THE EFFECTS OF KINESIO TAPING® ON POSTURAL CONTROL DEFICITS IN HEALTHY ANKLES, COPERS, AND INDIVIDUALS WITH FUNCTIONAL ANKLE INSTABILITY

by

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A thesis submitted to the Faculty of the University of Delaware in partial
fulfillment of the requirements for the degree of Master of Science in Exercise Science

Spring 2012

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ACKNOWLEDGMENTS

I would like to extend a special thank you to several persons and groups that have been of vital importance to this project. First I would like to thank all my friends and lab-mates for their help with completing this project. I would like to acknowledge the members of the Human Performance Lab including Jen Halterman, Athena DeAngelis, Craig Oates, Mehmet Uygur, Dan Tocci, Stephanie Segulin, Chris Clyde, Peter Braun, Matt Astolfi, and Alyssa Reyes. I would like to acknowledge Kathy Liu and Alan Needle for their mentorship and many contributions throughout this study. I would like to especially thank Alan Needle for serving as my doctoral mentor through this process and for his countless hours of work writing programs, editing my document, and general support and guidance through this process. I would also like to thank Caitlin Synovec, Jackie Palmer, Özge Uygur, Maria Bellumori, Kota Takahashi, and Rob Hulbert for their support and friendship over the past two years.

The professors at the University of Delaware have also been crucial to the completion of this project. I would like to thank each member of my committee for his time and countless contributions to this project: Dr. Buz Swanik and Dr. William Rose. I would also like to thank my chair and advisor, Dr. Thomas Kaminski, for guiding me through the research process, allowing me the flexibility to pursue a project that I had a true interest in, working with me to meet deadlines, and serving as a mentor for the past two years.

I would also like to thank the members of the University of Delaware Undergraduate Athletic Training Education Program who assisted me through participation in this study as well as their support and encouragement. I would also like to thank the University of Delaware athletic training staff for allowing me the flexibility to get all of my testing done and their encouragement throughout this project.

Last and certainly not least, I would like to thank my parents and family for their continued prayers and support. They have supported me throughout these past two years as they have through my whole life and I am truly grateful for their love and support, I could not have done this without them.

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ABSTRACT

BACKGROUND: Ankle sprains are the most common injuries among physically active people, with 40-70% developing functional ankle instability (FAI), characterized by frequent episodes of "giving way" and sensations of joint instability. Kinesio Taping,® an intervention that has recently gained popularity may help decrease postural control deficits related to FAI. This study examined the immediate and prolonged effects of Kinesio Taping® on postural control in subjects with FAI and investigated differences between healthy, coper, and unstable ankles as measured through single-limb balance on a forceplate. METHODS: Sixty physically active, college-aged participants (height: 172.5 ± 9.7 cm, mass: 74.2 ± 16.2 kg, age: 21.5 ± 2.6 years) were sorted into three separate groups: healthy control, copers, and FAI. Subjects were stratified using the Cumberland Ankle Instability Tool (CAIT) combined with their history of ankle injury. Dependent variables were time to boundary (TTB) measures and traditional center of pressure (COP) measures in both the mediolateral (frontal) and anteroposterior (sagittal) planes. Testing was performed at baseline, immediately after application of the tape, 24 hours post-tape application, and immediately after removal of the tape. RESULTS: Significant group main effects for COP standard deviation ($F_{2,57} = 4.309$, $p = 0.018$) and range ($F_{2,57} = 4.918$, $p = 0.011$) in the sagittal plane were noted. Significant condition main effects for TTB absolute minima (frontal plane, $F_{3,159} = 1.607$, $p = 0.015$) and standard deviation (frontal, $F_{3,138} = 5.710$, $p = 0.002$ and sagittal plane, $F_{3,141} = 0.889$, $p = 0.029$) were also noted. Post hoc testing revealed decreased COP standard deviation and range for the ankle instability group compared to controls and significant improvements at 24 hours post-tape in all groups for TTB absolute minima ($p = 0.025$) and standard deviation (frontal plane, $p = 0.002$). CONCLUSIONS: Deficits in COP variables were seen in unstable ankles as compared to both healthy ankles and copers. Minor improvements in TTB measures after 24 hours of continuous wear of Kinesio® tape were observed in healthy, coper, and unstable ankles. Since between group differences were seen in COP measures, but improvements post-tape application were seen only in TTB variables, we can conclude that Kinesio® tape did not improve the specific postural control deficits experienced by unstable ankles. Therefore, while Kinesio® tape may provide a small benefit to postural control at the ankle, it does not appear to be effective at improving ankle instability deficits.

Keywords: balance, time to boundary, center of pressure

Chapter 1

INTRODUCTION

Ankle sprains are the most common injuries among physically active people, with 40-70% developing functional ankle instability (FAI), characterized by frequent episodes of "giving way" and sensations of joint instability.(10,15,28,54,61) Common complaints of FAI include recurrent sprains, which have been linked to increased incidence of ankle osteoarthritis, as well as chronic pain, crepitus, or weakness at the ankle joint; and may be attributed to impaired proprioception, altered postural control, and reduced muscular strength following the initial sprain.(10,56) Functional ankle instability deficits have not been consistently linked to mechanical laxity, and may exist concurrently with, or independently of, excessive anterior displacement or inversion rotation.(10) Proprioception is defined as the combined afferent input from mechanoreceptors in the joint capsule, ligaments, muscles, tendons, and skin to the central nervous system comprising kinesthetic awareness, joint position sense, and force sense.(36) However, as proprioceptive tests have failed to predict functional deficits, balance tasks may be more useful because they require the integration of proprioceptive information and selection of appropriate motor responses.(39,42) Single-leg balance represents a measure of the dynamic restraint system of a joint, requiring regulation of muscle tone and joint stiffness, while continuously adjusting for altered loads as the center of pressure shifts throughout a balance trial.

Munn et al.(42) and Arnold et al.(1) performed separate meta-analyses, both of which support the presence of balance deficits in functionally unstable ankles. An assortment of static and dynamic postural control variables were examined, with both reviews determining that static and dynamic postural control measures discriminate healthy from unstable ankles.(1,42) Results from Arnold et al.(1) further determined that, of the static balance tasks, those that quantify some temporal aspect of center of pressure excursions, such as time-to-boundary, are most discriminating. Time-to-boundary (TTB) is a variation on standard center of pressure (COP) measures that estimates the amount of time it would take for a subject's COP to reach the boundary of the base of support if it were to continue in the same direction at its instantaneous velocity.(23) A lower TTB indicates greater postural instability.(23) Knapp et al.(33) attempted to establish a single variable of static postural control that could identify FAI; however, it was determined that TTB and traditional COP variables (such as COP displacement) quantify different components of postural control and therefore should be used concurrently. As the exact mechanism responsible for ankle instability remains unclear, research has recently begun to compare unstable ankles to a secondary control group of patients that have suffered a single lateral ankle sprain, but have not developed instability. This group of "copers" could provide valuable insight into potential adaptations following injury that could guide rehabilitation.

Copers are a cohort studied with regard to anterior cruciate ligament (ACL) injury, and have recently been investigated at the ankle joint.(13) Conflicting research exists regarding whether ankle sprain copers have either healed following injury and now function in a manner similar to healthy ankles, or adapted and adopted an effective compensatory mechanism despite the presence of mechanical laxity or proprioceptive deficits. Wikstrom et al.(63) observed decreased postural control, as measured by traditional COP and TTB variables, in unstable ankles compared to both copers and healthy controls, whereas Gutierrez et al.(19) observed copers behaving differently from healthy and unstable ankles by demonstrating increased tibialis anterior pre-activation during a step-down onto a supinating platform. Utilization of a coper group for comparison may reveal effective compensatory strategies which could assist with the development of interventions and rehabilitation plans aimed at preventing the development of FAI following an initial sprain.

Despite deficits observed in patients with FAI, limited interventions have been examined to reduce sensations of instability and associated dysfunctions. Long term balance training and joint mobilization have resulted in mild to moderate improvements in static postural control measures. Additionally, long term balance training has led to improvements in self-reported disability and a reduced number of recurrent sprains, while joint mobilizations have been associated with range of motion improvements.(27,47,62) Conversely, textured insoles, intended to increase plantar cutaneous mechanoreceptor stimulation, have been associated with a negative effect on postural control. While balance training and joint mobilization have been associated with improvements in unstable ankles; these interventions may not be readily available to the recreational athlete with limited access to skilled clinicians.

An intervention which has recently gained popularity that may improve postural control is Kinesio Taping®. It is presented to have a higher elasticity than that of traditional athletic tape, and uses an acrylic based adhesive that better withstands moisture and increases in temperature, allowing it to be worn for up to five days without re-application.(66) Kinesio® tape is reported to have four main functions: restore proper muscle function by facilitating or inhibiting muscular contraction, improve blood flow and lymphatic drainage, decrease pain through mechanoreceptor stimulation and gate control theory, and reduce muscle spasms leading to correction of improper joint arthrokinematics.(20,66) Research has been initiated to study potential proprioceptive benefits of Kinesio® tape, as its use may increase mechanoreceptor stimulation.(43)

There has been limited research on the proprioceptive benefits of Kinesio Taping® in injured populations. It is hypothesized that the tape will improve the reactive (feedback) postural control pathway in those with FAI through increased early stimulation of cutaneous mechanoreceptors associated with joint motion. Proprioceptive improvements in the form of improved grip force sense in healthy subjects(5) and postural control improvements quantified through COP and TTB measures in multiple sclerosis patients(7) have been observed with application of Kinesio® tape. Two studies examining ankle joint position sense with and without Kinesio® tape reported divergent findings. Improvements were not observed by Halseth et al.(20) from the tape in healthy subjects; however, Murray and Husk(43) reported significant improvements in active joint angle replication in subjects with a history of ankle sprain, suggesting that the tape may be more beneficial to previously injured or unstable ankles.

Therefore, the purpose of this study is to assess static postural control differences, as quantified through traditional COP and TTB measures, between healthy ankles, copers, and functionally unstable ankles; and to investigate immediate and prolonged effects of Kinesio® tape in these subjects. We hypothesized that healthy ankles and copers would perform significantly better at baseline than functionally unstable ankles and that static postural control would improve in all groups immediately following tape application and after prolonged use.

Chapter 2

METHODS

2.1 Participants

A total of 60 college-aged subjects were recruited for this study (Table 1). The subjects were classified into healthy ankles, copers, and FAI, with 20 subjects comprising each group.

Subjects were stratified using the Cumberland Ankle Instability Tool (CAIT) and an ankle injury history questionnaire.(26) Subjects with no history of ankle sprains and a CAIT score at or above 28 were classified as healthy controls; subjects with a history of one ankle sprain and a CAIT score at or above 28 were classified as copers; subjects with a history of one or more ankle sprains and a CAIT score at or below 24 were classified as FAI.

If an FAI subject had bilateral instability, the ankle with the lowest CAIT score was used and if a coper met the criteria for a coper bilaterally, the limb with the highest CAIT score was utilized. If scores were equal, the test limb was determined by a coin flip. In the healthy participants, the test leg was determined by matching the limb dominance to the dominance of the ankles tested in the FAI group. Limb dominance was determined by asking each participant which leg they would use to kick a soccer ball for maximum distance.(6) Prior to testing, all participants provided informed consent (UD IRB #224524).

2.2 Instrumentation

2.2.1 Forceplate

An in-ground forceplate (AMTI, Watertown, MA) was used to collect center of pressure and time-to-boundary data. The forceplate tracked the location and velocity of the participant's center of pressure throughout a single-leg quiet standing task, then the raw data were processed through a fourth order zero lag 10 Hz lowpass Butterworth filter. All forces and moments from the forceplate were collected at 200 Hz in custom LabVIEW software (National Instruments, Austin, TX).

2.3 Procedures

2.3.1 Foot Measurements

We obtained measurements of the length and width of each participant's foot, at the longest and widest areas respectively, before testing in order to model the foot on the forceplate coordinate system (Figure 1).

2.3.2 Forceplate Testing

Each participant was given five practice trials with their eyes closed and a one-minute rest between practice and test trials. Tape was placed on the forceplate in a "T" and each participant was instructed to line the back of their foot up with the top of the "T" and to line the middle of their foot up with the middle line of the "T". Each participant was instructed to stand on one leg with their hands on hips, and their non-stance leg bent to approximately 30° of knee flexion, making sure that the non-stance leg is not resting against the stance leg (Figure 2). Each subject performed three 20-second trials. If a participant's non-stance leg touched down or the stance foot moved on the force plate, it was recorded as a failed trial and repeated.

2.3.3 Taping

After gathering the baseline forceplate data, the Kinesio Taping® was applied to the test ankle by the principal investigator. A lateral ankle sprain adapted Halseth et al. (Figure 3) Kinesio Taping® technique was used on all subjects.(20) The foot was placed in a comfortable resting position in slight plantar flexion and tape adherent spray was used to help keep the tape in place. First, a strip was placed over the anterior midfoot and stretched to approximately 115-120% of its resting length ending just below the tibial tuberosity on the shin. The second strip originated just above the medial malleolous and stretched under the foot ending just lateral to the end of the first strip at a point near the fibular head. The final strip was stretched across the anterior aspect of the ankle from the medial to the lateral malleolous.

Once the tape was applied, each participant repeated the forceplate testing. The tape remained in place overnight and each participant returned 24 hours later and repeated the forceplate testing as described above. Following this session, the tape was removed and the participant repeated the postural control testing one final time.

2.4 Data Reduction

The foot was modeled as a rectangle in order to calculate TTB and allow for separation of the medio-lateral (ML) and anterior-posterior (AP) components. The COP data were processed in a custom LabVIEW program. For each COP data point, the distance between the COP and the border of the foot that it is moving towards was calculated. This was done in both the ML and the AP directions separately for each data point. The instantaneous velocity of each data point was also calculated and then the distance was divided by the instantaneous velocity to get the time it would take for the COP to reach the boundary of the base of support if it were to continue at its instantaneous trajectory and velocity for each COP data point (Figure 4). This gave us a time series of data points for the ML and AP directions, with the valleys (minima) representing points of potential instability (Figure 5).

2.5 Data Analysis

The traditional COP dependent variables measured included COP distance, COP standard deviation, COP range, and COP %range. The TTB dependent variables included TTB number of minima, TTB mean of the minima, TTB absolute minima, and TTB standard deviation of the minima. Each dependent variable was calculated in the medial/lateral and anterior/posterior directions separately. Independent variables included tape condition (pre, immediate, 24 hours, post-removal), and group (control, copers, FAI) (Figure 6). Separate two-way repeated-measures ANOVA's were used to analyze changes in each COP and TTB variable. Pairwise comparisons (paired t-tests) were used for post-hoc analysis with a Bonferroni correction. The significance level for all analyses was set a priori at $p \leq 0.05$.

Chapter 3

RESULTS

No significant group by condition interaction effects were found for any variable ($p>0.05$). There were significant group main effects for 2 variables: COP SD ($F_{2, 57}$, $p = 0.018$) and range ($F_{2, 57}$, $p = 0.011$) in the AP plane; and significant condition main effects for 3 variables: TTB absolute minima in the ML plane ($F_{3, 159} = 3.610$, $p = 0.015$), TTB SD in both ML ($F_{3, 138} = 5.710$, $p = 0.002$), and AP ($F_{3, 141} = 3.318$, $p = 0.029$) planes. It is important to note that the main effects represent pooled data. For example, this indicates that a significant group main effect represents a comparison of the means of all four conditions pooled together within a group to the means of another group. Post hoc analysis revealed unstable ankles have a higher center of pressure standard deviation than healthy ankles ($p = 0.027$), and a higher center of pressure range in the AP plane than both healthy controls ($p = 0.021$) and copers ($p = 0.033$), indicating decreased stability; however, no differences were observed between copers and healthy controls (Figure 7). There was a significant improvement in the ML plane for TTB absolute minima ($p = 0.025$) from pre-test to immediately after taping, for TTB standard deviation ($p = 0.002$) from immediately following tape application to twenty-four hours, and significantly higher TTB standard deviation at post test than at twenty-four hours (Figure 8). Despite a significant condition main effect for TTB SD AP, no significant difference was determined via post hoc analysis (Figure 9).

Chapter 4

DISCUSSION

The primary findings of this study were that limited postural control improvements were seen twenty-four hours following application of Kinesio® tape, with no changes seen immediately after taping or following tape removal. Furthermore, this study demonstrated balance deficits in unstable ankles when compared to groups of both healthy ankles and copers; however, the variables which showed improvements following taping were not the same variables that demonstrated ankle instability deficits.

Center of pressure and TTB are two measurements that have been used to quantify static postural control detriments in unstable ankles. Our research observed impaired postural control in traditional COP measurements; however, these deficits were not evident using the TTB variables. This finding is partially supported by previous research which reported decreased stability in traditional COP measures in unstable ankles (2,34,35,55); with other studies reporting decreased postural control only as measured through TTB measures (21,37). Previous research into TTB has reported 10-second trials of single-leg balance; while our study used 20-second trials. It is possible that our longer trial time may begin to test different aspects of postural control; however it remains unclear how the length of the trial may affect our ability to discriminate between groups with both COP and TTB variables. Hertel et al.(23) concluded that traditional COP and TTB variables quantify different aspects of postural control; therefore, since COP variables are summary measures of the entire trial whereas TTB variables comprise only points of potential instability, 20-seconds may better reveal traditional COP differences between groups while TTB variables may be better quantified with 10-second trials.

The two variables that demonstrated differences in our study, COP standard deviation and COP range in the sagittal plane, provide information regarding the variability and span of the subject's postural control. In other words, they represent measures of change in the COP throughout the trial and the distance between the most anterior and posterior points. Center of pressure standard deviation was observed to be significantly greater in unstable ankles when compared to healthy ankles, which is consistent with previous research that has shown increased COP variability following a lateral ankle sprain(16) as well as in Parkinson's patients compared to healthy controls(57). Variability has been debated in the literature with some studies arguing that decreased variability is indicative of better postural control(29,58,59) and others contending that decreased variability actually represents a loss of degrees of freedom making the postural control system less adaptable to unexpected perturbations(8,38,41). It is unclear why in our results the unstable group demonstrated increased variability similar to Parkinson's patients instead of the decreased variability seen by other studies. Range of the COP AP excursion was significantly greater in the ankle instability group compared to the coper and healthy groups, suggesting that those with ankle instability may shift their COP in the sagittal plane, perhaps attempting to position the ankle in greater dorsiflexion, improving bony stability. Increased dorsiflexion positions the wider, anterior portion of that talus into articulation with the ankle mortis, placing the joint in a closed packed position.

Further research may investigate full lower extremity motion analysis to determine if alterations in knee and hip angle occur as the COP range increases.

Following application of Kinesio® tape, improvements were seen at 24 hours, but not immediately after application or following tape removal. These improvements were limited as only two of the dependant measures, TTB absolute minima and TTB standard deviation in the frontal plane, displayed significant differences. The effect of prolonged tape use has been supported with changes in several variables after twenty-four of continuous wear.(14,18,53) Two studies, one measuring ankle joint stiffness(14) and one measuring cervical pain and range of motion(18) observed beneficial effects from Kinesio® tape immediately and at 24 hours, whereas, Slupik et al.(53) observed improvements in EMG activity during a weighted quad contraction at 24 hours but not immediately following application of Kinesio® tape. The mechanism (proprioceptive, mechanical, facilitative, inhibitory) through which Kinesio® tape is effective may determine whether benefits can be seen immediately, or if the tape must be in place for a period of time before improvements are observed. The effect on proprioception is theorized to occur through increased mechanoreceptor stimulation, leading to alterations in the efferent motor response, which may better stabilize the joint. The possibility of a training effect exists on the motor response, from overnight accommodation to the increased mechanoreceptor stimulation from the tape which may explain why improvements were seen at twenty-four hours but not immediately following tape application.

Increased stability, revealed via a greater frontal plane TTB absolute minima, was demonstrated 24 hours following tape application. Time-to-boundary absolute minima represents the point where the ratio of velocity to distance from the boundary of the base of support is greatest, indicating the point of peak instability during a trial. A decrease in this variable is significant because an ankle sprain event would represent an absolute minima in which the center of pressure moves past the lateral base of support; therefore, a shift towards a lower velocity to distance ratio (TTB minima) would represent the subject being further from this theoretical point of failure. Time-to-boundary standard deviation in the frontal plane also demonstrated a decrease after twenty-four hours. As previously mentioned, standard deviation represents variability of the postural control system which could be either a positive or negative adaptation. Previous research has either not observed differences in TTB standard deviation(57), or seen differences in TTB standard deviation in the sagittal plane but not the frontal plane (21,37). Variability may also be affected by the increased trial time length and may be an area for future study. Future research may examine precisely how long the tape must be worn before an effect is seen by taking serial time point postural control measurements between tape application and twenty-four hours.

Previous research has suggested that Kinesio® tape maintains an effect even after removal (53); however, our study does not support this claim. Improvements following tape removal were not observed in our study which helps to refute the argument that improvements may only have been seen due to a learning effect. If a learning effect was the reason for the improvements, the increased postural control would have also been observed following tape removal; however, since the post-tape condition revealed values similar to the pre-tape measures, the learning effect was likely controlled for by the five mandatory practice trials. One reason for this discrepancy may be that Slupik et al.(53) investigated EMG activity during a quad contraction whereas our study investigated a postural control measure, indicating that for proprioceptive benefits the tape must be on the subject to facilitate improvements.

We did not observe any significant group by condition interaction effects, indicating that each group responded to the four conditions in a similar pattern. This is not surprising based on the fact that improvements from the tape were seen in TTB measures, while postural control deficits in unstable ankles were seen in COP measures. Since the areas of improvement from the tape (TTB measures) were different than the areas of detriment (COP variables) in unstable ankles, it makes sense that the unstable group would not see greater improvements than the healthy or copers groups in the TTB variables. It does not appear that the tape is specifically useful for improving balance deficits associated with ankle instability. As this was the first study to investigate the benefits of Kinesio® tape on postural control in unstable ankles, future research could examine the effects of this tape on other aspects of the sensoriomotor system by observing EMG activity, motion capture analysis, or balance in a fatigued ankle.

Limitations of this study include lack of a sham or control treatment and inability to randomize the testing order. The lack of a sham or control treatment, such as a single strip of tape or a no tape condition, does not control for the possibility of a placebo effect. While the placebo effect is possible, we feel that an improvement in TTB absolute minima but not mean of the minima may indicate that the overall stability of the trial was not enhanced, but rather just those points of extreme instability, which would likely be less influenced by a placebo effect. Future research should investigate if application of a single strip of Kinesio® tape may provide an adequate sham treatment that could be used in future studies. Furthermore, the lack of randomization of the test order leaves to question whether or not improvements are related to a learning effect. In an attempt to control for the learning effect, we conducted a pilot investigation of repeated trials to see where the postural control measures plateau. This led to the inclusion of 5 mandatory practice trials before the start of each testing session to account for this effect. In addition, the observation that improvements were not seen at post-test lends support to the idea that the learning effect was adequately diminished.

In conclusion, minor improvements in TTB measures after 24 hours of continuous wear of Kinesio® tape were observed in healthy, coper, and unstable ankles. Additionally, deficits in COP variables were seen in unstable ankles as compared to both healthy ankles and copers. Since between group differences were seen in COP measures, but improvements post-tape application were seen only in TTB variables, we can conclude that Kinesio® tape did not improve the specific postural control deficits experienced by unstable ankles. Therefore, while Kinesio® tape may provide a small benefit to postural control at the ankle, it does not appear to be effective at improving ankle instability deficits.

Chapter 5

LEGEND

Table 1: Demographic Information by Group (Means and SDs)

Group	Gender	Height (cm)	Mass (kg)	Age (years)
AI	Females: 11 Males: 9	173.8 ± 8.6	82.2 ± 20.7	21.9 ± 2.5
PCOP	Females: 11 Males: 9	171.5 ± 10.3	69.3 ± 11.8	21.6 ± 2.9
CNT	Females: 13 Males: 7	172.3 ± 10.4	71.1 ± 11.9	21.1 ± 2.5
Totals	Females: 35 Males: 25	172.5 ± 9.7	74.2 ± 16.2	21.5 ± 2.6

AI: ankle instability, PCOP: copers, CNT: healthy controls

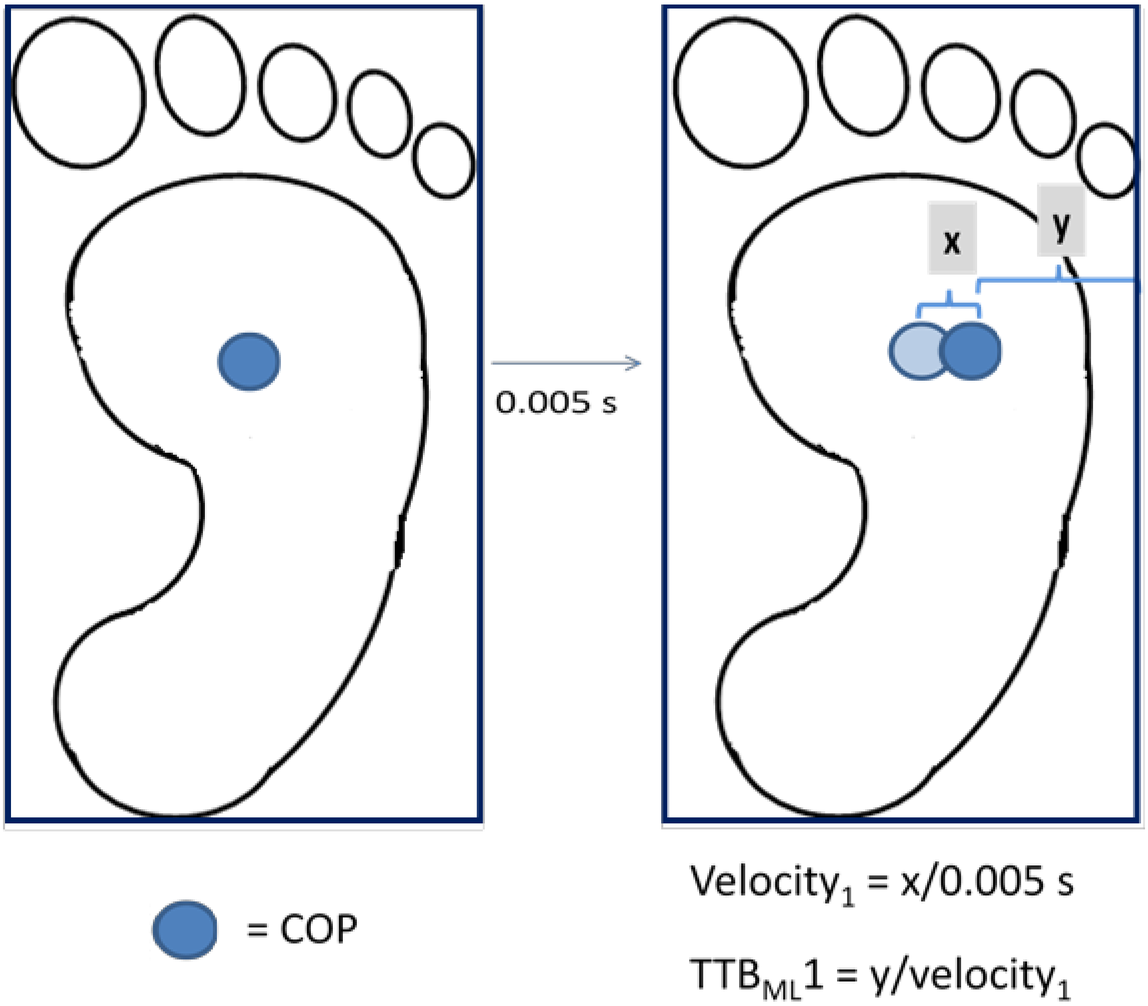

Figure 1: The boundaries of the foot are modeled as a rectangle in order to allow for TTB calculations. This figure the we created demonstrates the foot modeled as a rectangle to allow for calculation of the time-to-boundary for a data point in the medial/lateral direction.

Figure 2: Testing position with hands on hips, non-stance limb bent to 30° of knee flexion, non-stance leg not resting against the stance leg, barefoot on the forceplate. Front and side view.

Figure 3: Kinesio Taping® adapted from the method reported by Halseth et al.(20)

$$CP_x = \frac{M_y + F_x d_z}{F_z}$$

$$CP_y = \frac{M_x + F_y d_z}{F_z}$$

$$V_{COP_{ML}} = \frac{d_{COP_{ML}}}{0.005s}$$

$$TTB_{ML} = \frac{d_{ML-Boundary}}{V_{COP_{ML}}}$$

Figure 4: These formulas are used to calculate the time to boundary value from the center or pressure and the foot position on the forceplate.(23)

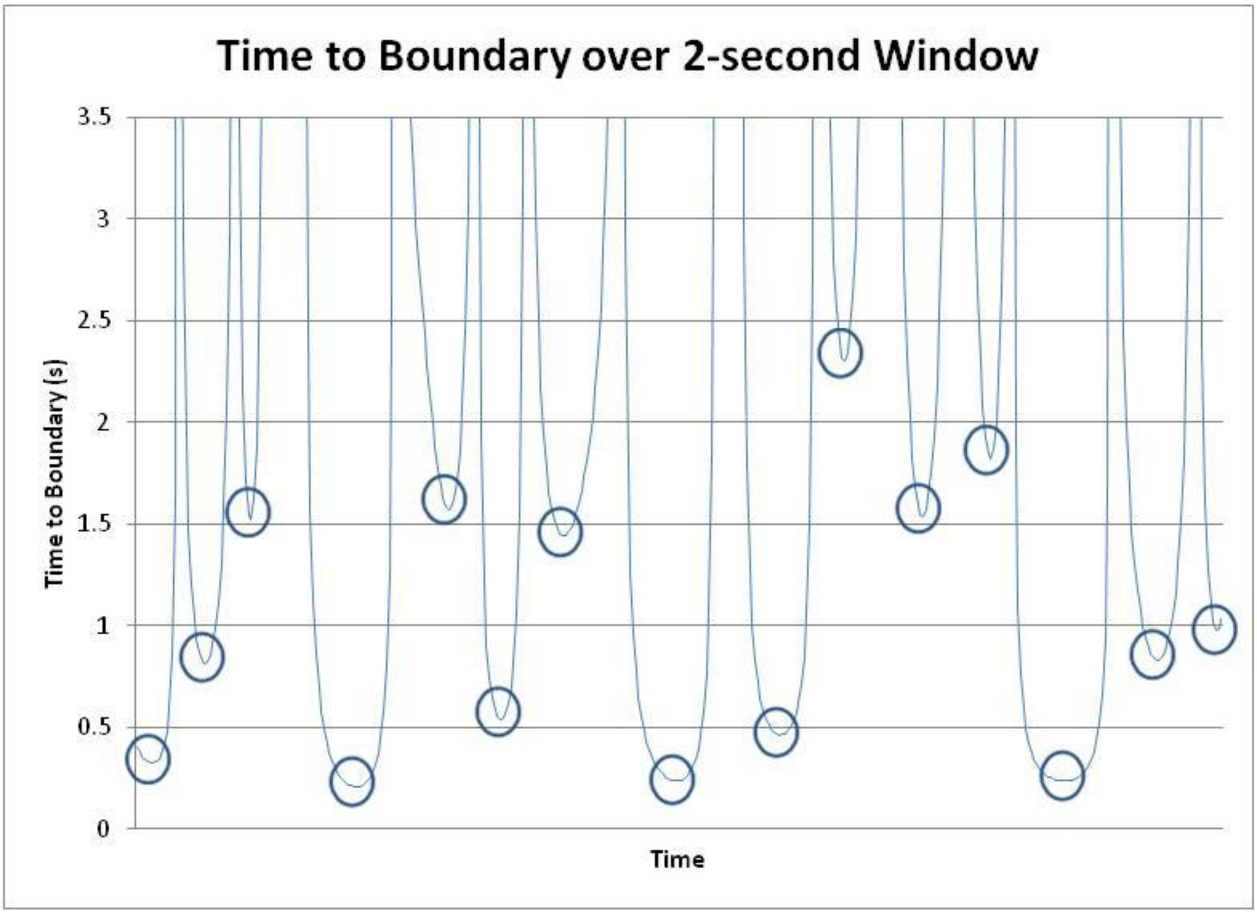

Figure 5: Time series of TTBML for 2 seconds of a postural control trial from our data. Circled points are absolute minima of the trial.

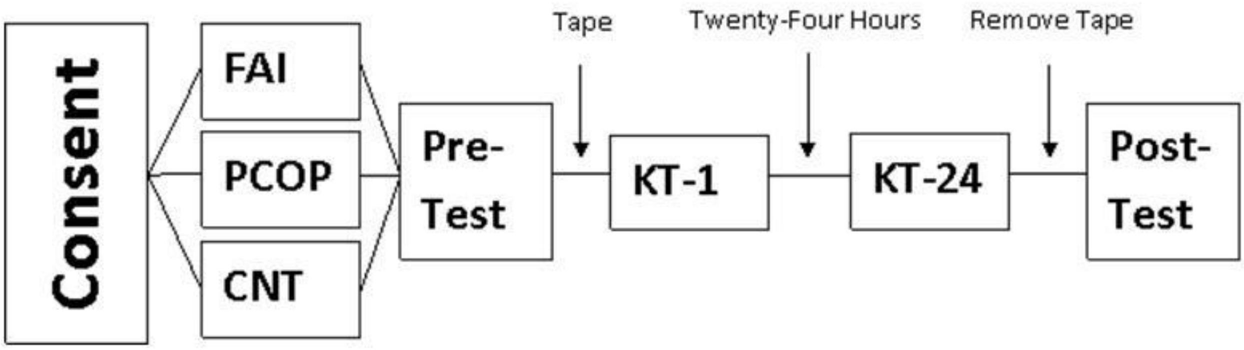

Figure 6: Statistical analysis will look at the interaction between each group (control, copers, FAI) and each tape condition (pre, immediate (KT-1), 24 hours (KT-24), post).

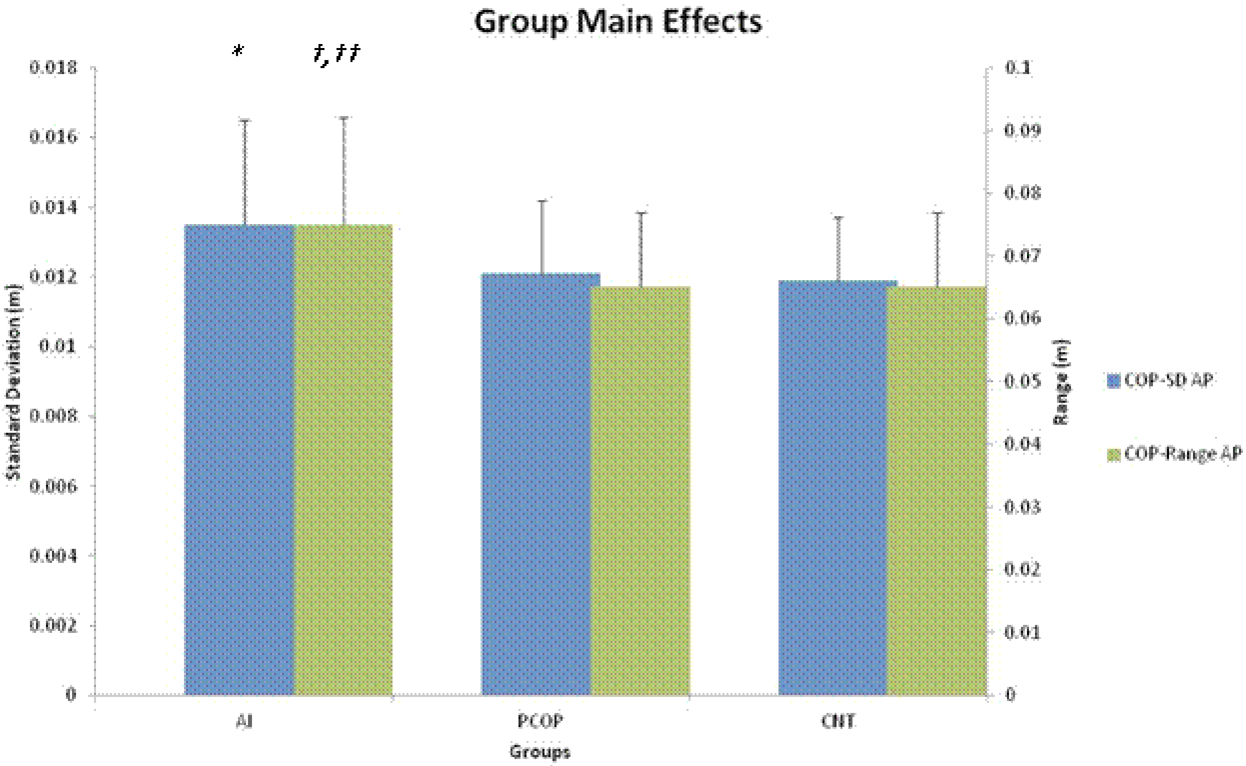

Figure 7: Differences between groups (AI, PCOP, CNT) for COP-SD AP and COP-Range AP. This graph demonstrates the differences between groups with error bars demonstrating the standard deviation with * indicating a significant difference between AI and CNT for COP-SD AP ($p = 0.027$), † indicating a significant difference between AI and CNT for COP-Range AP ($p = 0.021$), and †† indicating a significant difference between AI and PCOP for COP-Range AP ($p = 0.033$). AI: ankle instability, PCOP: copers, CNT: healthy controls, COP: center of pressure, AP: anteroposterior.

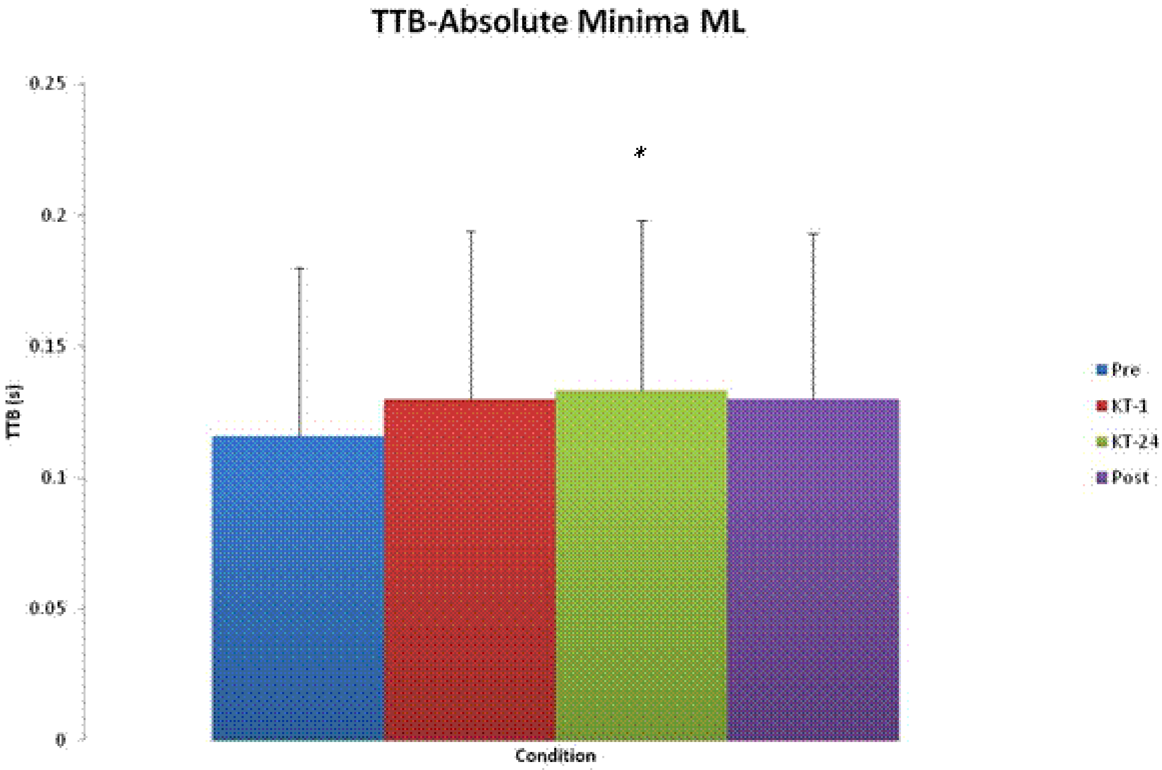

Figure 8: Differences between conditions (Pre-test, KT-1, KT-24, Post-test) for TTB-AbsMin ML. This graph demonstrates the differences between conditions with error bars demonstrating the standard deviation with * indicating a significant difference from pre to KT-24 ($p = 0.025$). Pre: pre-test, KT-1: immediately following tape application, KT-24: twenty-four hours following tape application, Post: post-test, TTB: time-to-boundary, ML: mediolateral.

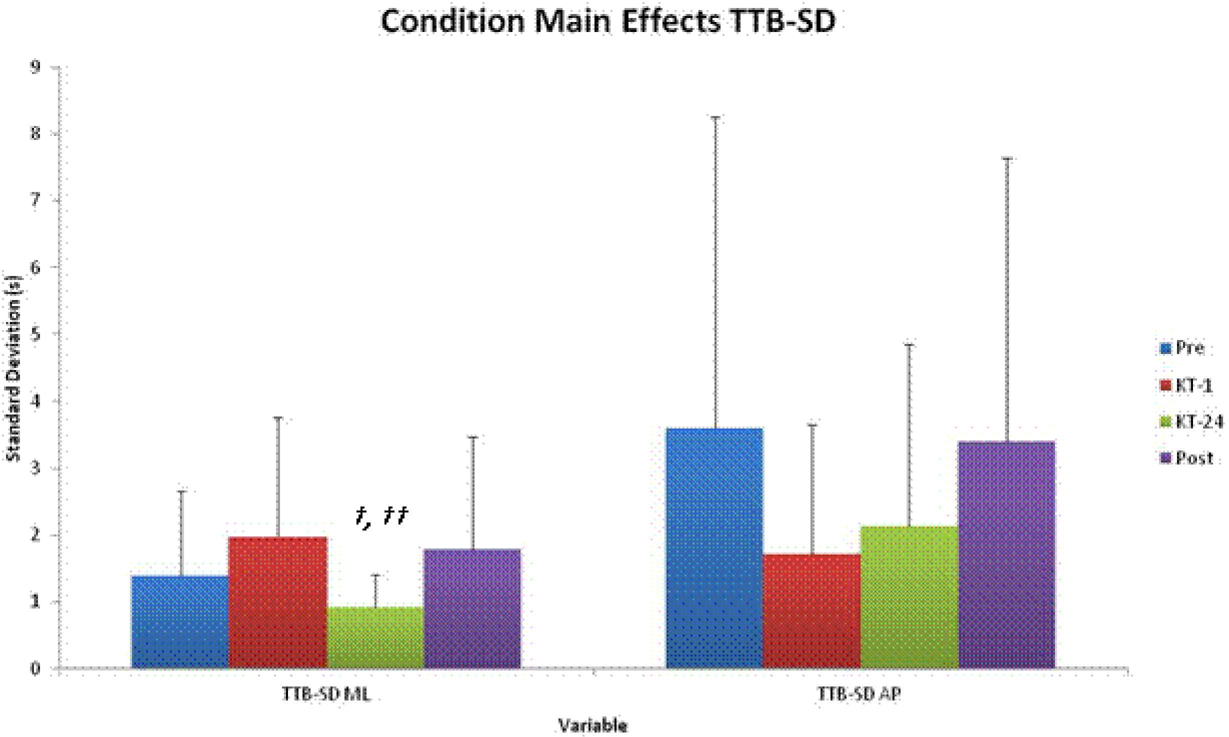

Figure 9: Differences between conditions (Pre-test, KT-1, KT-24, Post-test) for TTB-SD in the ML and AP planes. This graph demonstrates the differences between conditions with error bars demonstrating the standard deviation with † indicating a significant difference from KT-1 to KT-24 in the ML plane ($p = 0.002$) and †† indicating a significant difference between post-test to KT-24 in the ML plane ($p = 0.009$). No significant differences were found in the AP plane at post hoc. Pre: pre-test, KT-1: immediately following tape application, KT-24: twenty-four hours following tape application, Post: post-test, TTB: time-to-boundary, SD: standard deviation, ML: mediolateral, AP: anteroposterior.

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Appendix A

INFORMED CONSENT FORM

RESEARCH STUDY: The Effects of Kinesiology Taping on Postural Control Deficits in Individuals with Ankle Instability

INVESTIGATORS: Christina A. Shields (graduate student) and Thomas W. Kaminski, PhD (professor) in the Department of Kinesiology and Applied Physiology

INTRODUCTION

You are invited to take part in a research study to gain information that may help in the treatment of ankle sprains. Specifically, we will examine the effects of ankle taping on your balance.

PURPOSE

The purpose of this study is to determine the effects of ankle Kinesiology taping on balance during a single- leg standing task. The research is important from an injury treatment standpoint.

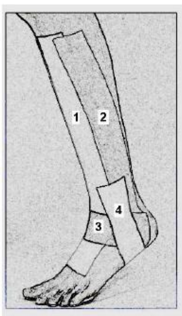
PROCEDURES

You are one of 90 subjects (male and female) being chosen to participate in this study. You will be assigned to one of three groups (CONT, AI, COP) based on your answers to ankle injury history questionnaires. Subjects in the CONT have no history of ankle sprain, subjects in the AI have a history of ankle instability, while subjects in the COP are subjects who have experienced and ankle sprain but do not have instability. Your participation will involve two testing sessions that involve an assessment of your balance on a specialized device called a forceplate. You will be asked to arrive for testing wearing running shoes and shorts. Each test session will last approximately 60 minutes. Each session will be separated by 24 hours. You will need to report to the Human Performance Lab at the University of Delaware to complete the testing. The two test sessions are explained here:

<u>Test Session I</u> - you will complete two questionnaires (ankle injury history and CAIT). The ankle injury history questionnaire will also ask you about your age, height, weight, and gender. This will be followed by:

Single-Leg Quiet Standing Task: You will stand on the test leg (previously injured or unstable ankle) with your hands on your hips, and your non-stance leg bent comfortably at your side. The test leg in subjects assigned to the CONT will be randomly determined by a coin flip, right vs. left. You will be given practice trials to familiarize yourself with the task. A one minute rest will be given between practice trials and test trials. There will be three test trials with the eyes open and three with the eyes closed, ten seconds each in length. If your non-stance leg touches down at any time during the trial, it will be recorded as a failed trial and repeated.

Ankle Taping: After your balance has been assessed you will be asked to sit on the taping table to have your test ankle taped using the procedures shown in the image below. If you have any known allergies to tape adherent/spray please indicate that to the investigator.



We will then repeat the balance testing as described above. At the conclusion of the testing we will ask that the tape remain in place for 24 hours. Subjects are able to shower during this period as the tape will remain in place. You will report back at the end of this 24 hour period for test session II.

Test Session II - At 24 hours you will return to the Human Performance Laboratory for a final series of ankle balance tests as described above. The tape will then be removed and the balance testing will be conducted one more time.

CONDITIONS OF SUBJECT PARTICIPATION

All of the data will be kept confidential. Your information will be assigned a code number. The list connecting your name to the 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, but the coded data will be kept indefinitely on a secured electronic file device (in case the results are needed in future analysis). Your name will not be used in conjunction with this study. In the event of physical injury during participation, you will receive first aid. If you require additional medical treatment, you will be responsible for the cost. You will be removed from the study if you experience any injury that interferes with the results or prevents you from completing it. There are no consequences for withdrawing from the study and you can do so at any time.

RISKS AND BENEFITS

There are no risks to you for participating. Minor skin irritation from the tape adherent/spray may occur in those with known allergies to this chemical. It is important that you let the examiner know if you have any past allergies to the spray. In the case of a known allergy the tape adherent/spray will not be used.

FINANCIAL CONSIDERATIONS

There will be no compensation for participating in this study. There will be no cost to you, the subject, for participating in the study. Transportation is provided on campus to the testing site and all materials will be provided by the researcher.

CONTACTS

Christina Shields (410) 279-3840 or shieldsc@udel.edu & Dr. Thomas W. Kaminski (302) 831-6402 or kaminski@udel.edu Questions regarding the research study can be directed to the above email addresses.
For questions of concerns about the rights to the individuals who agree to participate in the study:
Human Subjects Review Board, University of Delaware (302) 831-2137

ASSURANCE

Participation in this study is completely voluntary. You may stop at any time during the testing without penalty. Refusal or choosing to discontinue participation in this study is the right of the individual, with no loss of benefits to which the subject is otherwise entitled.

CONSENT SIGNATURES

Subject Consent Signature Date

Principal Investigator Signature Date

Signed consent forms will be retained by the researcher for three years after completion of the research.

Appendix B

CAIT QUESTIONNAIRE

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

	LEFT	RIGHT	Score
1. I have pain in my ankle			
Never	□	□	5
During sport	□	□	4
Running on uneven surfaces	□	□	3
Running on level surfaces	□	□	2
Walking on uneven surfaces	□	□	1
Walking on level surfaces	□	□	0
2. My ankle feels UNSTABLE			
Never	□	□	4
Sometimes during sport (not every time)	□	□	3
Frequently during sport (every time)	□	□	2
Sometimes during daily activity	□	□	1
Frequently during daily activity	□	□	0
3. When I make SHARP turns, my ankle feels UNSTABLE			
Never	□	□	3
Sometimes when running	□	□	2
Often when running	□	□	1
When walking	□	□	0

	LEFT	RIGHT	Score
4. When going down the stairs, my ankle feels UNSTABLE			
Never	□	□	3
If I go fast	□	□	2
Occasionally	□	□	1
Always	□	□	0
5. My ankle feels UNSTABLE when standing on ONE leg			
Never	□	□	2
On the ball of my foot	□	□	1
With my foot flat	□	□	0
6. My ankle feels UNSTABLE when			
Never	□	□	3
I hop from side to side	□	□	2
I hop on the spot	□	□	1
When I jump	□	□	0
7. My ankle feels UNSTABLE when			
Never	□	□	4
I run on uneven surfaces	□	□	3
I jog on uneven surfaces	□	□	2
I walk on uneven surfaces	□	□	1
I walk on a flat surface	□	□	0
8. TYPICALLY, when I start to roll over (or "twist") on my ankle, I can stop it			
Immediately	□	□	3
Often	□	□	2
Sometimes	□	□	1

	LEFT	RIGHT	Score
Never	□	□	0
I have never rolled over on my ankle	□	□	3
9. After a TYPICAL incident of my ankle rolling over, my ankle returns to “normal”			
Almost immediately	□	□	3
Less than one day	□	□	2
1–2 days	□	□	1
More than 2 days	□	□	0
I have never rolled over on my ankle	□	□	3

NOTE. The scoring scale is on the right. The scoring system is not visible on the subject’s version.

Appendix C

ANKLE HEALTH HISTORY QUESTIONNAIRE

University of Delaware
Ankle Study Inclusion Questionnaire

Subject Code Number ____
Age__________________ Height (cm)______________ Mass (kg)_____________
Phone Number ________________________ Email _________________________

1. Have you ever sprained your ankle before? YES NO

2. If yes: which ankle? Right Left

3. Number of sprains Right:____ Left:____

4. Approximately- when did you last sprain your ankle?

   ____

5. Do you ever have episodes of your ankle "giving way" or "rolling over" during daily activity (athletic or otherwise)? YES NO

6. Have you ever fractured your ankle before? YES NO

7. Have you ever had any injuries to your knees? YES NO
   If yes, please explain:

8. Have you ever had surgery on any part of your lower extremities:

YES NO

If yes, please explain:

9. Are you currently being treated for an ankle or lower leg injury?

YES NO

Appendix D

TABLES

Table 2: Main Effects for COP and TTB Variables

Dependant Variable	Main Effect	F	P-Value
COP-Dist ML	Condition	1.796 (3,171)	0.175
	Group	1.211 (2,57)	0.306
	Interaction	0.648 (6,171)	0.612
COP-SD ML	Condition	0.443 (3,171)	0.643
	Group	0.051 (2,57)	0.951
	Interaction	1.000 (6,171)	0.411
COP-Range ML	Condition	1.241 (3,171)	0.291
	Group	0.184 (2,57)	0.833
	Interaction	0.858 (6,171)	0.485
COP-%Range ML	Condition	1.272 (3,165)	0.283
	Group	0.946 (2,55)	0.394
	Interaction	0.811 (6,165)	0.512
COP-Dist AP	Condition	2.228 (3,171)	0.087
	Group	0.493 (2,57)	0.613
	Interaction	1.075 (6,171)	0.379
COP-SD AP	Condition	0.269 (3,171)	0.823
	Group	4.309 (2,57)	0.018 *
	Interaction	0.717 (6,171)	0.619
COP-Range AP	Condition	0.831 (3,171)	0.479
	Group	4.918 (2,57)	0.011 *
	Interaction	1.503 (6,171)	0.180
COP-%Range AP	Condition	0.833 (3,168)	0.478
	Group	1.947 (2,56)	0.152
	Interaction	1.464 (6,168)	0.194
TTB-#Min ML	Condition	0.623 (3,168)	0.558
	Group	1.844 (2,56)	0.168
	Interaction	1.297 (6,168)	0.272
TTB-MeanMin ML	Condition	1.607 (3,150)	0.190
	Group	0.298 (2,50)	0.743
	Interaction	2.099 (6,150)	0.057

TTB-AbsMin ML	Condition Group Interaction	3.610 (3,159) 0.665 (2,53) 1.566 (6,159)	0.015 * 0.518 0.160
TTB-SD ML	Condition Group Interaction	5.710 (3,138) 0.072 (2,46) 1.422 (6,138)	0.002 * 0.930 0.219
TTB-#Min AP	Condition Group Interaction	0.973 (3,171) 0.862 (2,57) 0.617 (6,171)	0.391 0.428 0.675
TTB-MeanMin AP	Condition Group Interaction	1.022 (3,150) 0.836 (2,50) 1.560 (6,150)	0.357 0.440 0.198
TTB-AbsMin AP	Condition Group Interaction	0.889 (3,171) 1.545 (2,57) 1.099 (6,171)	0.448 0.222 0.364
TTB-SD AP	Condition Group Interaction	3.318 (3,141) 2.109 (2,47) 1.120 (6,141)	0.029 * 0.133 0.354

* indicates a significant main effect for the specified variable ($p \leq 0.05$).
COP: center of pressure, TTB: time to boundary, Dist: distance, SD: standard deviation, #Min: number of minima, MeanMin: mean of the minima, AbsMin: absolute minima, ML: mediolateral, AP: anteriorposterior.

Table 3: Significant Group Differences for Traditional COP and TTB Variables

Dependent Variable	Group Main Effect	Means (m) and SD
COP-SD AP	0.018^{α}	AI: 0.0135 * ± 0.0030 PCOP: 0.0121 ± 0.0021 CNT: 0.0119 ± 0.0018
COP-Range AP	0.011^{α}	AI: 0.075*† ± 0.017 PCOP: 0.065 ± 0.012 CNT: 0.065 ± 0.012

α Indicates a significant difference between groups (ankle instability, copers, control) for the given variable ($p \leq 0.05$).
* Indicates significant difference from healthy controls ($p \leq 0.05$).
† Indicates significant difference from copers ($p \leq 0.05$).
COP: center of pressure, SD: standard deviation, AP: anteroposterior, AI: ankle instability group, PCOP: copers group, CNT: control group

Table 4: Significant Condition Differences for Traditional COP and TTB Variables

Dependent Variable	Condition Main Effect	Means (s) and SDs	Means (s) and SDs by Group
TTB-AbsMin ML	0.015^{α}	Pre: 0.116 ± 0.064	AI: 0.131 ± 0.063
			PCOP: 0.112 ± 0.050
			CNT: 0.106 ± 0.078
		KT-1: 0.130 ± 0.064	AI: 0.144 ± 0.063
			PCOP: 0.110 ± 0.560
			CNT: 0.137 ± 0.071
		KT-24: 0.133 * ± 0.065	AI: 0.149 ± 0.057
			PCOP: 0.120 ± 0.061
			CNT: 0.131 ± 0.074
		Post: 0.130 ± 0.063	AI: 0.135 ± 0.070
			PCOP: 0.129 ± 0.061
			CNT: 0.127 ± 0.061
TTB-SD ML	0.002^{α}	Pre: 1.383 ± 1.275	AI Pre: 1.889 ± 1.861
			PCOP Pre: 1.179 ± 0.894
			CNT Pre: 1.183 ± 0.955
		KT-1: 1.975 ± 1.786	AI KT-1: 1.942 ± 1.541
			PCOP KT-1: 2.331 ± 2.359
			CNT KT-1: 1.580 ± 1.069
		KT-24: 0.926†,†† ± 0.486	AI KT-24: 0.818 ± 0.427
			PCOP KT-24: 0.853 ± 0.356
			CNT KT-24: 1.107 ± 0.626
		Post: 1.780 ± 1.696	AI Post: 1.657 ± 1.703
			PCOP Post: 1.505 ± 1.440
			CNT Post: 2.214 ± 1.973
TTB-SD AP	0.029^{α}	Pre: 3.602 ± 4.659	AI Pre: 2.848 ± 4.910
			PCOP Pre: 5.551 ± 5.672

			CNT Pre: 2.390 ± 2.563
		KT-1: 1.724 ± 1.932	AI KT-1: 2.263 ± 2.024
			PCOP KT-1: 1.144 ± 0.968
			CNT KT-1: 1.819 ± 2.430
		KT-24: 2.138 ± 2.718	AI KT-24: 2.031 ± 2.616
			PCOP KT-24: 2.598 ± 3.194
			CNT KT-24: 1.793 ± 2.388
		Post: 3.394 ± 4.253	AI Post: 3.229 ± 3.136
			PCOP Post: 4.253 ± 5.280
			CNT Post: 2.721 ± 4.070

α Indicates a significant difference between condition (pre-test, immediately following tape application, twenty-four hours following tape application, and post-test) for the indicated variable.
* Indicates a significant difference from pre-test ($p \leq 0.05$).
† Indicates a significant difference from immediately following tape application (KT-1) ($p \leq 0.05$).
†† Indicates a significant difference from post-test ($p \leq 0.05$).
COP: center of pressure, TTB: time to boundary, Dist: distance, AbsMin: absolute minima, ML: mediolateral, AP: anteroposterior, IMMED: immediately following tape application, AI: ankle instability group, PCOP: copers group, CNT: control group

Appendix E

SPECIFIC AIMS

Ankle sprains are one of the most common injuries among physically active people, accounting for approximately 15% of all injuries seen in sport and physical activity (28). Ankle sprains account for approximately 800,000 emergency room visits a year in the United States amounting to an estimated cost of approximately 160 million dollars each year.(28,61) Reports estimate that 40-70% of ankle sprains result in FAI, which can include recurrent sprains, chronic pain, crepitus, instability, or weakness at the ankle joint.(15,54,61) These problems may be attributed to impaired proprioception, impaired postural control, and reduced muscular strength following the initial sprain.(22)

Various postural control measures have demonstrated that a difference exists between healthy control ankles and those with FAI. Munn et al.(42) and Arnold et al.(1) performed separate meta-analyses on different measures of postural control and both determined that balance deficits do occur in functionally unstable ankles. Munn et al.(42) determined that single-leg postural sway assessment can effectively distinguish between healthy controls and FAI (Table 5). Measures related to postural sway displacement, such as area of confidence ellipse, total sway, lateral sway, and mean sway, resulted in a medium effect size, and reach distances for the Star Excursion Balance Test (SEBT) resulted in a small effect size.(42)

Table 5: Postural Control Measures Differences between FAI and Healthy Ankles

	SDM	P-Value
PS-D	0.6	0.002*
SEBT	0.4	0.009*
TTS (ML)	0.6	0.0001*
TTS (AP)	0.7	0.0001*

The ability of postural control measures to demonstrate differences between FAI and healthy controls from Munn et al.(42) meta-analysis; * significant difference ($p<0.05$) (PS-D – Postural Sway Displacement, SEBT – Star Excursion Balance Test, TTS – Time to Stabilization, ML – Medial/Lateral, AP – Anterior/Posterior, SDM – Standard Difference of the Means)

Arnold et al.(1) examined the presence of balance deficits related to FAI by splitting the single-leg postural sway assessments into sub-groups. They classified static postural control measures into those related to the calculation of an area or confidence ellipse, those calculated as distance in the antero-posterior and medial-lateral directions, those calculating the time it would take the center of pressure (COP) to reach a certain point, those related to the speed of the COP, and other measures.(1) The dynamic tests consisted of the SEBT and time to stabilization (TTS) measurements. All measures differentiated between healthy controls and FAI, except for those related to the area of the COP. Stationary time measurements, such as time to boundary, and TTS had the largest standard differences of the mean (SDM) between healthy controls and FAI (Table 6).(1)

A variation on standard COP measures is time-to-boundary (TTB). Time to boundary is a measure that estimates the amount of time it would take for a subject's center of pressure to reach the boundary of the base of support if it were to continue in the same direction at its instantaneous velocity.(23) A lower time to boundary is indicative of greater postural instability.(23) Time to boundary has been proven to be valid and reliable and may be a particularly effective tool to monitor change between pre and post test data.(23) In a meta-analysis by Arnold et al.(1) TTB was among the best measures at detecting differences between healthy controls and subjects with FAI. Also, previous research has effectively used TTB to demonstrate a difference between pre and post test results of a healthy control and FAI group in a joint mobilization intervention study.(27)

Table 6: FAI vs. Healthy Control Ankles from Arnold et al.

	SDM	P-Value
Area	0.243	0.138
Linear	0.451	0.002*
Velocity	0.225	0.014*
Time	1.818	0.000*
Other	1.035	0.024*
Overall Static	0.324	0.001*
SEBT	0.287	0.000*
TTS	0.608	0.000*
Overall Dynamic	0.336	0.001*

The ability of postural control measures to demonstrate differences between FAI and healthy controls from Arnold et al.(1) meta-analysis; * significant difference ($p<0.05$) (SEBT – Star Excursion Balance Test, TTS – Time to Stabilization, SDM – Standard Difference of the Means)

The use of potential copers as a comparison group may reveal factors that influence whether someone will become a coper or develop FAI following a lateral ankle sprain.(63) Potential copers are defined as those who suffer a lateral ankle sprain but do not experience any subsequent injuries to that ankle.(4,24,63) A recent study by Wikstrom et al.(63) revealed that certain measures of postural control result in a difference between potential copers and FAI. They determined that COP velocity values and center of mass-center of pressure moment values were able to differentiate potential copers from unstable ankles.(63)

Kinesio® tape is a special kind of tape that can be stretched to 130-140% of its original length and is approximately the same thickness as human skin.(20) Kinesio Taping® is reported to restore proper muscle function by assisting weak muscles, improve blood flow and lymphatic drainage, decrease pain through neurological stimulation, and reduce muscle spasms leading to correction of abnormal joint position.(20) Another suggested function is improved proprioception through increased mechanoreceptor stimulation.(44) Proprioception is defined as the combined neural input from mechanoreceptors in the joint capsule, ligaments, muscles, tendons, and skin to the central nervous system.(52) Balance training has resulted in decreased symptoms of FAI, and proprioceptive improvements have been produced with balance training; therefore, we contend that the purported proprioceptive benefits of Kinesio® tape will improve postural control deficits in those with FAI. In addition, we argue, that the healthy controls and potentials copers may also see proprioceptive benefits from the tape.

Specific Aim 1: To determine if there are postural control differences between healthy controls, potential copers, and those with FAI, among the physically active, as assessed by COP measures and TTB measures.

Hypothesis 1.1: There will be a statistically significant difference in measures of COP and TTB between healthy controls and individuals with FAI as well as a significant difference between potential copers and individuals with FAI. There will be no significant difference between healthy controls and potential copers.

Specific Aim 2: To determine if the application of Kinesio® tape to the ankle will improve postural control in physically active individuals with FAI immediately following application of the tape and 24 hours following application. In addition, to determine the effect of Kinesio® tape on the healthy controls and potential copers.

Hypothesis 2.1: There will be a statistically significant improvement between pre and posttest COP and TTB measures in the FAI group immediately following application of Kinesio® tape.

Hypothesis 2.2: There will be a statistically significant improvement between pre and posttest COP and TTB measures in the healthy control and potential copers group immediately following application of Kinesio® tape.

Hypothesis 2.3: There will be a statistically significant improvement between pre and posttest COP and TTB measures 24 hours following tape application in the FAI group.

Hypothesis 2.4: There will be a statistically significant improvement between pre and posttest COP and TTB measures in the healthy control or potential copers groups 24 hours following tape application

Appendix F

BACKGROUND AND SIGNIFICANCE

Lateral ankle sprains are one of the most common injuries in sport and 40-70% of athletes who suffer a lateral ankle sprain develop FAI.(15,65) Each year in collegiate sports there are approximately 11,000 ankle sprains.(28) There are certain extrinsic and intrinsic factors that may predispose someone to developing ankle instability. Gender, age, and race are intrinsic factors that have been investigated in relation to ankle sprains; however, only age can be used as a predictor.(61) Similarly, extrinsic factors such as surface and sport have been considered, with most ankle sprains occurring during participation in athletics and the most occurring during basketball activities.(61)

Following an initial ankle sprain, various types of instability may persist. Across the literature, there has been some lack of clarity on the distinction between mechanical instability, functional instability, and chronic instability. Delahunt et al.(10) surveyed the literature and established operational definitions for these three terms. Mechanical instability refers to excessive anterior or inversion laxity, as assessed with instrumented or manual stress tests. Functional instability refers to frequent episodes of "giving way" of the ankle and feelings of ankle joint instability. Chronic instability refers to a subject with both mechanical and functional instability whose residual symptoms have lasted at least one year following the initial sprain.(10)

The talo-crural joint is made up of the articulations between the dome of the talus and the ankle mortis, made up of the medial and lateral malleoli, and the tibia.(22) When the joint is fully loaded in weight-bearing, the bony structures provide a significant amount of stability to the joint.(22) The ankle joint receives additional support from static restraints such as ligaments, combined with dynamic restraints, such as muscles and tendons.(22) Ankle sprain pathology primarily involves the lateral ligamentous structures. Some people are able to maintain stability following an ankle sprain using other restraint systems while others develop long term instability. In those individuals with FAI the damage to the ligamentous mechanoreceptors impairs afferent nerve information leading to alterations in dynamic stability and neuromuscular control. This can be related to loss of sensation from mechanoreceptors.(45,51)

Research has been performed on factors that affect whether someone with mechanical instability will develop FAI or become a potential coper.(11,12,63) Potential copers are those who suffer an ankle sprain but do not suffer any recurrent injury to that ankle.(63) Potential copers may allow for the identification of factors that influence whether or not someone develops FAI following an acute lateral ankle sprain resulting in mechanical instability.

Research supports that proprioceptive and postural control deficits are present in athletes with FAI when compared to healthy ankles and compared to potential copers.(4,9,11,12,46) The focus of this review will be to discuss postural control deficits following a lateral ankle sprain, describe assessment tools used to identify FAI, and discuss how Kinesio Taping® protocols may improve impaired proprioception and postural control at the ankle.

5.1 Postural Control

Postural control deficits have been linked to the sequelae of FAI following a lateral ankle sprain.(12) Postural control can be either static or dynamic in nature.(64) Static postural control is defined as maintaining stability over a stationary base of support. Dynamic postural control is defined as maintaining stability over a moving base of support.(64) A variety of both static and dynamic postural control measures have been used to demonstrate postural control changes related to FAI.

5.1.1 Static Measures

Static postural control measures that have been used include static balance on a forceplate, the Balance Error Scoring System (BESS), and foot lifts.(1) Static standing on a forceplate has provided a variety of variables to examine. The subject's COP is tracked using forceplate technology and measures of postural stability can be extracted from this information. Traditionally these measures include:

1) area of the confidence ellipse - a representation of the total excursion of the center of pressure made through creating an ellipse containing approximately 85% of the total data points

2) excursion length - a quantification of the distance the center of pressure traveled in the medial/lateral and anterior/posterior directions

3) mean sway - an average of the distance between the center of the base of support and the location of each data point.(1)

Two other measures that can be investigated are COP velocity and time to boundary measures. A meta-analysis by Arnold et al.(1) determined that time related measures, such as TTB, had the largest standard difference of the mean between the healthy control and FAI groups and area related measures had the smallest standard difference of the mean (Table 2). In other words, a larger standard difference of the mean indicates a greater difference between the healthy control and FAI groups.

Time to boundary (TTB) is a variation on COP related calculations, that examines different aspects of postural control versus traditional single-leg quiet standing measures. Traditional COP data examines the total length of the path of a subject's COP, the total area of the subject's excursion, and the standard deviation of the subject's COP in both the anterior/posterior and medial/lateral directions. To clarify, these measures provide an indication of how close a subject's center of pressure stays to their center of mass throughout a trial. Time to boundary looks at the amount of time it would take for a person's COP to reach the boundary of their base of support if it were to continue at its instantaneous trajectory and velocity at multiple times during a quiet standing trial.(23) The base of support is modeled as a rectangle to allow for separation of the base of support into mediolateral and anterioposterior portions (Figure 1).(23) Time to boundary has been used in bipedal stance to assess differences in postural control among age groups as well as in patients with Parkinson's disease.(60) Hertel et al.(23) hypothesized that TTB might be adaptable to single-leg stance to assess postural control changes in those with FAI. Time to boundary was compared to traditional COP measures to determine intrasession reliability and correlation between traditional COP measures and TTB. Hertel et al.(23) demonstrated that TTB had consistently higher intrasession reliability than traditional COP data and demonstrated that the correlation between the two measures was low, indicating that the two measures looked at different aspects of postural control. Another study by Hertel et al.(21) looked at the ability of TTB to distinguish CAI from a control group using only eyes open trials. Their results determined that five out of six TTB measures resulted in significantly lower numbers for the ankle instability group compared to the control group. McKeon et al.(37) looked at a similar question but utilized a more heterogeneous sample and looked at TTB during eyes open and eyes closed single-leg quiet standing. McKeon et al.(37) did not find any of the TTB measures to be significantly different between the ankle instability and healthy controls group with the eyes open, however they did find that four out of six TTB measures were significantly lower for the ankle instability group with eyes closed as compared to the control group. A recent study by Knapp et al.(33) examined whether or not a single TTB measure or traditional COP measure could predict if a subject has ankle instability. The results indicated that while three variables attained significance, the likelihood ratios indicated such a small shift that it was not clinically relevant and, therefore; one variable cannot effectively be used to determine if a subject has ankle instability.(33)

Two studies have used TTB as one of their dependent variables to look at the effects of various treatments or interventions on ankle stability. McKeon et al.(40) used TTB to look at ankle stability with and without an injection of lidocaine into the lateral ankle. Hoch et al.(27) used TTB to look at whether there was a change in postural control following joint mobilization. Both of these studies resulted in a significant difference between the control and intervention conditions, demonstrating that TTB can be sensitive to changes in postural control.

The BESS test is another static assessment of postural control. The subject balances on stable ground and then on an unstable surface in three different foot positions, double-leg, single-leg, and tandem stance.(25,49) The subject balances with their eyes closed for 20 seconds in each condition and an observer counts the number of errors. An error is counted if the subject removes their hands from their iliac crests, takes a step or stumbles and falls, opens their eyes, abducts or flexes their hip to 30 degrees, lifts the forefoot or heel off of the test surface, or remains out of the proper testing position for greater than 5 seconds.(49)

Counting foot lifts is another subjective method of evaluating static postural control that has demonstrated differences between healthy control ankles and FAI.(1) The test is quick and simple, requiring the subject to balance on one foot with their eyes closed and have an observer count the number of times the subject lifts a portion of the foot off the ground in thirty seconds.(25)

Of the static postural control measures, the time measures for static single-leg balance on a forceplate were best at demonstrating differences between healthy ankles and FAI, followed closely by the counting foot lifts method.(1) The BESS test also demonstrated differences between the healthy ankles and FAI but to a lesser magnitude than is seen with time measures and foot lifts.(1) Counting foot lifts and the BESS test are useful because they can be performed in the clinical setting with a minimal amount of equipment. Although a forceplate is more expensive and typically located in a laboratory setting rather than a clinical setting, it is useful because a variety of variables can be obtained while only having the subject perform one task. For example, information related to the COP velocity, area, and range of excursion provides information about a different aspect of a subject’s postural control than time to boundary measures, however; all of those variables can be collected at once.(23)

5.1.2 Dynamic Measures

The two main dynamic measures used to study postural control changes include TTS and the SEBT.(1) Time to stabilization is a measure that determines the amount of time that it takes to reach a stable condition following a dynamic movement or perturbation.(50) The Star Excursion Balance Test (SEBT) is a measure of postural control that involves the subject standing on the test leg with their hands on their hips in the center of a grid with eight rays placed on the floor. The rays are situated at 45 degree angles to each other and the subject is instructed to reach as far along each ray as they can without losing their balance.(32,48)

The meta-analysis by Arnold et al.(1) demonstrated that TTS is a superior method of distinguishing FAI from healthy ankles as compared to the SEBT (Table 2).(1) However, the SEBT is useful because it is relatively inexpensive and can be easily performed in the athletic training room whereas TTS requires a forceplate. Both tests demonstrated a difference between healthy ankles and FAI but TTS seems to be the test to use for dynamic postural stability when access to a forceplate is available.(1)

5.2 Kinesio Taping®

Kinesio® tape is a specialty tape, developed by Kenso Kase in Japan in 1996, that can be stretched to 130-140% of its original length and is approximately the same weight and thickness as human skin.(66) It is advertised that the tape will stay in place and be effective for three to five days of continuous wear. Kinesio Taping® is reported to have four main functions: restore proper muscle function by assisting weak muscles, improve blood flow and lymphatic drainage, decrease pain through neurological stimulation, and reduce muscle spasms leading to correction of out of place joints.(20,66) Another suggested function is improved proprioception through increased mechanoreceptor stimulation.(44)

The ability of Kinesio Taping® to increase muscle strength was looked at by three studies. Fu et al.(17) and Chang et al.(5) looked at increases in thigh strength and grip strength respectively in healthy college athletes. Both studies resulted in no statistically significant difference between the without tape and with tape conditions for muscle strength.(5,17) However, Slupik et al.(53) recorded significantly increased vastus medialis peak torque values post tape application as compared to baseline in healthy individuals. Specifically, Slupik et al.(53) recorded significantly higher peak torque values at 24 hours and 72 hours post application, but not at 96 hours post application or immediately following application.(53) Slupik et al.(53) also looked at peak torque values of the vastus medialis 48 hours after removal of the tape and determined that despite the tape being removed after 24 hours of wear, the subjects still had significantly higher peak torque values, as compared to baseline, 48 hours after tape removal.(53) Despite not finding increases in grip strength, Chang et al.(5) achieved a statistically significant difference in force sense values, which suggests that the tape may have some positive effect on the mechanoreceptors in the joints of the hand.

Muscle activation, as assessed by electromyography (EMG) has also been looked at with respect to Kinesio Taping®. Hsu et al.(30) and Huang et al.(31) both achieved increases in muscle activation to the area that the tape was applied, the lower trapezius and medial gastrocnemius respectively. Briem et al.(3) did not find any increase in peroneal activation when a single strip of the tape was applied to the lateral lower leg of subjects with ankle instability. This study looked at muscle activation of the peroneal muscle following a sudden inversion perturbation and looked only at muscle activation of the peroneal musculature.(3) Hsu et al.(30) looked at the effects of Kinesio Taping® on individuals with shoulder impingement and determined that in addition to increased lower trapezius activation, the subjects had improved scapular kinematics as assessed by motion analysis software. Huang et al.(31) examined muscle activation of the medial and lateral heads of the gastrocnemius and the soleus during maximal vertical jumping in healthy individuals and achieved a significant increase in muscle activation of the medial gastrocnemius as compared to baseline during a maximal vertical jump.

The ability of Kinesio Taping® to enhance proprioception was examined in three studies. Proprioception is defined as the combined neural input from mechanoreceptors in the joint capsule, ligaments, muscles, tendons, and skin to the central nervous system.(12) Cortesi et al.(7) looked at the effects of Kinesio Taping® on postural control involving multiple sclerosis (MS) patients. They examined forceplate data for individuals with MS with and without the Kinesio Taping® applied and achieved a significant decrease in total distance of sway in the anterior/posterior direction with the application of the tape.(7) None of their measures in the medial/lateral plane were significantly different between the with- and without- tape conditions.(7) Halseth et al.(20) and Murray and Husk(44) examined the effects of Kinesio Taping® on measures of joint position sense at the ankle joint. Halseth et al.(20) tested healthy participant's ability to reproduce joint positions between 1° and 35° of plantar flexion and between 1° and 10° of inversion with the ankle in 20° of plantar flexion. No significant difference was achieved in the amount of error between the without tape and with tape.(20) This may be due to the fact that the participants were healthy ankles that did not have a proprioceptive deficit. Murray and Husk(44) examined joint position sense in participants with a history of ankle sprain. They measured their participants' ability to reproduce 26° and 10° of plantar flexion as well as 8° of dorsiflexion while blindfolded.(44) They determined that with the tape on there was a statistically significant improvement when the participants were asked to reproduce 10 degrees of plantar flexion as compared to the pretest measures without the tape.(44) No significant differences were achieved for the other two positions.

Limited research has been done on Kinesio Taping® in general but even fewer studies have been done looking at its effects on injured populations. More studies should be done investigating the effects of Kinesio Taping® on athletes with injuries or functional deficits to see if the purported functions can be consistently measured.

5.3 Summary

FAI has been reported to result in measurable postural control deficits. Time to boundary has been effective in distinguishing stable from unstable ankles and has recently been suggested as an effective tool for establishing pre and post test differences, making it a useful measure for an intervention study. Kinesio Taping® is a relatively new technique that may help reduce functional deficits and improve performance. There is very limited research on the effects of Kinesio Taping® on functionally unstable ankles. This project intends to examine the effects of Kinesio Taping® on postural control deficits in physically active individuals immediately following application as well as 24 hours post application.

Appendix G

IRB Approval Letter

Please note that University of Delaware IRB has taken the following action on IRBNet:

Project Title: [224524-1] "The Effects of Kinesiology Taping on Postural Control Deficits in Individuals with Ankle Instability"
Principal Investigator: Thomas Kaminski

Submission Type: New Project
Date Submitted: March 3, 2011

Action: APPROVED
Effective Date: March 4, 2011
Review Type: Expedited Review

Should you have any questions you may contact Jody-Lynn Berg at jlberg@udel.edu.

Thank you,
The IRBNet Support Team

www.irbnet.org

Appendix H

IRB Approval Extension Letter

DATE: February 6, 2012

TO: Thomas Kaminski
FROM: University of Delaware IRB

STUDY TITLE: [224524-2] "The Effects of Kinesiology Taping on Postural Control Deficits in Individuals with Ankle Instability"

SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: February 6, 2012
EXPIRATION DATE: March 3, 2013
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 4

Thank you for your submission of Continuing Review/Progress Report materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years. Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Jody-Lynn Berg at (302) 831-1119 or jlberg@udel.edu. Please include your study title and reference number in all correspondence with this office.