# ANKLE INSTABILITY IN MALE COLLEGIATE ICE HOCKEY PLAYERS

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# ABSTRACT

There is a paucity of research concerning ankle injuries and ankle injury risk factors in ice hockey players. The purpose of this research was to measure ankle strength and stretch reflex response and to determine the prevalence of ankle instability (AI) in a group of male collegiate ice hockey players. A total of 23 male subjects recruited from a collegiate ice hockey team were screened for AI using the Cumberland Ankle Instability Tool (CAIT). Athletes were included if they were free from lower extremity injury for three months and had not undergone surgery within the past 12 months. Based on CAIT scores (< 27.5/30 = unstable), included ankles were sorted into two groups, unstable (UA, n=18), and stable (SA=23). With EMG electrodes placed bilaterally on the Tibialis Anterior (TA), Peroneus Longus (PL), and Peroneus Brevis (PB), all subjects were positioned on an ankle perturbation platform. Ten measurements on each leg were taken; stretch reflex response and intensity were measured. Subjects also performed strength testing on an isokinetic dynamometer for ankle inversion (INV) and eversion (EV). Both eccentric (ECC) and concentric (CON) muscle actions were assessed at velocities of 30°/s and 120°/s. Eighteen of 41 (43.9%) included ankles were determined unstable. Ankle strength ratios, stretch reflex intensity, and reaction time do not appear to be significantly different between the UA and SA in these athletes. Given the high prevalence of AI in this population, additional research is needed to examine its cause.

# Chapter 1

# INTRODUCTION

## Ankle Injury Epidemiology

Lateral ankle ligament sprains are the most common injuries in recreational and athletic activity[1-5] with an estimated 23,000 occurrences per day in the United States alone.[6] Many athletes continue to experience residual symptoms from the initial injury including joint laxity, proprioceptive deficits, and peroneal muscle weakness.[6-9] Anandacoomarasamy[10] reported that 74% of patients continued to experience symptoms such as pain, swelling, weakness, and a feeling of "giving way" 1.5-4 years after the initial injury. Individuals experiencing these symptoms have a condition referred to as functional ankle instability, first described as a phenomenon characterized by a feeling of the ankle "giving way" within the individual's normal range-of-motion, but beyond volitional control.[11]

Furthermore, those suffering an injury to the lateral ankle ligaments are significantly more likely to suffer a future injury than those without a history.[2,7,12,13] Repetitive injury can become a significant financial burden as each sprain may cost the individual between $318-941 in medical expenses.[14] Recurrent injury has additional health implications as repeated sprains may lead to an augmented risk of developing osteoarthritis in the ankle.[5,6] This may be of increased importance to athletes participating in sports that require running, jumping, and sudden changes of direction. Specifically, soccer and basketball consistently have the highest rate of ankle sprain.[2,15] Soccer has an ankle injury rate of 1.7-2.0 per 1000 hours of participation, with these injuries comprising 17-21% of all injuries incurred during participation. Basketball has an ankle injury rate of 3.85 per 1000 participations.[12]

## Ankle Injuries in Ice Hockey

Comparatively, ice hockey is a contact sport characterized by spontaneous, dynamic movement including rapid acceleration, deceleration, and changes of direction. All of these movements are conducted on a thin, hollowed skate blade. The majority of skating maneuvers involve a skater on the lateral and medial edges, spending a significant amount of time in single-leg support, especially during acceleration.[16] In such cases, lower limb forces can exceed 1.5-2.5 times the player's body weight.[17-19] Successful utilization of the ice skate necessitates eversion and inversion of the foot. Fast speeds, rapid changes of direction, single-leg weight support, and lateral ankle movements may put ice hockey players at an increased risk for non-traumatic ankle injuries.

Ankle and lower leg injuries in ice hockey players seem to be overlooked as an area of concern. Despite this lack of attention, research suggests that these injuries continue to occur at all levels of hockey. Non-traumatic injuries constitute 14.6-20% of all injuries in elite hockey players.[19-23] Injuries to the lower leg and foot constitute 4.2-12% of all injuries suffered in elite European and American hockey players[21-24] and 5% in American high school hockey players.[25] Specifically, ligament damage to the lower leg and ankle constituted 14% of all injuries in elite Finnish hockey players.[26] Furthermore, the lateral ankle ligaments were the second most sprained ligaments in Junior A hockey players (elite players no older than 20 years of age),[19] and 10.5% of all sprains in elite Finnish ice hockey players.[27] These studies demonstrate the existence of ankle injuries in hockey players of all ages, levels, and countries.

Recovery time from an ankle injury varies, depending on the nature and severity of the injury. Ferrara and Schurr[28] reported leg and foot injuries to result in the highest associated average time missed (i.e., time-loss) of all body injuries in collegiate hockey players, causing players to miss an average of 14 days. Similarly, Flik et al.[21] reported that ankle sprains resulted in players missing six practices and two games in collegiate hockey players, the equivalent of about two weeks. Ankle injuries have been found to be responsible for the fifth most player games missed in collegiate hockey players, following the knee, shoulder, groin, and hip.[29] While extensive research has been conducted on these areas in hockey players and other contact sport athletes, there is a paucity of data on the ankle for the skating population.

## Neuromuscular Considerations of Ankle Instability

Potential causes of ankle instability have mechanical and functional implications; however, for the purposes of this paper only the functional aspects will be considered. Functional instability refers to changes in the neuromuscular system resulting in impaired proprioception, sensation, neuromuscular firing patterns, postural control, and strength.[6] Subsequent discussion focuses specifically on muscle strength, peroneal reaction time, and peroneal reaction intensity.

Research amongst various populations has been conducted to elucidate which factors are related to or predictive of ankle instability or injury. Strength of the lower leg musculature has been tested using an isokinetic dynamometer. Concentric (CON) and eccentric (ECC) muscle actions have been measured for inversion (INV) and eversion (EV) movements at a variety of speeds and used to calculate eversion to inversion (E:I) torque ratios.[1,8,30-33] Traditional ankle strength ratios are denoted as: $EV_{CON}/INV_{ECC}$ ($CON_{EVERTORS}/ECC_{INVERTORS}$) and $EV_{CON}/INV_{CON}$ ($CON_{EVERTORS}/CON_{INVERTORS}$).

More recently researchers have begun to use *functional* strength ratios denoted as $EV_{ECC}/INV_{CON}$ ($ECC_{EVERTORS}/CON_{INVERTORS}$). Agonist/antagonist action does not allow the two muscle groups to contract concentrically across the same joint. As the agonist contracts concentrically, the antagonist can contract eccentrically to slow the rate of limb movement manifested through the agonistic contraction. Functional strength ratios have been shown to better describe the way muscles interact to stabilize the knee[34] and shoulder joints.[35] Kaminski and Hartsell[9] introduced functional strength ratios for the ankle, stating that this ratio best describes the way the ankle evertors work to slow the rate of inversion. As the ankle begins to invert, the peroneal muscles are stimulated and contract eccentrically, producing force while lengthening. This force counteracts the inversion stimulus, slowing the rate of inversion and potentially stopping inversion before injury occurs. In a prospective study, Willems et al.[15] reported significantly lower $EV_{CON}$ and $EV_{ECC}$ strength at 30°/sec and $EV_{ECC}$ strength at 120°/s in female athletes who later sustained an ankle injury, compared to uninjured female athletes. Conversely, Baumhauer et al.[30] measured $INV_{CON}$, $EV_{CON}$, $PF_{CON}$ ($CON_{PLANTAR\ FLEXORS}$), and $DF_{CON}$ ($CON_{DORSIFLEXORS}$) torque at 30°/s in male and female collegiate athletes participating in lacrosse, soccer, and field hockey. These authors reported no significant differences in any of the strength measurements between those who later sustained an ankle injury, and those who did not. However, the injured group did have a significantly higher average E:I ratio (1.0) than the uninjured group (0.8). A later study conducted on a similar population measured inversion and eversion strength, concentrically and eccentrically at 30°/s.[1] No significant differences were found between injured and uninjured men for any of the strength measures or strength ratios.

A lack of differences in strength measurements has also been found when comparing ankles of those with unilateral functional ankle instability (FAI).[32,8,9] Kaminski et al.[33] found no significant differences in E:I strength ratios at 30°/s or 120°/s between the involved and uninvolved ankle in those with unilateral FAI. It appears that strength of the ankle invertors and evertors is not consistently related to ankle instability or risk of injury, especially in males.

Another factor potentially related to ankle instability or injury is the reaction time (i.e., short latency response; M1) of the lower leg musculature when exposed to an inversion stimulus by a perturbation device. Beynnon et al.[1] measured muscle reaction times for the medial gastrocnemius and tibialis anterior (TA) for a dorsiflexion perturbation and the TA, peroneus longus (PL), and peroneus brevis (PB) for an inversion perturbation. Both perturbations produced 4° of rotation at a velocity of 50°/s. None of these variables were statistically related to ankle injury in men or women. In order to more closely replicate the foot positioning most commonly associated with inversion ankle sprains, several researchers have utilized a slightly different protocol with the subject's feet starting in 40° plantar flexion and 15° of adduction, and ending in 50° of inversion.[15,36,37] Vaes et al.[36] found no significant differences between healthy and unstable ankles for total inversion time, time of second deceleration point, or PL latency. However, the unstable ankles did have a significantly shorter average reaction time for the first deceleration point, which the authors described as the mechanism responsible for protecting the ankle most immediately after the onset of inversion. Willems et al.[15,37] found no significant relationship between muscle reaction times and risk of ankle sprain in females,[37] but reported that men with decreased reaction time in the TA and gastrocnemius were more likely to sprain their ankle.[15]

In a classic study, Konradsen and Bohsen Ravn[38,39] reported a significantly shorter peroneal reaction time in stable ankles compared to functionally unstable ankles. However, only the single shortest reaction time of three trials was used for analysis. It is possible that one trial may not be representative of the individual's true response to sudden ankle inversion. Also, functional instability was determined subjectively, represented by the subject complaining of frequent sprains or feeling of the ankle giving way. A more objective measure of ankle instability would help distinguish between those with functional instability and those with symptoms arising from mechanical instability. Similarly, Karlsson and Andreasson[40] found that stable ankles had a significantly shorter peroneal reaction time than unstable ankles with and without tape, but did not specify how ankles were determined functionally unstable, stating only that all functionally unstable ankles also had mechanical instability. Differences in methodology make it difficult to compare these studies, but it appears that when the mechanism of lateral ankle sprain is most closely replicated by a perturbation device, there may be some relationship between delayed muscle reaction and risk of ankle injury.

## Assessing Ankle Instability

Although a number of questionnaires have been developed to assess functional ankle instability, the authors chose to utilize the Cumberland Ankle Instability Tool

(CAIT). The CAIT was the first questionnaire to provide a measure of ankle instability that included a grade of severity and independence from the contralateral limb.[41] The CAIT was shown to be a valid and reliable (ICC = 0.96) determinant of functional ankle instability.[41]

## Purpose

Although several studies have assessed strength and reaction times of the lower leg musculature in various populations, little to no research has been conducted on ice hockey players. Furthermore, most of these studies do not report reaction intensities relative to maximal voluntary isometric contractions (MVICs). A better understanding of these variables in male ice hockey players will help identify differences in ankle injury risk factors within the athletic population, and between athletes and non-athletes. The purpose of this research was to compare a population of ice hockey players with stable and unstable ankles on inversion and eversion strength, muscular reaction time, and muscular reaction intensity. The secondary purpose was to report the prevalence of ankle instability in male collegiate ice hockey players. For the purposes of this study, functional ankle instability is defined as a CAIT score below the threshold value of 27.5. It was hypothesized that unstable ankles would have higher E:I strength ratios, increased reaction times, and decreased reaction intensities compared to stable ankles.

# Chapter 2

# MATERIALS AND METHODS

## Subjects

A total of 23 (age: 20.6 ± 1.0 yrs, height: 178.0 ± 5.6 cm, mass: 85.5 ± 8.1 kg) were recruited from the University of Delaware (UD) men's ice hockey team. Subjects were included if they were between the ages of 18 and 24 and played on the UD men's ice hockey team. All subjects filled out a demographic/injury history questionnaire (Appendix A) and the Cumberland Ankle Instability Tool (Appendix B). The injury history section of the first questionnaire was used to identify any exclusion criteria. Any athlete who sustained a lower extremity injury within the previous three months or had undergone lower extremity surgery within the previous 12 months was excluded from participation. Of the 23 subjects, 41 ankles (21 left, 20 right) satisfied the inclusion and exclusion criteria and were utilized for analysis. All subjects gave their written informed consent (Appendix C) approved by the Human Subjects Review Board (HS 07-077: Appendix D) before participation in the study.

## Instrumentation

Bipolar surface electrodes (Ag-AgCl, 6 mm contact diameter, 2 cm spacing) were used to record EMG activity in the tibialis anterior (TA), peroneus longus (PL), and peroneus brevis (PB). Subsequently, a Bortec AMT-8® EMG system (Bortec Biomedical Ltd., Calgary, Alberta, Canada) was used to amplify (input impedance 10 MΩ, gain 5000x, common mode rejection ratio > 115 dB) the raw EMG data. A laptop computer with a 12-bit analog-to-digital converter (6024-E, National Instruments Corp., Austin, TX) was used to collect the EMG signals, at a sampling rate of 1000 Hz. The computer utilized custom designed Labview software (version 7.1, National Instruments Corp., Austin, TX) to synchronize and save the data for future analysis.

The Kinetic Communicator (Kin Com) 125-AP isokinetic dynamometer (Chattecx Corp., Chattanooga, TN) was utilized for dynamic strength measurements and to stabilize the foot for maximal voluntary isometric contraction measurements. The Kin Com, using the isokinetic overlay function, measured concentric and eccentric resistive forces generated by the subject at 30°/s and 120°/s for inversion and eversion motions.

A pneumatic pressure ankle inversion platform constructed and used by Beckman and Buchanan[42] (Figure 2.1) was utilized to induce the sudden inversion perturbation. The footplates, which invert independently, were driven by pneumatic actuators. Potentiometers were positioned at the axes of rotation to measure the range-of-motion. Each footplate was inverted at a velocity of 400-700°/s for a range-of-motion of 25-30°. The researcher stimulated unilateral perturbation using a custom trigger, which supplied a TTL (Transistor-Transistor Logic) pulse of 100ms duration.

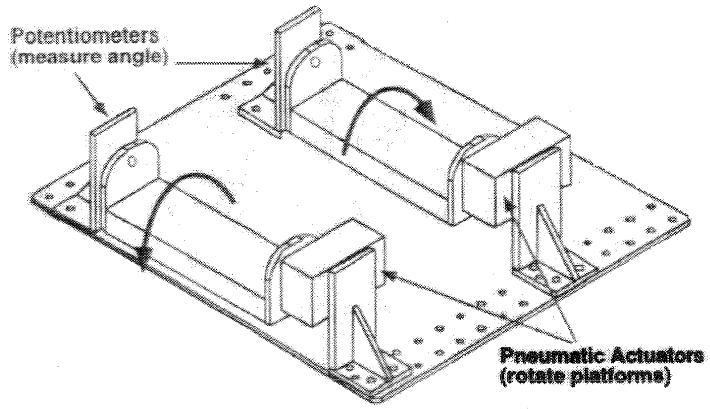


**Figure 2.1 Inversion perturbation device as pictured in Beckman and Buchanan.[42]**

## Procedure

Each subject reported to the Athletic Training Research Laboratory for a single testing session lasting approximately 90 minutes. All subjects filled out the subject demographic/injury history questionnaire, completed the CAIT, and read and signed the informed consent prior to participation. Subsequently, the primary investigator measured height and mass. Then participants did a five-minute warm-up on a stationary bicycle. Following the warm-up, leg dominance was determined. Each subject was asked to kick a ball, take one step on a staircase and hop on one leg. The leg used in two of the three tests was deemed the dominant leg.

The subject was then fitted with EMG electrodes bilaterally on the muscle belly of the TA, PL, and PB. Electrode placements were determined using finger and handbreaths utilized by Perotto.[43] Prior to electrode placement, the subject's skin was shaved, abraded, and wiped with an alcohol pad in the area of the muscle belly. The electrodes were affixed to the leg parallel to the underlying muscle fibers. The EMG leads connected to an EMG pack, secured around the subject's waist, which linked directly to the EMG system.

The subject was then positioned on the Kin Com isokinetic dynamometer according to manufacturer specifications for ankle inversion/eversion. With the knee in 45° flexion and the hip flexed to approximately 75°, the subject's foot was securely fastened to the footplate (Figure 2.2). The subject wore shoes. Mechanical stops were placed in a position that locked the footplate in a neutral position. The subject was instructed to invert or evert the foot as hard as possible for five seconds. Three trials for inversion and eversion of each leg were performed with approximately 30 seconds rest between each trial. Leg and movement were randomized.

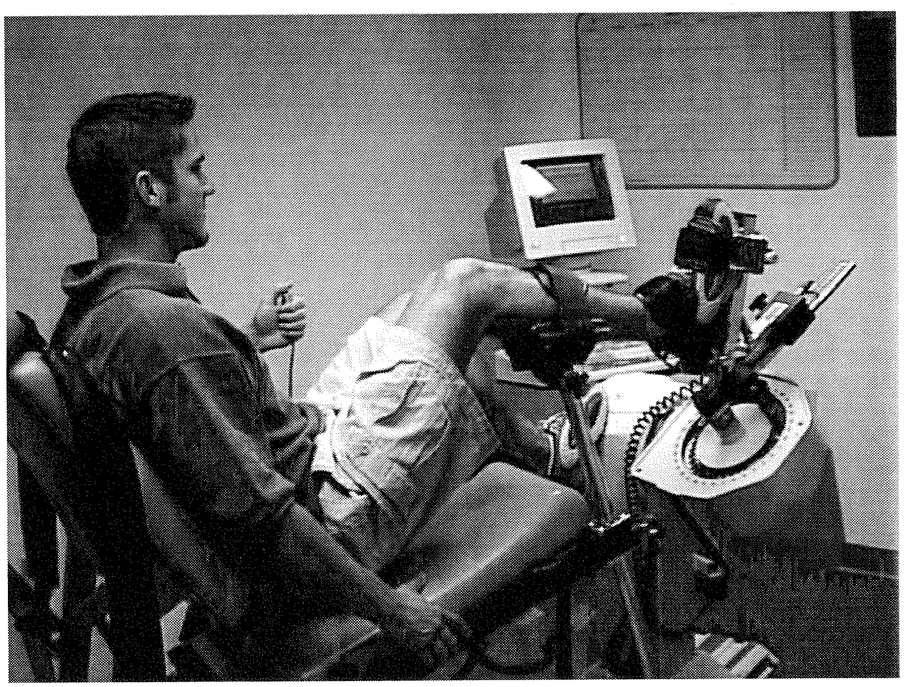

**Figure 2.2 Subject positioning during MVIC and torque testing on the Kin Com.**

The subject then stood barefoot on the ankle perturbation device, with the feet placed comfortably on the outer edges of the platform. The subject was instructed to stand normally, facing a wall and wearing ear plugs to minimize visual and auditory stimuli, serving to decrease distractions and anticipatory effects (Figure 2.3). Each subject was allotted a familiarization period consisting of one repetition per leg. Ten trials were taken on each leg, with approximately 30 seconds between each trial. The order of trials was randomized and inversion was stimulated unbeknownst to the subject.

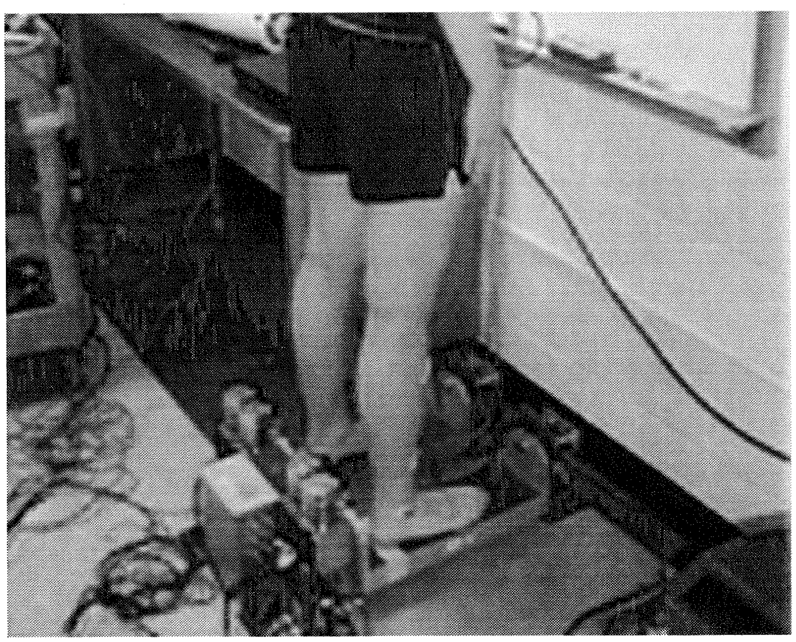

**Figure 2.3 Subject positioning during inversion perturbation.**

The subject then returned to the Kin Com isokinetic dynamometer and was positioned as previously described. The mechanical stops were positioned in accordance with manufacturer specifications; manual stops were set to allow the subject's ankle to move through approximately 25° inversion and 20° eversion for a total of 45° motion. A warm-up consisting of three sub-maximal repetitions was allotted to familiarize the subject with the CON-ECC inversion and eversion movements at the different speeds. The subject performed three maximal repetitions of CON-ECC inversion and eversion at 30°/s and 120°/s, with a five-second rest between each trial. The trials were averaged for each parameter (i.e. concentric inversion at 120°/s) and peak torque values were obtained. A coin was flipped to determine which leg (right or left), movement (inversion or eversion), and speed (30°/s or 120°/s) would be utilized first. Only the movement was changed for the subsequent set of trials.

## Data Analysis

Ten standard deviations above the baseline potentiometer reading was the threshold value for the onset of footplate movement. Ten standard deviations above baseline EMG activity was the threshold value for the onset of muscle activity. All EMG data were band-pass filtered ($2^{nd}$ order, zero-lag, Butterworth filter, with cutoff frequencies of 10Hz and 500 Hz) and visually inspected to verify that the onset of EMG and movement were accurately calculated by the software (Figure 2.4). Reaction time was calculated as the difference between movement and EMG onset. Torque ratios were calculated at 30°/s and 120°/s as $EV_{ECC}/INV_{CON}$ and $EV_{CON}/INV_{ECC}$. Outliers for all variables, as defined by three standard deviations above or below the mean, were identified and removed.

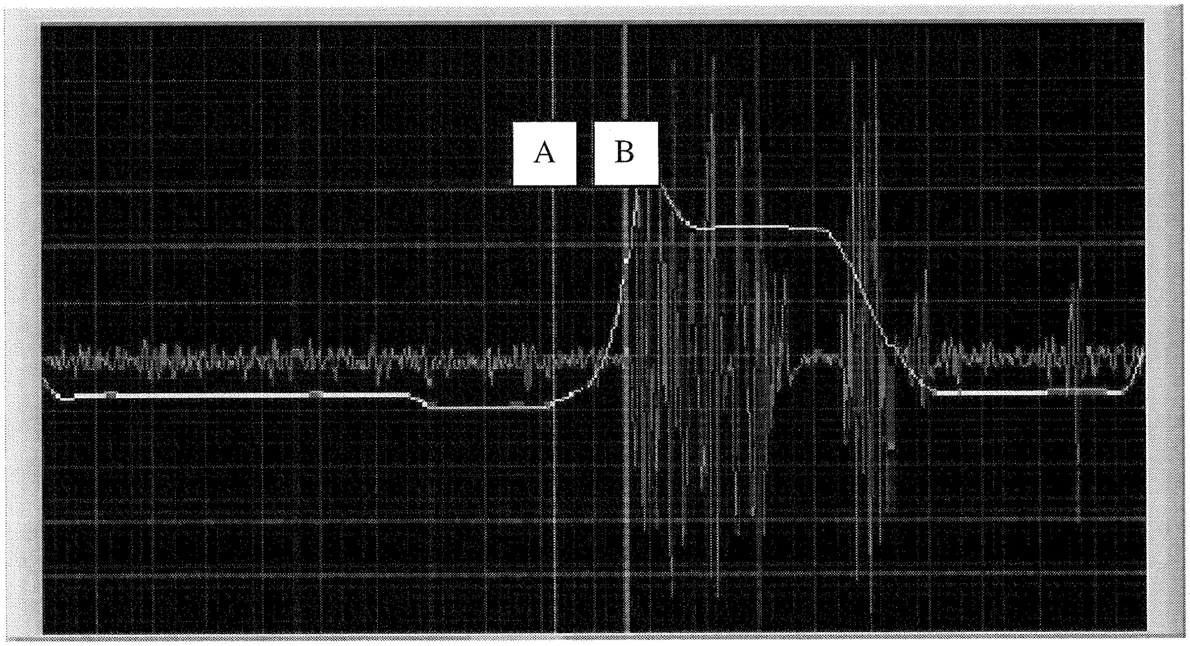


**Figure 2.4 Visual analysis of reaction time of one muscle on one trial. The red line is the EMG signal and the white line is the footplate position dictated by the potentiometer. The yellow lines "A" and "B" represent the onset of inversion perturbation and the onset of EMG activity, respectively.**

## Statistical Analysis

The independent variable in this study was ankle status (stable or unstable). The dependent variables were: (1) average peak torque; (2) torque ratios; (3) muscular reaction time; (4) muscular reaction intensity; (5) leg dominance; (6) height; (7) mass; (8) years participating; and (9) position played. To identify any differences between stable and unstable ankles, an analysis of variance (ANOVA) was performed. In order to identify existing differences between dominant (Dom) and non-dominant (Non-dom) ankles, a 2x2 ANOVA was conducted with ankle dominance (Dom or Non-dom) and ankle status (stable or unstable) as the independent variables. All the aforementioned dependent variables were included in the secondary analysis.

## Chapter 3

## RESULTS

*Primary Analysis*

Of the 23 male collegiate ice hockey players tested, there were 15 forwards (65.2%), six defenseman (26.1%), and two goalies (8.7%). Nine of 21 left ankles and nine of 20 right ankles were determined unstable by a CAIT score under 27.5. All 23 subjects were right leg dominant. The ANOVA did not reveal any statistically significant differences for any of the measured variables. The mean torque outputs for all measurements are presented in Table 3.1. Mean torque ratios, reaction times and reaction intensities are presented in Figures 3.1-3.3. Please refer to Appendix E for all mean values.

| Torque (Nm) | Stable (n=23) | Unstable (n=18) |
|---|---|---|
| | Mean ± STD | Mean ± STD |
| **30°/s Inversion** | | |
| *Concentric* | 26.30 ± 5.25 | 25.89 ± 5.32 |
| *Eccentric* | 32.65 ± 7.09 | 31.44 ± 6.55 |
| **30°/s Eversion** | | |
| *Concentric* | 28.17 ± 6.84 | 30.11 ± 5.59 |
| *Eccentric* | 34.83 ± 8.64 | 37.94 ± 10.46 |
| **120°/s Inversion** | | |
| *Concentric* | 28.65 ± 7.58 | 28.17 ± 5.18 |
| *Eccentric* | 34.39 ± 8.41 | 34.61 ± 6.79 |
| **120°/s Eversion** | | |
| *Concentric* | 28.17 ± 7.83 | 30.06 ± 5.76 |
| *Eccentric* | 36.96 ± 9.28 | 38.50 ± 6.40 |

**Table 3.1 Peak torque values in stable and unstable ankles for all strength measurements.**

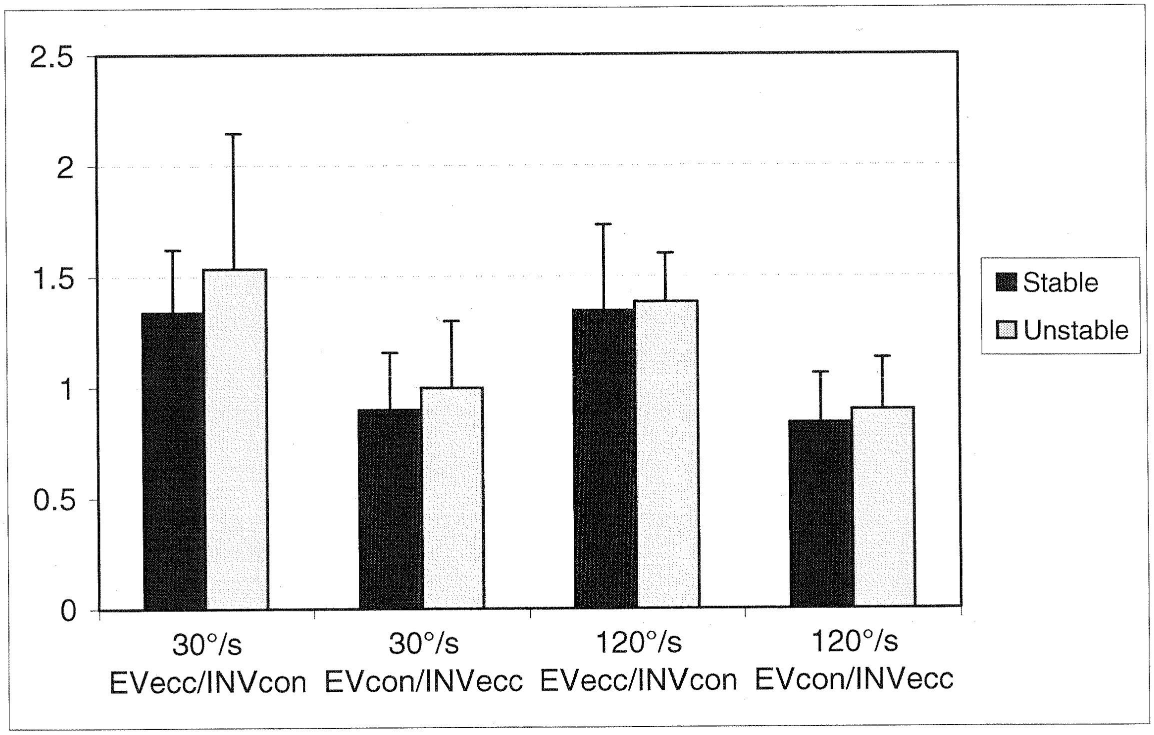


**Figure 3.1 Peak torque ratios in stable and unstable ankles at 30°/s and 120°/s.**

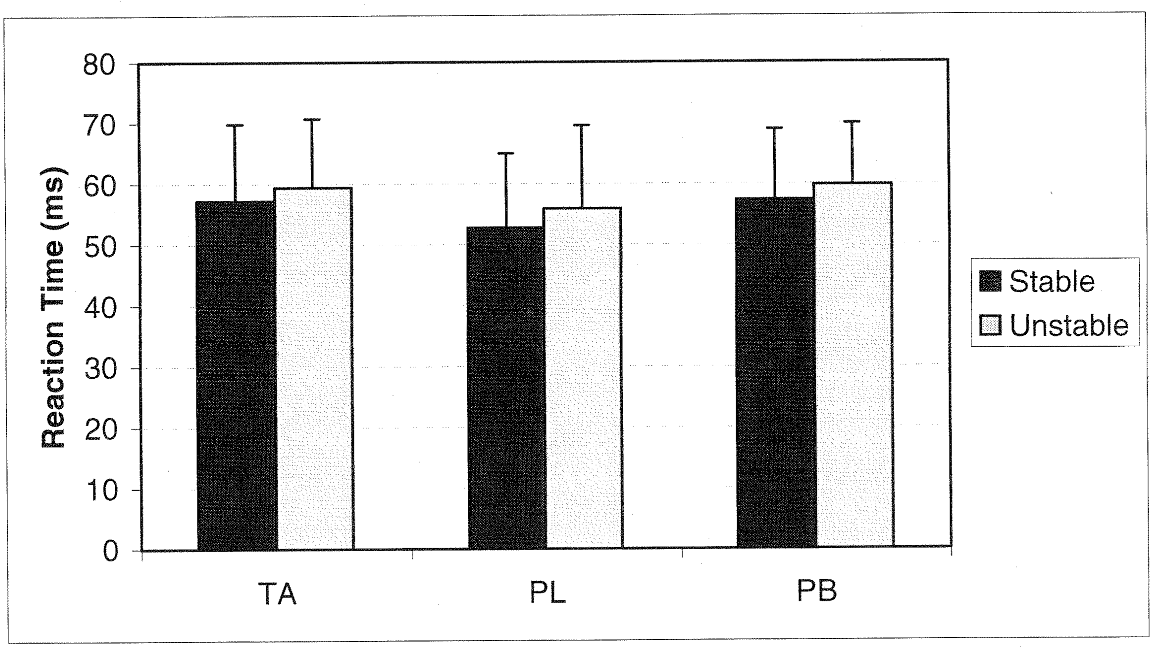


**Figure 3.2 Mean muscle reaction times in stable and unstable ankles for the TA, PL, and PB.**

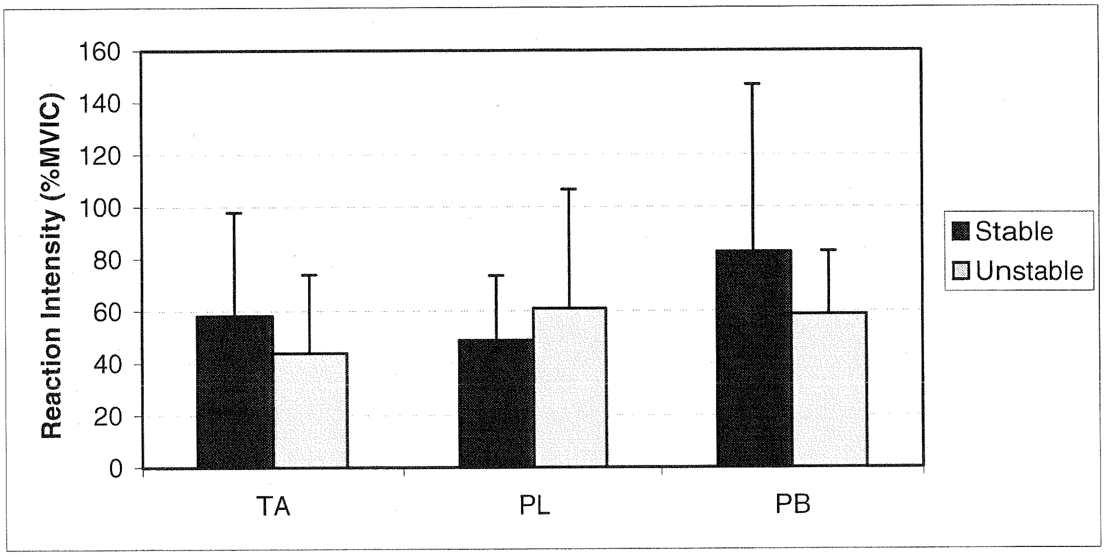


**Figure 3.3 Mean muscle reaction intensities in stable and unstable ankles for the TA, PL, and PB.**

*Secondary Analysis*

The 2x2 ANOVA did not reveal any statistically significant differences for any of the measured variables. However, there was a trend towards significance for $EV_{CON}$ of the dominant ankle at 30°/s ($F(1, 18)=3.458$, $p=0.079$) and for $EV_{CON}$ at 120°/s ($F(1, 18)=3.519$, $p=0.077$) and $EV_{ECC}$ at 120°/s ($F(1, 18)=3.439$, $p=0.080$; Figure 3.4).

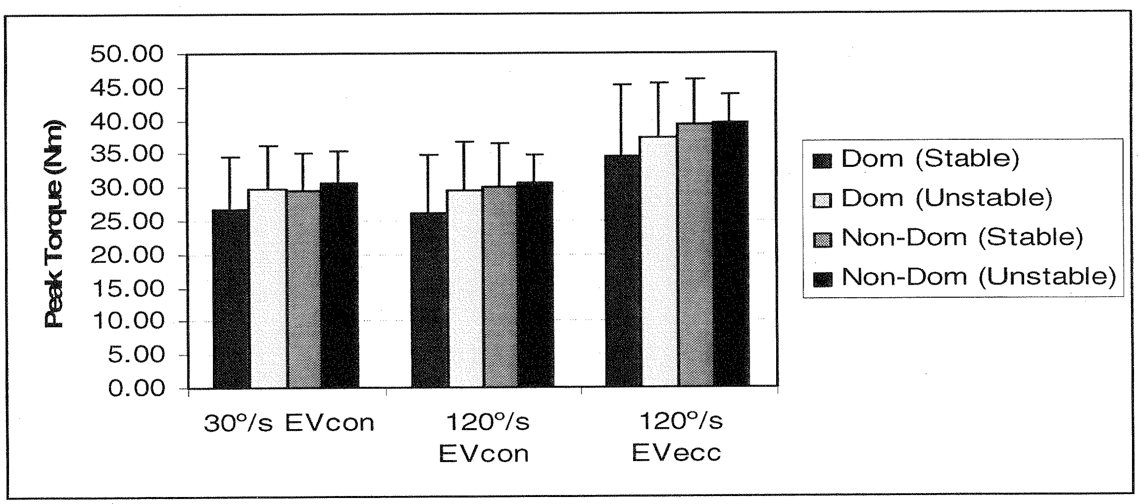


**Figure 3.4 Peak torque values in dominant and non-dominant, stable and unstable ankles for EVCON at 30°/s, EVCON at 120°/s, and EVECC at 120°/s $EV_{CON}$ at 120°/s, and $EV_{ECC}$ at 120°/s.**

Although not statistically significant, slight differences in reaction times and intensities were present between dominant and non-dominant ankles. For the non-dominant ankles, the unstable ankles had slower mean reaction times in comparison to stable ankles. This was not the case for the dominant ankles. Muscle reaction intensities were lower for all the muscles in the unstable ankles, compared to the stable ankles, except for the non-dominant PL.

## Chapter 4

## DISCUSSION

The present study investigated whether unstable ankles differed from stable ankles using three main parameters: (1) Peak torque; (2) Muscular reaction time; and (3) Muscular reaction intensity in a group of male collegiate ice hockey players. It was hypothesized that E:I torque ratios would be higher in unstable ankles. Although the differences were not statistically significant, unstable ankles did have slightly higher E:I ratios. Kaminski and Hartsell[9] reported ranges of 0.34 to 2.38 Nm/kg and 0.62 to 3.77 Nm/kg for the traditional ($EV_{CON}/INV_{ECC}$) and functional ($EV_{ECC}/INV_{CON}$) peak torque strength ratios, respectively. All calculated torque ratios were within these ranges and ranges reported elsewhere.[33]

Research is inconclusive on the existence of a delayed muscle reaction in the presence of sudden ankle inversion.[15,36,37] Median times (msec) have been reported for stable and unstable ankles in the TA (SA: 65.8, UA: 68.3),[44] PL (SA: 65, UA: 66-82),[38,39,44] and PB (SA: 69, UA: 84).[38,39] These reaction times are similar to the mean times reported by Karlsson and Andreasson.[40] The mean reaction times reported in our study are lower for all three muscles, in both stable and unstable ankles.

The results from this study show a slight increase (slower) in muscle reaction time in unstable ankles, although not statistically significant. Regardless, one may question whether or not a difference in muscle reaction time of less than ten milliseconds is clinically significant. In other words, a delayed muscular contraction of six milliseconds, as opposed to a 20 millisecond delay, would not increase the risk of ankle inversion injury. There is a paucity of reported research on muscle reaction intensities. In our subjects, unstable ankles had decreased muscular reaction intensities in the TA and PB, but not the PL. However, it is difficult to compare muscular intensities among subjects since EMG intensity readings are variable depending on the placement of the electrodes relative to the muscle belly, which varies within and among subjects. In an effort to minimize such electrode placement errors, the authors utilized an identical muscle belly location strategy, as described previously by Perotto.[43]

An interesting finding is the difference between dominant and non-dominant ankles. Baumhauer et al.[30] reported a higher incidence of ankle injury in left leg dominant individuals, while Beynnon et al.[1] found no differences. Because our sample consisted of all right leg-dominant individuals, our results cannot support or refute a higher incidence of instability in left leg dominant individuals. However, it may be worth noting that the reaction times were slower for the TA, PL, and PB in the non-dominant unstable ankles, but only slower in the PB for the unstable dominant ankles. This may suggest a difference in neuromuscular coordination for the dominant leg, although the literature reveals a lack of supporting empirical evidence. With more muscles reacting slower to an inversion stimulus, non-dominant ankles may be at a greater risk for injury.

Our sample had a surprisingly high prevalence of instability, with 18 of the 41 (43.9%) included ankles deemed unstable. It may be worth noting that only three of the participants had unilateral instability, while nine had bilateral instability. Most studies measuring differences in muscular strength and reaction time use subjects with unilateral instability, comparing stable ankles to unstable ankles within subjects.

Because of individual differences in the aforementioned variables, comparing athletes with bilateral instability to those with no instability may not be appropriate. For instance, it is possible that an individual has quick muscular reaction time, but two unstable ankles. Comparing this person to someone with quick muscular reaction time with no ankle instability would not be a fair comparison. Utilizing subjects with unilateral instability may be a more valid measure because it provides a measure of whether an individual's stable ankle is stronger or reacts quicker to an inversion stimulus than his/her unstable ankle.

Regardless, the high prevalence found in this study is striking due to the nature of the ice hockey skate boot, which provides rigid support above the level of the malleoli. This design seemingly minimizes inversion and eversion, while still allowing some plantar flexion and dorsiflexion. However, a number of other factors may affect the support provided by the boot. Some skate boots are constructed stiffer than others. A less rigid skate boot would allow a greater degree of inversion and eversion range-of-motion. Similarly, the integrity of the skate boot decreases with age and use. Even the type of laces used may affect the stability provided by the boot as waxed laces maintain their position throughout the duration of practice and competition better than un-waxed laces. Consequently, as the player skates, the laces loosen slightly, resulting in a greater degree of available ankle range-of-motion. Furthermore, some players tie the laces tight at the bottom of the boot and leave the top very loose allowing them to turn tighter while maintaining an upright posture. While tight turning is not the cause of ankle injury, the looser skate may allow a more extreme range-of-motion at the ankle, contributing to injury. In addition to the mechanical stability provided by the boot, it is possible that the skate boot also stimulates local proprioceptors, which has been shown to occur with ankle wraps.[45] Both enhanced mechanical and proprioceptive feedback from the skate boot may help contribute to the low incidence of on-ice ankle injury.

Another issue to consider is that of syndesmotic ankle injuries, which are characterized by damage to the syndesmotic ligament connecting the tibia and fibula. These injuries, also known as "high ankle sprains", typically result from internal rotation of the leg with a planted foot, resulting in the foot and ankle externally rotating. The skate boot stabilizes the ankle joint to some degree, but does not prevent twisting of the lower leg. The extremely thin base of support provided by the skate blade may result in more twisting of the lower leg.[46] This twisting, coupled with a stabilized foot, could put ice hockey players at an increased risk for syndesmotic ankle injuries. In professional ice hockey players, these injuries have resulted in an average of 55 days of recovery, compared to an average of 28 days for lateral ankle sprains.[47] Pain or discomfort from these injuries may have also contributed to our high prevalence of ankle instability as well, as the CAIT is a self-assessment questionnaire. The athletes in this study may have experienced generalized pain during activity from syndesmotic injuries, or other injuries (i.e., musculotendinous, connective tissue, etc.) not involving damage to the lateral ligaments of the ankle. Consequently, the athletes may have mistaken their symptoms for those of ankle instability, producing faulty CAIT results. Supplementing this self-assessment questionnaire with a clinical evaluation may provide a better measure of ankle instability.

Because ice time is expensive and limited, most elite ice hockey programs conduct a significant portion of their training off the ice. Rule changes in the game have lead to a greater reliance on speed, quickness, and agility, as opposed to overall size and strength. It is reasonable to believe that hockey programs will respond with an increase in the appropriate training on land, including an increase in jumping and cutting movements. Many of these exercises (e.g., lateral bounding) take the ankle joint through its full range of motion and involve single-leg loading. While single-leg forces are also encountered on the ice, the nature of the skating stride does not produce the single-leg loading associated with off-ice jump landing. Placing a high amount of landing force on an ankle that is inverted or everted may predispose these athletes to on-ice injuries.

Furthermore, a higher incidence of ankle injury has been noted in sports such as basketball[12,48] and soccer[3,4] possibly due to the jumping, cutting, and rapid changes of direction involved in these sports.[2] Considering research supporting a low prevalence of on-ice ankle injuries, the high prevalence of ankle instability found in this study may be explained through off-ice circumstances. A number of training techniques, including balance and flexibility training, have successfully decreased an individual's risk of ankle injury.[49,50] Consequently, it may be necessary for these athletes to take specific precautions to decrease their risk of ankle injury.

With a slight increase in muscular reaction time in unstable ankles, it is possible that results were not significant due to a lack of subjects. Future studies on male collegiate ice hockey players should include a higher number of subjects, subjects with unilateral ankle instability compared to control subjects without ankle instability, and a clinical evaluation of ankle instability. Future research should also monitor on- and off-ice activity, and ankle injury during the season to help elucidate if ankle instability is related to or predictive of on-ice ankle injury.

## Chapter 5

## CONCLUSION

Surprisingly, this group of male collegiate ice hockey players demonstrated a high prevalence of AI. Previous studies have described mixed influences of muscle strength imbalances and delayed muscle reaction time on ankle injury and instability. We did not find significant differences in strength ratios, muscle reaction time, or muscle reaction intensity between stable and unstable ankles. It is possible that the athletes developed ankle instability through participation in sports other than ice hockey, or through agility-based off-ice conditioning activities involving high speeds and quick changes of direction. Further research is needed to determine the underlying factors associated with ankle instability in this population.

## REFERENCES


1. Beynnon, B.D., Renstrom, P.A., Alosa, D.M., Baumhauer, J.F., & Vacek, P.M. (2001). Ankle Ligament Injury Risk Factors: A Propective Study of College Athletes. *Journal of Orthopaedic Research*, 19, 213-220.

2. Beynnon, B.D., Vacek, P.M., Murphy, D., Alosa, D., & Paller, D. (2005). First-Time Inversion Ankle Ligament Trauma. *The American Journal of Sports Medicine*, 33(10), 1485-1491.

3. Ekstrand, J., & Tropp, H. (1990). The Incidence of Ankle Sprains in Soccer. *Foot & Ankle*, 11(1), 41-44.

4. Giza, E., Fuller, C., Junge, A., & Dvorak, J. (2003). Mechanisms of Foot and Ankle Injuries in Soccer. *The American Journal of Sports Medicine*, 31(4), 550-554.

5. Liu, S.H., & Jason, W.J. (1994). Lateral Ankle Sprains and Instability Problems. *Foot and Ankle Injuries*, 13(4), 793-809.

6. Hertel, J. (2002). Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability. *Journal of Athletic Training*, 37(4), 364-375.

7. Denegar, C.R., Hertel, J., & Fonseca, J. (2002). The Effect of Lateral Ankle Sprain on Dorsiflexion Range of Motion, Posterior Talar Glide, and Joint Laxity. *Journal of Orthopaedic & Sports Physical Therapy*, 32, 166-173.

8. Kaminski, T.W., Perrin, D.H., & Gansneder, B.M. (1999). Eversion Strength Analysis of Uninjured and Functionally Unstable Ankles. *Journal of Athletic Training*, 34(3), 239-245.

9. Kaminski, T.W., & Hartsell, H.D. (2002). Factors Contributing to Chronic Ankle Instability: A Strength Perspective. *Journal of Athletic Training*, 37(4), 394-405.

10. Anandacoomarasamy, A., & Barnsley, L. (2005). Long Term Outcomes of Inversion Ankle Injuries. *British Journal of Sports Medicine*, 39(3), 14-17.

11. Freeman, M.A., Dean. M.R., Hanham, I.W. (1965). The Etiology and Prevention of Functional Instability of the Foot. *The Journal of Bone and Joint Surgery. British Volume*, 47, 678-685.

12. McKay, G.D., Goldie, P.A., Payne, W.R., & Oakes, B.W. (2001). Ankle Injuries in Basketball: Injury Rate and Risk Factors. *British Journal of Sports Medicine*, 35, 103-108.

13. Tropp, H., Askling, C., & Gillquist, J. (1985). Prevention of Ankle Sprains. *The American Journal of Sports Medicine*, 13(4), 259-262.

14. Soboroff, S.H., Pappius, E.M., & Komaroff, A.L. (1984). Benefits, Risks, and Costs, of Alternative Approaches to the Evaluation and Treatment of Severe Ankle Sprains. *Clinical Orthopaedics and Related Research*, 183, 160-168.

15. Willems, T.M., Witvrouw, E., Delbaere, K., Mahieu, N., De Bourdeaudhuij, I., & De Clercq, D., (2005a). Intrinsic Risk Factors for Inversion Ankle Sprains in Male Subjects. *The American Journal of Sports Medicine*, 33(3), 415-423.

16. Humble, R.N., & Gastwirth, B.W. (1988). The Biomechanics of Forward Power Skating. *Clinics in Podiatric Medicine and Surgery*, 5(2), 363-376.

17. Sim, F.H., & Chao, E.Y. (1978). Injury Potential in Modern Ice Hockey. *The American Journal of Sports Medicine*, 6(6), 378-384.

18. Sim, F.H., Simonet, W.T., Melton, L.J., & Lehn, T.A. (1987). Ice Hockey Injuries. *The American Journal of Sports Medicine*, 15(1), 30-40.

19. Stuart, M.J., & Smith, A. (1995). Injuries in Junior A Ice Hockey: A Three-Year Prospective Study. *The American Journal of Sports Medicine*, 23(4), 458-461.

20. Daly, P.J., Sim, F.H., & Simonet, W.T. (1990). Ice Hockey Injuries: A Review. *Sports Medicine*, 10(3), 122-131.

21. Flik, K., Lyman, S., & Marx, R.G. (2005). American Collegiate Men's Ice Hockey: An Analysis of Injuries. *The American Journal of Sports Medicine*, 33(2), 183-187.

22. Lorentzon, R., Wedren, H., & Pietila, T. (1988). Incidence, Nature, and Causes of Ice Hockey Injuries: A Three-Year Prospective Study of a Swedish Elite Ice Hockey Team. *The American Journal of Sports Medicine,* 16(4), 392-396.

23. Tegner, Y., & Lorentzon, R. (1991). Ice Hockey Injuries: Incidence, Nature and Causes. *British Journal of Sports Medicine*, 25(2), 87-89.

24. Jorgensen, U., & Schmidt-Olsen, S. (1986). The Epidemiology of Ice Hockey Injuries. *British Journal of Sports Medicine*, 20(1), 7-9.

25. Gerberich, S.G., Finke, R., Madden, M., Priest, J.D., Aamoth, G., & Murray, K. (1987). An Epidemiological Study of High School Ice Hockey Injuries. *Child's Nervous System*, 3, 59-64.

26. Molsa, J., Kujala, U., Nasman, O., Lehtipuu, T., & Airaksinen, O. (2000). Injury Profile in Ice Hockey from the 1970s through the 1990s in Finland. *The American Journal of Sports Medicine*, 28(3), 322-327.

27. Molsa, J., Airaksinen, O., Nasman, O., & Torstila, I. (1997). Ice Hockey Injuries in Finland: A Prospective Epidemiologic Study. *The American Journal of Sports Medicine*, 25(4), 495-499.

28. Ferrara, M.S., & Schurr, K.T. (1999). Intercollegiate Ice Hockey Injuries: A Causal Analysis. *Clinical Journal of Sports Medicine*, 9, 30-33.

29. Biasca, N., Simmen, H., Bartolozzi, A.R., & Trentz, O. (1995). Review of Typical Ice Hockey Injuries: Survey of the North American NHL and Hockey Canada versus European leagues. *Unfallchirurg*, 98, 283-288.

30. Baumhauer, J.F., Alosa, D.M., Renstrom, P.A., Trevino, S., & Beynnon, B. (1995a). A Prospective Study of Ankle Injury Risk Factors. *The American Journal of Sports Medicine*, 23(5), 564-570.

31. Baumhauer, J.F., Alosa, D.M., Renstrom, P.A., Trevino, S., & Beynnon, B. (1995b). Test-Retest Reliability of Ankle Injury Risk Factors. *The American Journal of Sports Medicine*, 23(5), 571-574.

32. Kaminski, T.W., Perrin, D.H., Arnold, B.L., Gansneder, B.M., Dieck, J.H., & Saliba, E.N. (1996). Concentric and Eccentric Force-Velocity Relationships between Uninjured and Functionally Unstable Ankles [Abstract]. *Journal of Athletic Training*, 31, S54.

33. Kaminski, T.W., Buckley, B.D., Power, M.E., Hubbard, T.J., Hatzel, B.M., & Ortiz, C. (2001). Eversion and Inversion Strength Ratios in Subjects with Unilateral Functional Ankle Instability. *Medicine and Science in Sports and Exercise*, 33(5), S135.

34. Aagaard, P., Simonsen, E., Magnusson, S. Larsson, B., & Dyhre-Poulsen, P. (1998). A New Concept for Isokinetic Hamstring: Quadriceps Muscle Strength Ratio. *The American Journal of Sports Medicine*, 26(2), 231-237.

35. Noffal, G. (2003). Isokinetic Eccentric-to-Concentric Strength Ratios of the Shoulder Rotator Muscles in Throwers and Nonthrowers. *The American Journal of Sports Medicine*, 31(4), 537-541.

36. Vaes, P. Duquet, W., & Van Gheluwe, B. (2002). Peroneal Reaction Times and Eversion Motor Response in Healthy and Unstable Ankles. *Journal of Athletic Training*, 37(4), 475-480.

37. Willems, T.M., Witvrouw, E., Delbaere, K., Philippaerts, R., De Bourdeaudhuij, I., & De Clereq, D. (2005b). Intrinsic Risk Factors for Inversion Ankle Sprains in Females: A Prospective Study. *Scandinavian Journal of Medicine and Science in Sports*, 15, 336-345.

38. Konradsen, L., & Bohsen Ravn, J. (1990). Ankle Instability Caused by Prolonged Peroneal Reaction Time. *Acta Orthopaedica Scandinavica*, 61(5), 388-390.

39. Konradsen, L., & Bohsen Ravn, J. (1991). Prolonged Peroneal Reaction Time in Ankle Instability. *International Journal of Sports Medicine*, 12(3), 290-292.

40. Karlsson, J., & Andreasson, G. (1992). The Effect of External Ankle Support in Chronic Lateral Ankle Joint Instability: An Electromyographic Study. *The American Journal of Sports Medicine*, 20(3), 257-261.

41. Hiller, C.E., Refshauge, K.M., Bundy, A.C., Herbert, R.D., & Kilbreath, S.L. (2006). The Cumberland Ankle Instability Tool: A Report of Validity and Reliability Testing. *Archives of Physical Medicine and Rehabilitation*, 87, 1235-1241.

42. Beckman S.M., & Buchannan T.S. (1995). Ankle Inversion Injury and Hypermobility: Effect on Hip and Ankle Muscle Electromyography Onset Latency. *Archives of Physical Medicine and Rehabilitation*, 76, 1138-1143.

43. Perotto A. *Anatomical guide for the electromyographer: the limbs and trunk.* (3rd Ed.) Charles C. Thomas, Springfield, IL; 1994.

44. Lofvenberg, R., Karrholm, J., Sundelin, G., & Ahlgren, O. (1995). Prolonged Reaction Time in Patients with Chronic Lateral Instability of the Ankle. *The American Journal of Sports Medicine*, 23(4), 414-417.

45. Mattacola, C.G., & Dwyer, M.K. (2002). Rehabilitation of the Ankle after Acute Sprain or Chronic Instability. *Journal of Athletic Training*, 37(4), 413-429.

46. Walsh, W.M., & Blackburn, T. (1977). Prevention of Ankle Sprains. *The American Journal of Sports Medicine*, 5(6), 243-245.

47. Wright, R.W., Barile, R.J., Surprenant, D.A., & Matava, M.J. (2004). Ankle Syndesmosis Sprains in National Hockey League Players. *The American Journal of Sports Medicine*, 32(8), 1941-1945.

48. Shambaugh, J.P., Klein, A., & Herbert, J.H. (1991). Structural Measures as Predictors of Injury in Basketball Players. *Medicine and Science in Sports and Exercise*, 23(5), 522-527.

49. Chaiwanichsiri, D., Lorprayoon, E., & Noomanoch, L. (2005). Star Excursion Balance Training: Effects on Ankle Functional Stability after Ankle Sprain. *Journal of the Medical Association of Thailand*, 88, S90-S93.

50. McCluskey, G.M., Blackburn, T.A., & Lewis, T. (1976). Prevention of Ankle Sprains. *The American Journal of Sports Medicine*, 4(4), 151-157.

## APPENDIX A

## DEMOGRAPHIC/INJURY HISTORY QUESTIONNAIRE

**Ankle Instability in Male Collegiate Ice Hockey Players**
**Subject Demographic Questionnaire**

Name________________________________ Date_____________________

Date of Birth____________________

Height (cm)____________________ Mass (kg)________________

Years Participating____________________

Primary Position Played ________________

______________________________________________________________
______________________________________________________________

Have you experienced any of the following:

A lower extremity injury other than an ankle sprain in the last 3 months (Yes / No)

If Yes, Explain ______________________________________________

A lower extremity surgery in the last 12 months (Yes / No)

If Yes, Explain ______________________________________________

An ankle sprain (Yes / No)

If Yes:

Was it diagnosed by a doctor?________________________________

If yes, what was the formal diagnosis and severity?______________________

______________________________________________________________

When did it happen?______________________________________

How did it happen?_______________________________________

How much training time did you miss?___________________________

# APPENDIX B

# CUMBERLAND ANKLE INSTABILITY TOOL

## Cumberland Ankle Instability Tool (CAIT)

Please tick the ONE statement in EACH question that BEST describes your ankles.

| | | LEFT | RIGHT |
|---|---|---|---|
| 10. I have pain in my ankle | Never | ☐ | ☐ |
| | During sport | ☐ | ☐ |
| | Running on uneven surfaces | ☐ | ☐ |
| | Running on level surfaces | ☐ | ☐ |
| | Walking on uneven surfaces | ☐ | ☐ |
| | Walking on level surfaces | ☐ | ☐ |
| 11. My ankle feels UNSTABLE | | | |
| | Never | ☐ | ☐ |
| | Sometimes during sport (not every time) | ☐ | ☐ |
| | Frequently during sport (every time) | ☐ | ☐ |
| | Sometimes during daily activity | ☐ | ☐ |
| | Frequently during daily activity | ☐ | ☐ |
| 12. When I make SHARP turns my ankle feels UNSTABLE | | | |
| | Never | ☐ | ☐ |
| | Sometimes when running | ☐ | ☐ |
| | Often when running | ☐ | ☐ |
| | When walking | ☐ | ☐ |
| 13. When going down the stairs my ankle feels UNSTABLE | | | |
| | Never | ☐ | ☐ |
| | If I go fast | ☐ | ☐ |
| | Occasionally | ☐ | ☐ |
| | Always | ☐ | ☐ |
| 14. My ankle feels UNSTABLE when standing on ONE leg | | | |
| | Never | ☐ | ☐ |
| | On the ball of my foot | ☐ | ☐ |
| | With my foot flat | ☐ | ☐ |
| 15. My ankle feels UNSTABLE when | | | |
| | Never | ☐ | ☐ |
| | I hop from side to side | ☐ | ☐ |
| | I hop on the spot | ☐ | ☐ |
| | When I jump | ☐ | ☐ |
| 16. My ankle feels UNSTABLE when | | | |
| | Never | ☐ | ☐ |
| | I run on uneven surfaces | ☐ | ☐ |
| | I jog on uneven surfaces | ☐ | ☐ |
| | I walk on uneven surfaces | ☐ | ☐ |
| | I walk on a flat surface | ☐ | ☐ |
| 17. TYPICALLY when I start to roll over (or 'twist') on my ankle I can stop it | | | |
| | Immediately | ☐ | ☐ |
| | Often | ☐ | ☐ |
| | Sometimes | ☐ | ☐ |
| | Never | ☐ | ☐ |
| | I have never rolled over on my ankle | ☐ | ☐ |
| 18. Following a TYPICAL incident of my ankle rolling over, my ankle returns to 'normal' | | | |
| | Almost immediately | ☐ | ☐ |
| | Less than one day | ☐ | ☐ |
| | 1-2 days | ☐ | ☐ |
| | More than 2 days | ☐ | ☐ |
| | I have never rolled over on my ankle | ☐ | ☐ |

# APPENDIX C

# INFORMED CONSENT



approved 10/30/01

**University of Delaware Human Subjects Review Board**
**Informed Consent Form**

**Project Title:** "Predicting ankle instability in male collegiate ice hockey players"

**Principal Investigators:** Kevin L. Neeld
Al T. Douex, Jr.
Dr. Thomas W. Kaminski
*Athletic Training Research Laboratory, University of Delaware*

**Please read this consent form carefully before you decide to participate in this study.**

**Purpose of the Research Study:**
Twenty-four collegiate ice hockey players, between the ages of 18 and 24, will be recruited from the University of Delaware Men's Ice Hockey team to participate in this study. The purpose of this study is to determine the influences of strength and muscle reaction time on ankle instability (AI) athletes demonstrating a history of AI and those that have no apparent history.

**What You Will Do in the Study:**
Prior to the study, you have filled out a demographic/eligibility questionnaire and have been deemed eligible for participation. Upon reporting to the Athletic Training Research Laboratory, you will be asked to participate as described below:

*Group Selection:* You will be asked to fill out the Cumberland Ankle Instability Tool (CAIT) to determine which group you will be assigned to. Based on the established scoring system, you will be placed in either the AI group or the NO AI group.

*Leg Dominance Testing:* You will be asked to perform 3 simple tests (kicking a ball, climbing a stair, and hopping on one leg) to determine which of your legs is your skill (i.e., kicking) leg and which of them is your stance leg.

*Warm-up:* You will be asked to perform a five-minute warm-up on a stationary bike, followed by a four minute stretching period for your hip, thigh and leg muscles.

*EMG Electrodes:* You will be fitted with seven surface electrodes, attached via self-adhesive strips, to both of your lower legs (4 on the right leg and 3 on the left). These electrodes will be used to measure electrical activity in your lower leg muscles during the maximum contraction task and the muscle reaction time task. In order to create the best possible electrode contact with your skin, small patches of the skin's surface may require shaving with a disposable razor and cleansing with an alcohol swab. Each electrode and corresponding wire will conveniently connect to a control box-belt to be worn around your waist.

Subject Initials: ____________
Date: ____________
HSRB 11/06

approved 10/30/06 JB

*Maximum Contraction Testing:* You will be seated in an apparatus designed to measure the strength of your ankle musculature. Your leg and foot will be strapped into the device, and after a brief warm-up and familiarization period, you will be asked to perform 3 ankle movements pushing the foot outward and 3 ankle movements pushing the foot inward. All repetitions will be performed with maximal effort. This procedure will be repeated for both legs.

*Muscle Reaction Time Testing:* With the electrodes firmly in place, you will be asked to stand on a platform that is designed to move your foot inward and outward; with stops to prevent the ankle/foot from going to a point of injury. The device is driven by an air compressor. After an instruction and familiarization period, you will be instructed to insert ear plugs (to eliminate background noice) and look straight ahead. We will be measuring how quickly your lower leg muscles respond to this sudden movement. You will not be aware of the precise moment the device is activated, but you will be asked to stop your ankle from turning as soon as the motion occurs. A total of twenty trials (10 per leg) will occur in random order.

*Strength Testing:* After removing the electrodes, you will once again be seated on the strength testing apparatus. Similar to Maximum Contraction Testing, your leg and foot will be strapped firmly to the device. You will then be asked to perform ankle muscle strength testing on each leg using maximal effort. Testing motions will be performed at two speeds (slow/fast). A total of three (3) trials for each speed and for each ankle will be performed.

*Cool Down:* At the conclusion of all testing, you will be allotted time to stretch the muscles of your hip, thigh, and leg.

**Time Required:**
Testing will require approximately 1 hour 30 minutes.

**Risks:**
You may experience some mild muscle soreness in your lower legs at a period 24-48 hours after the test session. It is important that all warm-up and cool-down stretching exercises be performed as instructed to lessen the chances of this occurring. A minor risk of skin irritation may be associated with the shaving of the skin prior to the attachment of the surface electrodes. The sudden and fast movements associated with the ankle movement device are novel, however the movement does not drop (invert) the ankle far enough to cause any harm. In the event of physical injury as a direct result of these research procedures, you will receive first aid. If you require additional medical treatment, you will be responsible for the cost.

**Benefits:**
There are no direct benefits to you for your participation in this study.

**Confidentiality:**

Subject Initials: ________
Date: ________
HSRB 11/06

approved 10/30/06

All data will be kept confidential. Your information will be assigned a code number. The list connecting your name to this code number will be kept in a locked file. When the study is completed and the data have been analyzed, that list will be destroyed, however the data will be stored indefinitely. Your name will not be used in any report whatsoever.

**Voluntary Participation:**
Your participation in the study is completely voluntary. There is no penalty for not participating.

**Right to Withdraw from the Study:**
You have the right to withdraw from the study at anytime without penalty.

**Payment:**
You will receive no payment for participating in this study.

**Who to Contact if You Have Questions About the Study:**
Kevin L. Neeld or Al T. Douex, Jr., (302) 831-8222 (Athletic Training Laboratory)
Dr. Thomas W. Kaminski, (302) 831-6402

**Who to Contact About Your Rights in the Study:**
Chair of the Human Subjects Review Board, (302) 831-2136 Office of the Vice Provost for Research University of Delaware

**Agreement:**
I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

**Participant:**__________________________ **Date:**____________

**Principal Investigator:**____________________ **Date:**____________

Subject Initials: ________
Date: __________
HSRB 11/06

# APPENDIX D

# HSRB APPROVAL

## HUMAN SUBJECTS REVIEW BOARD ACTION

University of Delaware
Newark, DE 19716

| | |
|---|---|
| Protocol title: | **Predicting Ankle Instability in Male Collegiate Ice Hockey Players** |
| Principal investigator(s): | **Thomas Kaminski; Health, Nutrition and Exercise Sciences** |
| HSRB number: | **HS 07-077** |
| Type of review: | ☐ Expedited ☒ Full Board |

The Human Subjects Review Board has reviewed the above-referenced protocol with respect to (1) the rights and welfare of the subjects: (2) the appropriateness of the methods to be used to secure informed consent; and (3) the risks and potential benefits of the investigation, and has taken the following action:

☐ Approved without reservation

☒ Approved as revised

☐ Disapproved for reasons noted below

| | |
|---|---|
| Approval date: | **October 30, 2006** |
| Approval period: | **11+ months** |
| Expiration date: | **October 17, 2007**<br>**(One year from date of convened IRB meeting)** |
| Submittal date for continuing review: | **August 1, 2007** |

Changes in the protocol must be approved in advance by the HSRB.
Comments:

Dr. Richard D. Holsten, Associate Provost for Research — Date: 11/1/06
Chairman, Human Subjects Review Board
210 Hullihen Hall
302-831-2383, fax: 302-831-2828, rholsten@udel.edu

## APPENDIX E

| | Reaction Time (ms) | | Reaction Intensity (%MVIC) | |
|---|---|---|---|---|
| | **Stable (n=23)** | **Unstable (n=18)** | **Stable (n=14)** | **Unstable (n=12)** |
| **TA** | 57.21 ± 12.64 | 59.43 ± 11.30 | 58.29 ± 39.63 | 43.91 ± 30.12 |
| **PL** | 52.79 ± 12.21 | 55.89 ± 13.70 | 48.78 ± 24.91 | 61.02 ± 45.59 |
| **PB** | 57.31 ± 11.63 | 59.82 ± 10.09 | 82.66 ± 64.13 | 58.72 ± 24.21 |

**Mean muscle reaction times and intensities in stable and unstable ankles.**

| | Non-Dominant Ankle | | Dominant Ankle | |
|---|---|---|---|---|
| | **Stable (n=12)** | **Unstable (n=9)** | **Stable (n=11)** | **Unstable (n=9)** |
| **30°/s (Nm)** | | | | |
| **Inversion** | | | | |
| ***Concentric*** | 26.58 ± 6.46 | 25.78 ± 5.59 | 26.00 ± 3.82 | 26.00 ± 5.39 |
| ***Eccentric*** | 33.58 ± 7.42 | 32.67 ± 7.75 | 31.64 ± 6.93 | 30.22 ± 5.26 |
| **Eversion** | | | | |
| ***Concentric*** | 29.50 ± 7.76 | 30.56 ± 6.44 | 26.73 ± 5.68 | 29.67 ± 4.95 |
| ***Eccentric*** | 37.25 ± 9.65 | 40.67 ± 9.06 | 32.18 ± 6.85 | 35.22 ± 11.56 |
| **120°/s (Nm)** | | | | |
| **Inversion** | | | | |
| ***Concentric*** | 28.67 ± 9.05 | 28.78 ± 6.91 | 28.64 ± 6.04 | 27.56 ± 2.92 |
| ***Eccentric*** | 34.75 ± 9.22 | 34.78 ± 6.72 | 34.00 ± 7.87 | 34.44 ± 7.26 |
| **Eversion** | | | | |
| ***Concentric*** | 30.00 ± 8.66 | 30.56 ± 7.14 | 26.18 ± 6.65 | 29.56 ± 4.36 |
| ***Eccentric*** | 39.25 ± 10.89 | 39.56 ± 8.14 | 34.45 ± 6.77 | 37.44 ± 4.28 |

**Mean torque values for all strength measurements.**

| Reaction Time (ms) | Non-Dominant Ankle | | Dominant Ankle | |
|---|---|---|---|---|
| | Stable (n=12) | Unstable (n=9) | Stable (n=11) | Unstable (n=9) |
| TA | 57.50 ± 10.27 | 62.5 ± 10.8 | 56.89 ± 15.34 | 56.32 ± 11.54 |
| PL | 53.09 ± 9.78 | 59.8 ± 13.7 | 52.46 ± 14.90 | 51.95 ± 13.30 |
| PB | 60.43 ± 9.61 | 63.3 ± 10.7 | 53.90 ± 13.10 | 56.33 ± 8.58 |

**Mean muscle reaction times in non-dominant and dominant, stable and unstable ankles for the TA, PL, and PB.**

| Reaction Intensity (%MVIC) | Non-Dominant Ankle | | Dominant Ankle | |
|---|---|---|---|---|
| | Stable (n=12) | Unstable (n=9) | Stable (n=11) | Unstable (n=9) |
| TA | 61.63 ± 46.03 | 46.93 ± 25.94 | 54.95 ± 35.48 | 40.89 ± 36.01 |
| PL | 48.14 ± 30.54 | 75.53 ± 62.30 | 49.43 ± 20.26 | 46.51 ± 13.65 |
| PB | 84.51 ± 89.12 | 54.68 ± 34.59 | 80.82 ± 31.01 | 62.76 ± 7.33 |

**Mean muscle reaction intensities in non-dominant and dominant, stable and unstable ankles for the TA, PL, and PB.**