ankle bracing was effective in lowering the risk of more severe ankle sprains in previously injured ankles only.

A possible explanation for the difference in findings may be the different sports studied. The study involving basketball players[1], and this investigation, both suggest that ankle braces are effective in reducing the risk of ankle sprain regardless of injury history (although the present study demonstrated that the 95% confidence intervals included the null value). The studies involving soccer athletes suggest ankle braces are effective in reducing recurrent injuries only[35, 36].

Previous research is not in agreement regarding the effect of ankle taping on the risk of ankle sprain. One study involving female soccer athletes suggested that the frequency of recurrent ankle sprains does not differ for taped and unsupported ankles[82] whereas another, involving male basketball athletes reported a significant reduction in the risk of ankle sprain for a taped group compared to an untaped group[80]. There is no known previous research that suggests an increase in the risk of ankle sprain with ankle taping.

Differences in point estimates reported by this study suggest that the effects of ankle bracing and taping on the risk of ankle sprain may differ, independently, for men and women, contact and non-contact injuries, among player positions and for different shoe types. However, the 95% confidence intervals for all point estimates overlapped considerably and contained the null value, suggesting that the differences were not statistically significant. This is the first known study to examine the effectiveness of ankle bracing and taping in reducing the risk of injury for men compared to women. The majority of previous research has included male subjects only[1, 35, 36, 81] and one included female subjects only[82]. The differences in point estimates reported by this study suggest a differential effect of ankle bracing and taping for women compared to men. For women, the risk of ankle sprain may be lower for both braced and taped ankles relative to unsupported ankles. However for men, ankle bracing may have no effect on the risk of injury and taping may increase the risk of ankle sprain almost two-fold. These observed effects, however, may not be true differences as the 95% confidence intervals contained the null value.

The difference in point estimates for contact and non-contact injuries suggest that the effect an ankle brace or ankle tape has on the risk of ankle sprain may also depend on the type of injury sustained. A similar risk of contact injury for braced and unsupported ankles suggest that ankle braces may not be effective in reducing injuries involving contact (i.e. landing on another player's foot). On the other hand, the higher risk of ankle sprain for taped ankles relative to unsupported ankles suggests taped ankles may have almost twice the risk of sustaining an injury if contact is involved. For injuries not involving contact (i.e. resulting from a cutting or twisting movement), taped and braced ankles may have a similar risk of injury. This risk may be slightly lower than the risk of ankle sprain in unsupported ankles. However, all of the 95% confidence intervals for the point estimates contained the null value and overlapped considerably.

Sitler et al.[1] also reported that the reduction in ankle injuries with the application of a brace may depend on the mechanism of injury. However, an opposite relationship was observed. For contact injuries, braced players had significantly fewer injuries than non-braced players did whereas there was no statistical difference in the risk of injury between braced and non-braced groups for non-contact injuries.

In addition, the difference in point estimates for different player positions suggest that the effect of ankle bracing and taping on the risk of ankle sprain may depend on player position. However, the 95% confidence intervals for the point estimates comparing risk of injury by player position all overlapped and include the null value. Point guards may be four times less likely to sustain and ankle injury if wearing an ankle brace and three times less likely to sustain an injury if wearing ankle tape compared to no support. The risk of ankle sprain may also be lower for guards with the application of either an ankle brace or tape, although not as dramatically as for point guards. For centres, ankle bracing may have a protective effect whereas taping may have no effect on the risk of ankle sprain. Forwards, on the other hand may have a higher risk of ankle sprain with the application of either an ankle brace or ankle tape. For forwards, the risk of ankle injury may be almost two times higher for braced and one and half times higher for taped ankles relative to the unsupported ankles.

This is not consistent with the previous research of Sitler et al.[1]. After cross-classifying player position (guard, forward, centre) by support group (brace or none) the researchers reported that the incidence of ankle injury by position was independent of brace assignment. Fewer ankle injuries occurred to braced players than to control players across all player positions.

Differences in the relative risks of injury for different shoe types suggest the effect of ankle bracing or taping on the risk of sustaining an ankle sprain may also depend on the type of shoe it is combined with. However, the confidence intervals for all point estimates, comparing the risk of ankle sprain by shoe type, contained the null value and overlapped considerably. The risk of ankle sprain for braced or taped ankles was either similar to or higher than the risk for unsupported ankles when combined with all shoe types studied with the exception of Reebok. The differences in point estimates suggested that when wearing Reebok shoes braced athletes were four times less likely to sustain an ankle sprain than athletes wearing no support. However, university may have confounded the relationship between ankle bracing and risk of injury within this stratum. Reebok shoes were worn by both male and female athletes at Brandon and the U of S and by female athletes only at the U of A. Athletes from Brandon and the U of S were distributed evenly between the brace and control groups. However, the majority of female athletes at the U of A wore an ankle brace. In addition, the risk of injury for female athletes at the U of A was over four times lower than the risk of injury for athletes at either Brandon University or the University of Saskatchewan. This may have produced an underestimation of the risk of ankle sprain in the brace group. In this case positive confounding may have occurred resulting in an over estimation of the true effect. However, this cannot account for the possible protective effect of taping on risk of ankle sprain when combined with a Reebok shoe. When a Reebok shoe was combined with tape, the risk of sustaining an ankle injury was approximately one and one half times lower than wearing the Reebok shoe alone.

On the other hand, it appears that athletes wearing Converse shoes and braces may have almost twice the risk of injury as those athletes wearing Converse shoes with no external ankle support. The risk of ankle sprain may also be higher for taped ankles than unsupported ankles when combined with Converse shoes. However, for this study, Converse shoes were worn only at the U of W. It is possible that some other underlying factor inherent to the athletes at this university may have been responsible for the higher risk of sprain for braced and taped ankles relative to unsupported ankles.

The risk of injury was also higher for braced or taped ankles relative to unsupported ankles when combined with a Nike shoe. For Adidas shoes, the risk of injury was similar for brace and unsupported ankles but was higher for taped ankles relative to unsupported ankles.

Although interesting differences in point estimates comparing the risk of braced or taped ankles relative to unsupported ankles were observed for men and women, contact and non-contact injuries, player position an shoe type, the 95% confidence interval for all estimates overlapped and included the null value. This suggests that although differences in the point estimates were observed for the different variables, they are not significantly different. Therefore, overall, the difference in the risk of ankle sprain for braced, taped and unsupported ankles was not found to be significant.

5.2. Strengths and Limitations

An intervention study in which athletes were randomly assigned to a brace group, tape group or a control group would have been the ideal design for this type of investigation. However, approximately half the basketball players currently wore external support; thus it was not feasible to conduct a randomized control trial. Although not randomized, subjects were studied prospectively and an attempt was made to control for the effects of confounding. Stratification on a number of potential factors, that have been proposed as risk factors for ankle injury and may be associated with support use, was used to detect the presence of confounding and effect modification.

In addition, the chance of selection bias was limited as the study was conducted prospectively. Prospective studies are less likely to be susceptible to selection bias than other study types. If the injury has not occurred at the time subjects are selected into a study, the chance of selection bias is less likely. However, selection bias can be introduced into a prospective study through dropouts or by individuals who refuse participation in the study. The drop out rate for this study was low. Only 8% of the subjects were removed from the study before the end of the study period. No athletes dropped out due to an injury. In addition, 96% of all potential subjects consented to participate in the study.

Data was collected using a validated reporting system, the Canadian Intercollegiate Sport Injury Registry. There was a high rate of completion for the data collected. Ninety-nine percent of Weekly Exposure Sheets were received. Furthermore, 100% of all Individual Injury Report Forms corresponding to the Injury ID# recorded on the Weekly Exposure Sheets were received. In addition, the nature of the data collection allowed for a certain degree of blinding. Therapists at the universities were aware of the study but collected injury and exposure data for all injuries, as part of the CISIR, not just those relevant to the study.

Although the CISIR is a validated reporting system, this is the first year the Weekly Exposure Sheet designed to record brace, tape and shoe type on a session by session basis was used. In previous years, external support and shoe type information was collected on a weekly basis. However, reporting on a weekly basis may increase the chance for misclassification bias if there is a tendency for athletes to change their support type on a session to session basis. Sixty-two percent of subjects changed their support type at least once during this study period. Recording of exposures on a session to session basis would minimize the chance for misclassification of exposure status. For the majority of the Weekly Exposure Sheets brace, tape and shoe type were recorded on a session to session basis. However, for 11% of the Weekly Exposure Sheets information regarding brace, tape and shoe usage was recorded on a weekly basis.

5.3. Conclusions

No significant differences were found in the risk of ankle sprain for braced, taped and unsupported ankles. However, this study had low power to detect small differences. The data did suggest some interesting trends that may warrant further research. Future research should include a greater number of individuals or should be conducted over a longer period of time.

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APPENDIX A

THERAPIST LETTER OF AGREEMENT

Canadian Intercollegiate Sport Injury Registry

Therapist Letter of Agreement

I ______________________ , the team therapist for the University of ______________________,
(first name) (initial) (last name)

agree to participate in, and contribute to the Canadian Intercollegiate Sport Injury Registry (CISIR). I understand that:

At the start of the season, I will:
a) explain the purpose of the study to all of the players
b) ask all players (during a team meeting/briefing) if they would object to having their medical/injury information sent to the registry in Calgary.

At the end of every second week throughout the season, I will:
a) send the Weekly Exposure Sheets to the central registry (UofC Sport Medicine Centre).

As injuries occur, I will:
a) complete the Individual Injury Report Form as soon as possible after the injury
b) send them to the central office on a biweekly basis with the Exposure Forms.

Signature ______________________ Date __________

I, Willem H. Meeuwisse, Director of the Canadian Intercollegiate Sport Injury/Illness Registry, agree to:

a) provide you, the team therapist, with a year-end injury report.
b) give you, the team therapist, access to the raw (anonymous) data, or collaborate with you in future research projects.
c) provide you, the team therapist, with an honorarium for data collection.

Signature W. Meeuwisse Date Oct 24/97

APPENDIX B

INJURY HISTORY QUESTIONNAIRE

Canadian
Intercollegiate
Sport
Injury
Registry

INJURY HISTORY QUESTIONNAIRE

1998/99 Basketball

To be completed by the athlete.

Last Name ______________________ First Name ______________________

Address ______________________ City ______________ Province __________

Date of Birth ______________ Home Phone # (____) ______________ Postal Code __________
Day Month Year

Health Care # ______________________ Province ______________

FOR EMERGENCY NOTIFY: Name ______________________ Relationship __________

Address ______________________ Phone ______________

Family Doctor's Name ______________________ Date of Last Physical ______________
Month Year

Sport ______________________

Year of Varsity Sport (circle): 1st 2nd 3rd 4th 5th 6th

Year of Eligibilty (circle): None ("Red Shirt") 1st 2nd 3rd 4th 5th

What position will you be playing this year? __________

Check any of the areas that you have **INJURED IN THE PAST** and explain the injury below:

Hand ___	Elbow ___	Head ___	Hip ___	Shin/Calf ___
Wrist ___	Arm ___	Neck ___	Thigh ___	Ankle ___
Forearm ___	Shoulder ___	Chest ___	Knee ___	Foot ___
		Back ___		

Year of injury	Type of Injury	Side (right, left, both)	Is it still a problem? (Yes/No)

Do you have any incompletely healed injury? .... Yes ☐ No ☐

If yes, which injury? ______________________

I hereby certify the above information to be correct.

Athlete Signature ______________________ Date __________

Injury History Summary

(To be completed by a P.T./Therapist).

Please summarize below the relevant injury information for the CISIR database and for your own records.

Athlete's Name: ______________________________

Problem Description	Side	Treatment	Date Active	Status (eg. Active, Inactive, Recurrent, Ongoing, etc.)	Date Inactive (if appropriate)

Date:______________________ P.T. / Therapist:______________________________

APPENDIX C

CWUAA REASSESSMENT FORM

C.W.U.A.A. Annual Health Reassessment

PLEASE NOTE: Athletes using this form MUST have at least one complete pre-season physical examination on file from previous seasons

Last Name: ______________________ First Name: ______________________

SPORT ______________ UNIVERSITY ______________ DATE ______________

DATE OF LAST PHYSICAL ______________________ DATE OF BIRTH ______________

ADDRESS ____

PHONE NUMBER ____

FAMILY DOCTOR ____

Provincial Health Care No. ______________ Province __________ Student No. ______________

Year of participation in this Varsity Sport (circle): 1st 2nd 3rd 4th 5th 6th

Year of Eligibility (circle): None ('Red Shirt') 1st 2nd 3rd 4th 5th 6th

What position will you be playing this year? ______________________________

In the past year, have you experienced.....? (please explain "YES" answers below)

any injury requiring you to miss more than one practice or game	YES	NO
any injury requiring physiotherapy or other treatment	YES	NO
any concussion or head injury	YES	NO
any burner/stinger or neck injury	YES	NO
any surgery or operation for any reason	YES	NO
any hospital admission for any reason	YES	NO
any illness or medical condition lasting longer than one week	YES	NO
any heat exhaustion or heat stroke	YES	NO
are you now on, or have you been advised to be on, any medication on a regular basis	YES	NO
any new allergies to medication, insects, etc.	YES	NO
chest pain or severe shortness of breath on exertion	YES	NO
coughing or wheezing on exertion	YES	NO
fainting or dizzy spells on exertion	YES	NO
irregular heartbeat	YES	NO
bone or joint pains not related to injury	YES	NO
frequent or severe headaches	YES	NO
abdominal pains	YES	NO
skin problems	YES	NO
unexplained weight change	YES	NO
(women only) any abnormality of menstrual cycles	YES	NO
Do you currently have any incompletely healed injury?	YES	NO
Do you have anything you wish to discuss with the team physician?	YES	NO
Have you started using any special equipment? (pads, braces, orthotics, etc.)	YES	NO

Explain "YES" answers: ____

Any YES answer may require further evaluation by the team physician.

I hereby certify the above information to be correct

Athlete's Signature: ____

APPENDIX D

WEEKLY EXPOSURE SHEET

Canadian Intercollegiate Sport Injury Registry
Basketball-1998

Weekly Exposure Sheet

University: __________

Date ([illegible])								
Session (Game/Practice)								
Duration (0.0 hours)								
Session Description (ie scrimmage, jumping, etc.)								
Court Surface (wood, etc.)								
Recorder's Initials								
Athlete		IID	IID	IID	IID	IID	IID	IID
	Participation:							
	Shoes:							
	*B/S/O/T:							
	Participation:							
	Shoes:							
	*B/S/O/T:							
	Participation:							
	Shoes:							
	*B/S/O/T:							
	Participation:							
	Shoes:							
	*B/S/O/T:							
	Participation:							
	Shoes:							
	*B/S/O/T:							
	Participation:							
	Shoes:							
	*B/S/O/T:							

Please enter a participation code for each player indicating:
⇓

F	Full (75%)
P	Partial (<75%)
O	or None (0)

If athlete is not fully participating (i.e. coded "P" or "O") please indicate if they are:
⇓

I	Injured
S	Sick, or
A	Absent for any other reason

⇓

IID	Injury ID#
2	specifies injury report form id number to attribute time loss

*B/S/O/T - braces/splints/orthotics/tape for the ankle

APPENDIX E

INDIVIDUAL INJURY REPORT FORM

Injury ID#

Individual Injury Report Form

Basketball-1998/99

№ 0492

Canadian Intercollegiate Sport Injury Registry

Date of Injury: ____________

Date Reported: ____________

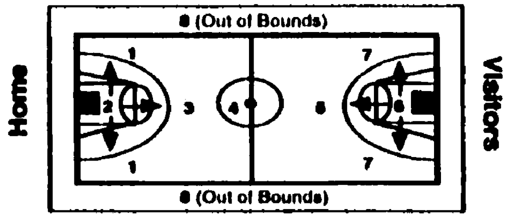
1) Athlete Name: ____________

2) Position played when injured:

1-point guard 4-power forward
2-off-guard 5-centre (post)
3-small forward other: ________

3) Normal Position: ❑ Same as #2
Other: ____________

4) Mark Injury Zone #: ❑ N/A



5) Contact with other obstacles:
❑ Yes ❑ No ❑ N/A (list): ____________

6 Injury Status:
❑ New Injury
❑ Recurrence of injury from this season
❑ Recurrence of injury from previous season (this sport)
❑ Recurrence of non/other sport injury
❑ Ongoing Injury

7) Bracing or Taping used on Injured area at time of injury?:
❑ No
❑ Yes: If so what type?: ____________

8) Dental: Mouthguard?: ❑ Yes ❑ No ❑ N/A
If so what type?: ____________

9) Injury Conditions: ❑ Known ❑ Unknown

a) Game: ❑ Home ❑ Away

i) Exhibition	ii) Regular Season	iii) Playoffs
❑ Warm-up	❑ Warm-up	❑ Warm-up
❑ Half #: __	❑ Half #: __	❑ Half #: __
❑ Overtime#: __	❑ Overtime#: __	❑ Overtime#: __

b) Practice:
i) Skill Training: ❑
ii) Conditioning: ❑
iii) Scrimmage: ❑ beg. ❑ middle ❑ end

c) ❑ Weight Training
d) ❑ Non-sport
e) ❑ Other Conditioning
f) ❑ Gradual Onset
g) ❑ Other Sport

10) Did athlete return to play the same session?:
❑ Yes ❑ No ❑ N/A

11) Illegal play?: ❑ Yes ❑ No ❑ N/A
Penalty called?: ❑ Yes ❑ No

12) Shoe Type if applicable (please specify brand and model):
____
(eg. Adidas FYW T2000)

Describe Events Surrounding Injury (including exact mechanism of injury): ❑ Known ❑ Unknown ____________

Remarks: ____________
(subjective report of cause; e.g. unsafe action, illegal play, hazardous conditions, equipment, etc.)

Other Assessment Notes: ____________

Assessment: ____________

Side (Right/Left/Both) **Body Region (and structure)** **Type of Injury ("Diagnosis")** **(e.g. Right shoulder A/C joint 3° sprain)**

Treatment Plan (Check all that apply):

❑ Protect	❑ Stretch	❑ Transfer to hospital	❑ Observe
❑ Rest	❑ Strengthen	❑ Tape/Brace/Crutches (circle)	❑ Refer to Physician
❑ Ice	❑ Manual therapy	❑ Modalities	❑ Refer to Dentist
❑ Compression	❑ Heat	(specify):	
❑ Elevation	❑ Modify activity	____________	

Other Treatment Notes: ____________

Estimate of time Loss from Injury (days): ______ **Therapist's Name (print):** ____________ **Therapist's Signature:** ____________

Physician's Name

White-Therapist Copy Yellow-C.I.S.I.R. Copy Pink-Physician Copy