THE EFFECT OF KINESIO TEX TAPE IN PARTICIPANTS WITH CHRONIC ANKLE INSTABILITY AFTER A FATIGUE PROTOCOL

by

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ABSTRACT

JASON HERBERT CLINE. The effect of Kinesio Tex tape in participants with chronic ankle instability after a fatigue protocol. (Under the direction of DR. TRICIA TURNER)

Lateral ankle sprains are one of the most common sports related injuries in the United States. The development of chronic ankle instability (CAI) is estimated to occur in 30-80% of people after the initial sprain. Several factors contribute to recurrent lateral ankle sprains and feelings of "giving way" to include mechanical and functional instabilities. Of the therapeutic interventions used to treat CAI, Kinesio Tex (KT) tape has recently gained popularity. This study investigated the effects of KT tape among those who have CAI before and after a fatigue protocol. We examined the effects of KT tape relative to Standard tape and a Control in dynamic and static postural control outcome measures. Secondary outcome measurements included plantar flexion strength and a visual analog scale (VAS) to provide insight to the psychological aspect KT tape may provide. A total of 24 subjects were recruited and underwent 3 sessions separated by at least 7 days. Subjects were randomly assigned to groups by counterbalancing them in the order they appeared in the study. The results identified better SEBT scores in the KT tape condition relative to Standard tape condition. However, Baseline measurements were also better than Standard tape condition, but no different than the KT tape condition. No significant findings were identified in static postural control measurements. The VAS results identified significant findings in both tape conditions relative to Baseline and Control conditions. Also, the fatigue protocol failed to identify significant results in dynamic and static postural control. In conclusion, the lack of significant findings does not support the use of KT tape to improve postural control.

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LIST OF ABBREVIATIONS

CAI – chronic ankle instability

KT – Kinesio Tex

SEBT – star excursion balance test

PF – plantar flexion

VAS – visual analog scale

COP – center of pressure

TTB – time to boundary

IdFAI – Identification of Functional Ankle Instability

CHAPTER 1: INTRODUCTION

1.1 Background

Sport related injuries are inevitable, especially in sports where constant changing of direction and jumping is occurring. One of the most common injuries seen in sports is a lateral ankle sprain.[1,2] It is estimated that lateral ankle sprains occur at a rate of one sprain per 10,000 athletes daily.[2] After the initial injury, 30-80% of people develop chronic ankle instability[3] resulting in recurrent lateral ankle sprains and feelings of "giving way."[1,4,5] Not only is this a burden to the individual, but also costs the healthcare system billions of dollars annually.[6] This seemingly nuisance of an injury can be quite debilitating in the long run. Researchers have found mechanical and functional instabilities they believe are contributing factors to the chronic issues seen in patients following lateral ankle sprains.[2,5,7-11] There are a wide range of therapeutic interventions currently used to treat acute ankle sprains and the resulting chronic issues. One such intervention that has gained popularity recently has been Kinesio Tex (KT) tape. Although like most therapeutic interventions, the scientific data supporting its use are still disputed. Another more common intervention is the use of Standard or Traditional tape such as Johnson and Johnson Coach Athletic Tape.

The degree of ligamentous damage as a result of a lateral ankle sprain varies depending on the amount of force applied to the joint during injury. The mechanical and functional alterations of the joint and surrounding tissues can lead to CAI. Researchers have found hypermobility and hypomobility conditions in subjects with various grades of lateral ankle sprains.[2,8] Hypermobility would be a typical adaptation seen in the joint after injury due to the overstretching of the ligamentous support. On the other hand, hypomobility is also seen with limited range of motion possibly caused by excessive scar tissue or other adaptations in or around the joint. Studies have also shown mechanical instabilities such as abnormal positioning of the lateral malleoli due to the initial injury.[7,12] Functional instabilities dealing with proprioception, neuromuscular control, postural control, and strength have also been well documented throughout the literature.[2,5,6,8-10,13-18] Not only do these mechanical and functional instabilities pose a problem alone, but when neuromuscular fatigue is achieved either through sport, a rehabilitative, or research protocol the individual with CAI demonstrates an abnormal response (e.g. symptoms, such as feeling of giving way or instability, worsen to a greater extent than a healthy control individual) which may place him/her at a greater risk for re-injury.[1,13,16,17]

The evidence supporting the use of KT tape for CAI is non-existent. The lack of scientific data on this therapeutic intervention is shocking considering the popularity KT tape has in today's athletic population and the frequency of CAI development. Therefore, the primary aims of this investigation are: 1) to determine if KT tape is more effective than non-elastic athletic tape at improving static and dynamic postural control in those with CAI, and 2) to determine if KT tape is more effective at mitigating the effect of fatigue on static and dynamic balance in those with CAI. The findings of this study will help clarify the use of KT tape as an effective intervention in the CAI population.

1.2 Purpose/Hypothesis

The purpose of this study will be to identify the effects of KT tape by examining outcome measures of dynamic postural control in college-aged subjects with CAI. This study will have two specific aims:

- To determine if KT tape is more effective than Johnson and Johnson Coach Athletic Tape at improving static and dynamic postural control in those with CAI
- To determine if KT tape is more effective than Johnson and Johnson Coach Athletic Tape at mitigating the effect of fatigue on static and dynamic balance in those with CAI

The following will be specific hypotheses for this study:

- Dynamic postural control but not static postural control outcome measures will improve with application of KT tape relative to Johnson and Johnson Coach Athletic Tape
- Static and dynamic postural control outcome measures will be negatively affected after the fatigue protocol in the non-taped control condition
- Static and dynamic postural control outcome measures will be significantly better after fatigue in those wearing KT tape compared to those wearing non-elastic athletic tape

1.3 Significance

This study is significant because if found effective, KT tape offers a simple method by which to limit the risk of re-injury in a physically active population by improving postural control and mitigating the effects of fatigue on postural control. The majority of studies observing the effects of KT tape only include a healthy population, especially when looking at the ankle. Identifying the effects of KT tape after a fatigue protocol in a population with CAI will begin to provide scientific data to the tape's purported benefits and may lead to changes in clinical practice.

1.4 Limitations

The limitations of the study are noted below.

- Only using one type of fatigue protocol
- Only using one type of KT tape application
- The tape applicator has limited experience with KT tape application
- The tape will only be worn for the time it takes to complete test session

1.5 Delimitations

The delimitations of this study are noted below.

- College-aged individuals age 18-30 with CAI
- Only analyzing dynamic and static postural control outcome measures of SEBT, COP, and TTB
- The use of the VAS to measure subjective data related to the perception of KT tape effectiveness from participants
- The use of the handheld dynamometer to quantify fatigue individually

1.6 Definition of Terms

The following terms will be used throughout this study

- Chronic ankle instability – residual symptoms of giving way, recurrent lateral ankle sprains, pain, swelling, persistent weakness, and decreased function.[19,20]

- Mechanical instability – any alteration in the mechanics of one or more articulations with in the ankle joint complex.[2]
- Functional instability – specific insufficiencies in proprioception, neuromuscular control, postural control, or strength.[2]
- Proprioception – afferent information arising from internal peripheral areas of the body that contribute to postural control, joint stability, and several conscious sensations.[14]
- Neuromuscular fatigue – any reduction in the force-producing capacity of a muscle, measured preferably in a maximal voluntary contraction or in an electrically evoked tetanus.[21]

CHAPTER 2: LITERATURE REVIEW

2.1 Epidemiology

Lateral ankle sprains are one of the most common injuries athletes endure in sport and physical activity.[1,2] The mechanism of injury is typically an excessive inversion and plantar flexion force resulting in overstress to the lateral ankle ligaments.[20] The ankle while in dorsiflexion is at it's most stable position due to the congruency between the dome of the talus and the mortise created by the tibia and fibula. Of the ligaments, which make up the lateral ankle ligament complex, the anterior talofibular ligament (ATFL) is most commonly injured followed by the calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL). Kobayashi and Gamada[6] indicated 73% to 96% of lateral ankle sprains involve the ATFL and 80% involved the CFL.

According to Kannus and Renstrom[22], an estimated 23,000 ankle sprains occur each day in the US, which equates to one sprain per 10,000 people daily. Another study conducted by Hootman et al.[23] claim the incidence of sustaining a lateral ankle sprain to be around 60%. Hootman et al.[23] also observed a higher incidence rate among athletes participating in basketball, soccer, volleyball, and gymnastics as opposed to baseball, softball, and ice hockey. Although this type of injury is common, little is known about the long-term effects that lateral ankle sprains have on the athlete. Ferran et al.[24] reported, 45% of all athletic injuries are ankle sprains and cost the health care system of the United States millions of dollars in treatment costs. Also, based on a survey conducted by Kobayashi and Gamada[6] in 2003, high school soccer and basketball players in the United States were reported to have $1.1 billion in indirect annual medical costs due to lateral ankle sprains.

Unfortunately, people who have sprained their ankle for the first time are susceptible to developing chronic problems in the future. Studies have shown ranges from 30-80% of people who sprain the lateral ligaments of their ankle will develop CAI.[1,4,5] While the definition of CAI varies across studies, the International Ankle Consortium endorses the Delahunt et al.[25] and Kaminski et al.[20] definitions of CAI as the residual symptoms of giving way, recurrent lateral ankle sprains, pain, swelling, persistent weakness, and decreased function. Similarly, Hiller et al.[26] define CAI as the giving way of the ankle, mechanical instability, pain and swelling, loss of strength, recurrent sprain, and functional instability. Mechanical and functional instability definitely play a major role in the acute lateral ankle sprain that develops in to CAI. To understand the structures or functions mechanical and functional systems have on CAI development, we need to define them. Mechanical instability is described as any alteration in the mechanics of one or more articulations with in the ankle joint complex.[2] On the other hand, functional instability is specific insufficiencies in proprioception, neuromuscular control, postural control, or strength.[2]

Further evidence of the long-term consequences of CAI was provided by Hiller et al.[26] who reported 15-64% of people who sustained a lateral ankle sprain had not recovered in 3 years. Additionally, Anandacoomarasa and Barnsley[4] reported that out of forty-seven participants, 74% had persisting symptoms 1.5-4 years after their injury. The lingering symptoms may lead to instability affecting activities of daily life and in some cases the development of post-traumatic osteoarthritis of the ankle.[27] Furthermore, Harrington[28] and Hirose et al.[29] found that 77% of those with CAI developed post-traumatic ankle osteoarthritis.

These profound statistics should be alarming to a clinician dealing with sports related injuries and the general public. Yet, despite these statistics, many continue to view lateral ankle sprains as a minor injury with no lasting effects, when in truth, ankle sprains and their consequences, such as CAI, are a billon dollar burden on the US and deserves the attention of researchers and clinicians to decrease the consequences of CAI.

2.2 CAI Deficits

Following injury to the lateral ankle ligaments, several changes and adaptations occur in attempt to maintain normal function. Deficits related to CAI have been seen throughout the literature as alterations in functional and/or mechanical stability. While these instabilities may occur separately, some literature shows a relation between mechanical and functional instabilities.[2,5,8] However, before talking about instability, classification of ankle stability needs to be defined. Stability related to ankle injury is defined as the state of a joint remaining or promptly returning to proper alignment through an equalization of forces.[14] Changes seen in ankle stability, as observed in people with CAI, can have serious consequences on not only the structures directly involved with the ankle, but proximal lower extremity joints as well.[2,9,30,31]

Mechanical adaptations can include hypermobility or hypomobility of the ankle joint complex, laxity of the lateral ligaments, decrease in range of motion, and alterations in joint kinematics. Mechanical instability is described as any alteration in the mechanics of one or more articulations within the ankle joint complex.[2] Hypermobility due to ligamentous laxity is apparent in lateral ankle injuries at the talocrural and subtalar joints.[2] Excessive motions can be seen by clinicians during a physical evaluation, however the patient may not note perceived instability. Hypomobility of the talocrural joint will limit the joint from reaching full ROM, which is commonly observed as limited dorsiflexion. This limitation will affect the closed pack positioning during the stance phase and place the joint in a more inverted and internal rotated position.[2] A study conducted by Hubbard et al.[8] found a decrease in posterior laxity and posterior-lateral reach distance while performing the Star Excursion Balance Test (SEBT) as a result of altered mobility of the talus.

Another mechanical instability worth noting from the literature is differences in fibular positioning following injury to the lateral ankle. Hubbard et al.[7], in a study looking at unilateral CAI, showed differences in fibular position as a result of anterior positional fault, which developed after initial injury. Hertel[2] also showed the relationship between repetitive insult to the lateral ankle complex, as seen with CAI, and restrictions seen at the inferior tibiofibular joint. Another study, using MRI to measure several positions of the structures creating the ankle complex, found a more anterior position of the fibula to be significantly different when comparing a recurrent ankle sprain group to a control group.[12] Wikstrom and Hubbard[11] also found the positioning of the talus to be significantly more anterior in the CAI group when comparing the involved limb to the uninvolved limb and the matched control limb.

On the other hand, functional instability deals with insufficiencies in proprioception, neuromuscular control, postural control, or strength. Rienmann and Lephart[14] define proprioception as the afferent information arising from internal peripheral areas of the body that contribute to postural control, joint stability, and several conscious sensations. Deficits in proprioception have been reported by several authors to be present not only in those with CAI, but also after an acute first time ankle injury.[5,6]

An early theory commonly cited in the literature on functional ankle deficits comes from Freeman in the 1960s. He claimed these deficits were the result of damaged afferent receptors after ligamentous injury to the ankle. He also stated the damage caused proprioceptive deficits and impaired the CNS from being able to detect the ankle joint accurately in space. This impairment would then lead to an increased risk of re-injury.[5] This theory has been the popular belief and few studies have challenged this theory and found conflicting results. Hoch et al.[32] observed decreases in CAI participants' levels of sensitivity while measuring their threshold of vibrotactile detection. This study also reported higher detection threshold measurements at the heel on those with CAI. These results may suggest that disruption in sensory information of the plantar cutaneous receptors may affect a person's ability to prevent future ankle joint injury. A study conducted by McKeon et al.[33] showed reductions in time to boundary measurements in CAI participants during a single limb stance by altering sensory input via a textured sole within the participant's shoe. However, Konradsen et al.[9], claims that afferent information from the muscles and tendons of the lower leg are strong enough to somewhat make up for the lack of information that would have been received from the ankle. To test this hypothesis, De Carlo and Talbot[30] attempted to stimulate deafferentation by injecting the ATFL with Xylocaine and measure a subjects' proprioception. Their results actually showed an increase in balance time when comparing uninjured to the standardized group which supports the hypothesis of

Konradsen et al.[9] These findings suggest that while impairing the ankle joint other surrounding structures can adequately make up for the loss of afferent information, but this compensation still does not prevent recurrent injury and episodes of giving way in those with CAI.

Neuromuscular impairments have also been studied throughout the literature and according to Hertel[2] are commonly assessed by the reflexive response times of the peroneal muscles to inversion or supination. The peroneus longus and brevis muscles, along with the muscles of the anterior compartment of the lower leg, are important in maintaining the dynamic stability of the ankle. Specifically, the peroneus longus and brevis muscles are critical to the protection of the common mechanism for lateral ankle sprains. The literature has shown the importance of muscle-spindle activity in the peroneal muscles over the articular mechanoreceptors of the ankle and how alterations to the muscle spindles, seen with CAI, may not play as an important role in functional deficits.[34] Hubbard et al.[7] showed a significant correlation between an increased anterior laxity of the ankle with an increased dorsiflexion peak torque. This would suggest that as lateral ankle ligamentous laxity increases, tension of the stabilizing muscles would adapt and increase to protect excessive motion from occurring via a stretch reflex. Another study showed results of neuromuscular impairments with respect to arthrogenic muscle response (AMR) in subjects with CAI at the lower leg muscles as well as the quadriceps and hamstring musculature. Arthrogenic muscle response is defined as an ongoing reflex reaction of the musculature surrounding a joint after distension or damage to structures of that joint.[35,36] This study found facilitation of the quadriceps muscle in the involved limb of patients in the CAI group compared to the uninvolved limb, as well as, bilateral inhibition of the hamstrings compared to the control group. These results suggest that alterations caused by CAI may affect the proximal musculature as well as the musculature adjacent to the ankle joint.

Deficits seen in postural control have consistently been shown in several studies.[2,5,13,18] Postural control is commonly measured using the SEBT. Hertel[2] described impairments of postural control during a single limb stance in subjects with CAI, as well as after an acute ankle sprain. Alterations in postural control have also been seen in center of gravity measurements while balancing on a single leg which may explain why a more "hip strategy" appears to be used in those with CAI.[2,8,13] Hertel[2] also explains how the combination of impaired proprioception and neuromuscular control results in postural control deficits. However, Myo-Hla et al.[34] found conflicting results while injecting an anesthetic agent into the sinus tarsi to deafferenate the receptors in the sinus tarsi. This study showed improvements in feelings of stability while on an unstable surface in the CAI group, which may indicate that the removal of deafferenated receptors can improve postural control. Postural control deficits in CAI participants were observed by Wikstrom et al.[37] in the anterior-posterior stability index and dynamic postural stability index measurements captured during a jump landing. The authors claim these results may be due to a lack of or failure to develop compensatory changes in feed-forward neuromuscular control.[37] Successful compensatory changes to feed-forward neuromuscular control could be the reason people who suffer an acute ankle sprain do not develop CAI.

While mechanical and functional instabilities can be measured with objective measurements, the self-perceived disability of a person is subjective. Typical subjective measurements are completed through questionnaires, such as the Foot and Ankle Disability Index (FADI), Foot and Ankle Disability Index Sport (FADI-S), and Self Reported Questionnaire of Ankle Function (SRQAF). A study conducted by Wikstrom et al.[38] showed how these 3 questionnaires had significantly greater self-perceived disability ratings in the CAI group compared to a control. This study also showed how self-assessed disability questionnaires were able to detect differences significantly better than functional testing, such as the hop test.[38] Donahue et al.[39] showed similar results with self-assessed disability questionnaires in a study comparing the Ankle Instability Instrument (AII) and Cumberland Ankle Instability Tool (CAIT). These authors found that a combination of the AII and CAIT was the most effective in identifying ankle instability. Moreover, Simon et al.[40] conducted a study to develop the Identification of Functional Ankle Instability (IdFAI) self-assessed questionnaire, which is being used in the current study, to clearly define “giving away” and detect characteristics of ankle instability. This study found when participants scored an 11 or higher (out of a total of 37) the IdFAI to had an overall accuracy of 89.6% in diagnosing whether or not the participant had ankle instability.[40] Although there is no self-assessed questionnaire gold standard to use, the IdFAI has been shown to be accurate and reliable in detecting CAI.

Furthermore, CAI can cause impairments on more than just the injured structures. Mechanical and functional instabilities cover a wide range of mechanisms from ligamentous laxity to dynamic postural control. Individually mechanical and functional systems provide various amounts of information to determine the best course of action to respond to various situations. However, together these systems create stability and the ability to adapt to overall demands, which are altered with such an injury as recurrent lateral ankle sprains.

2.3 Fatigue

It is expected that some level of fatigue will be achieved during any sporting event whether in competition or practice. It has been reported that most injuries occur during the final minutes of competition or periods where rest is about to take place, such as half time during American football.[17,41,42] Neuromuscular fatigue is defined as any reduction in the force-producing capacity of a muscle, measured preferably in a maximal voluntary contraction or in an electrically evoked tetanus.[21] Along with the challenges of fatigue alone on the body, an athlete with CAI is thought to have more to overcome to maintain postural control as fatigue progresses. The ability to maintain postural control during athletic events is critical to performance and preventing re-injury.

The effects of fatigue and the alterations seen in the peripheral system are more commonly studied compared to the central nervous system (CNS). Overall, postural control is the result of the visual, vestibular, and somatosensory systems working together to provide the body with information of its surroundings at a particular moment.[13,43] Disruptions in any of these systems places more load on the others and can cause impairments in postural control if the disruption is not overcome. A study conducted by Corbeil et al.[44] induced muscular fatigue in eleven healthy males by repeated ankle plantar-flexion using an ankle training device. They found that fatigue did not alter the amplitude of the center of pressure (COP) oscillations compared to measurements without fatigue. However, this study did show an increase in body sway and instantaneous oscillations in the anterior-posterior direction, suggesting inducing fatigue causes a deficiency in the motor and/or sensory system. Gimmon et al.[41] showed similar results in a study using ten healthy participants where plantar-flexion fatigue was induced and caused an increase in body sway in the anterior-posterior direction as well as center of pressure measurements. One explanation to the alterations seen in these studies could be somatosensory inputs are altered causing deficiencies in neuromuscular and postural control during lower limb muscle fatigue. The somatosensory system is responsible for providing afferent information from receptors located in joints, muscles and other surrounding tissues. Lower limb muscular fatigue can also lead to a decrease in muscle tone causing a decrease in stabilization of the lower limb and increasing the likelihood of an ankle injury. Muscle spindle threshold has been shown to increase with fatigue and subsequently alters afferent feedback resulting in impaired postural control responses.[13,43]

Researchers have also shown how fatigue in proximal leg muscles can negatively impact postural control in those with CAI.[13,42,43,45] Reimer and Wikstrom[42] showed significant deficits in the overall stability index after an ankle fatigue protocol in healthy individuals. This same study showed significant anterior/posterior and medial/lateral stability deficits after both an ankle and hip fatigue protocol. Salavati et al.[45] showed greater impairments in overall, medial/lateral, and anterior/posterior stability indices after a hip fatigue protocol in both the frontal and sagittal plane compared to an ankle fatigue protocol. Gribble and Hertel[43] found larger impairments in center of pressure velocity measurements after a hip and knee fatigue protocol compared to an ankle fatigue protocol. These findings may provide insight into how adopting a hip strategy, which is commonly seen in people with CAI, may predispose this population to recurrent injury.

While understanding the mechanical and functional instabilities related to CAI, it is important to understand how fatigue will affect these instabilities. Some authors state fatigue is reached when the subject's maximal effort fails to reach 50% of their initial maximal effort established during baseline.[15-17] However, since fatigue is an ongoing process, it would not be possible to identify a single point of fatigue. A study conducted by Gribble et al.[13] found participants with CAI after a fatigue protocol to the lower extremity had a negative impact on dynamic postural control. This study also showed a decrease in anterior, medial, and posterior reach distances, as well as decreases in knee and hip flexion. Studies inducing fatigue in subjects with CAI have also found significant differences in dynamic postural control during unfatigued and fatigued states.[16,17] Steib et al.[17] compared copers, subjects with no residual symptoms or subjective instability, and an uninjured control group and found that after fatigue dynamic postural control was decreased in copers. They go on to hypothesize that small and normally undetectable sensorimotor deficits, due to an ankle sprain, under a regular unfatigued condition might become evident in the presence of physical fatigue.[17] Another study conducted by Steib et al.[16] found significant differences between a CAI group and control group after inducing fatigue on a treadmill in SEBT reach distances, time-to-stabilization times, and baseline scores with the CAI group performing worse in each measurement.

The progression of fatigue on the body typically occurs in the periphery or musculature and then progresses to the CNS. As fatigue progress, which is expected during an athlete event, there may be a delayed muscular response. During peripheral and muscular fatigue the body is able to adapt and compensate to maintain a certain level of postural control using other sensory information.[46] One compensatory mechanism may be to adopt a hip strategy if fatigue to the lower leg is present and vice versa. Another mechanism may be sensory re-weighting. As the somatosensory system becomes impaired, the visual and vestibular systems may be able to provide enough correct input to maintain postural control. However, as fatigue progresses in both the peripheral and central nervous systems, compensatory mechanisms may not be able to maintain postural control. When central fatigue to the CNS is achieved, descending information to the working muscles and joints may be altered or impaired.[13,47] In general, when muscles of the lower leg are not activated properly, deficits are seen in postural control. Researchers can use center of pressure displacement measurements to visualize deficits associated with postural control. In the case of a participant's center of gravity moving excessively within their base of support, center of pressure displacement measurements will become worse and alterations may be seen in postural control.

Furthermore, the neuromuscular system plays an important role in maintaining dynamic postural control. When fatigue is induced either intentionally or over time through an athletic event, changes can be observed in subjects with CAI. However, as studies have shown fatigue specifically to the distal musculature of the lower leg have not had a tremendous effect compared to fatigue of the proximal leg or a combination of both. This could suggest either central mechanisms are able to compensate for the disrupted afferent information from the lower leg until central fatigue is reached or proximal musculature is able to overcome deficits of the lower leg.

When it comes to inducing fatigue to the lower limb, studies have demonstrated isokinetic and functional protocols to both being effective.[22] A study conducted by

Wikstrom et al.[48] showed that in healthy subjects there was no difference between isokinetic and functional fatigue protocols. Another study conducted by Reimer and Wikstrom[23] used a functional fatigue protocol to compare differences between a hip and ankle fatigue protocol resulting in both protocols impairing postural control. While isokinetic protocols may provide more objective control for the researcher, a functional protocol may be more appropriate for athletes. This may also prove to be true with the CAI population. As studies previously mentioned have shown, fatiguing entire musculature to the lower leg, hip, or both produces impairments in postural control. This may be more beneficial compared to isolating specific motions to fatigue, such as plantar-flexion for example.

2.4 Kinesio Tex Tape

Kinesio Tex tape has become a popular therapeutic intervention used among clinicians and athletes. Dr. Kenzo Kase, a licensed practitioner in chiropractor and acupuncture, developed KT tape in the 1970s. With many purported benefits, the efficacy of KT tape is still vastly debated. For example, several studies have shown KT tape to be an effective modality,[49-52] while other studies have shown there to be no improvements.[51,53-58]

The benefits Dr. Kenzo Kase claims KT tape can achieve, by applying to practically any part of the body, are intriguing. This elastic latex free tape is 100% cotton and designed to mimic the qualities of the skin. The thickness is approximately that of the epidermis. The application side of the tape is designed in a wave-like pattern made of 100% acrylic. This feature purportedly gives the tape the ability to lift the skin to facilitate lymphatic drainage and promote good circulation and healing.[59] The acrylic adhesive is heat activated and the longer the tape is worn the better the adhesion. Depending on the goal the clinician is trying to achieve, the stretch rate can range from 55-60% of the resting length for optimal effects. Beyond this range the effects can be diminished. One of the greatest qualities of KT tape is that it can be worn for several days. Another benefit, along with wearing KT tape for longer periods of time, is the continuous support and rehabilitation gained from one application. A study conducted on healthy subjects with no history of ankle sprains showed an increase in ankle stiffness 24-hours post-application.[49] This may provide the much needed constant support for those with CAI. Other purported benefits of KT tape include re-educating the neuromuscular system, alleviating pain through the somatosensory system, and reducing inflammation.

The application of KT tape is just as much an art as it is science. Although there are published manuals for some applications, there are no established standards on the best method to use when it comes to treating CAI or any other condition. When applying KT tape for lateral ankle instability, emphasis is placed on the anterior tibialis, peroneus longus and brevis, and the gastrocnemius to provide muscular support and assist in range of motion.[59] It is recommended when applying KT tape to clean the skin and prepare the area by either removing the hair or trimming to allow for better adhesion to the skin.[55] Also, KT tape is applied from distal to proximal or from insertion to origin of a muscle. When applying KT tape to the skin, the ends of the tape are used as anchors while the desired amount of tension is applied to the middle. To achieve this, the clinician must tear off the paper backing approximately one inch from one end of the tape and apply it to the skin with no tension. The backing is then peeled back, ensuring not to touch the adhesive surface, to approximately one inch from the other end. The desired stretch magnitude is applied and the KT tape is laid down. The other end of the tape is applied with no tension. Other variations, such as combining KT tape and non-elastic athletic tape are used clinically and can be used to provide for additional support, although the evidence supporting this is lacking.

Although KT tape remains appealing, especially in the athletic realm, the current research remains controversial to its actual benefits. A study conducted by Briem et al.[53] focused on inversion perturbations of the ankle in healthy male athletes and found no improvements from the application of KT tape. Another study on healthy subjects showed no change in dorsiflexion muscle strength during slow and fast velocities.[54] Additionally, several studies have shown a lack of improvements in balance[51,56,57] and jump performance[51,56] among healthy subjects. However, Nakajima and Baldridge[51] demonstrated a significant increase in the posterior-medial and medial SEBT reach directions among female participants. Furthermore, Gonzalez-Iglesias et al.[50] showed, in subjects with acute whiplash-associated disorders, KT tape is effective in improving cervical ROM and neck pain. A study consisting of ankle instability subjects showed significant improvement in force sense reproduction after wearing KT tape for 72-hours.[52] Lastly, a meta-analysis conducted by Williams et al.[58], reported KT tape only provides a small beneficial effect on an injured body part for outcome measures of strength, force sense error, and active ROM. This same study also revealed no significant results for the use of KT tape for pain, joint position sense, or muscle activity.

Despite these cumulative results, the many purported benefits of KT tape on causing clinically significant effects are still debated. However, most studies include or are strictly composed of healthy participants. Undoubtedly, these samples will skew the data since the tape was ultimately designed for an injured population and there is likely a ceiling effect on most of the tested outcomes when using healthy participants. The lack of standardized taping techniques also creates a challenge for a clinician when determining the most effective application to utilize for a specific treatment. In regards to CAI, KT tape has not been adequately studied.

Ankle sprains are common and often lead to CAI. Those with CAI have a wide range of impairments including balance problems, which increase their risk of re-injury. Fatigue also impairs balance and those with CAI respond abnormally to fatigue relative to healthy individuals. There are a number of possible interventions for those with CAI, including KT tape that is popular at the moment. KT tape may also be able to mitigate the effects of fatigue based on the purported benefits. Therefore, KT tape may be an excellent intervention for those with CAI but evidence to support this hypothesis is lacking.

CHAPTER 3: METHODS

3.1 Research Design

This crossover investigation seeks to identify the effects of KT tape before and after a fatigue protocol on college-age students with CAI. Randomization will occur by counterbalancing the order college-age students participate in each group. The independent variables of this study will be Tape Technique (KT Tape vs. Standard Tape vs. Control) and Time (Baseline, Post-Tape, Post-Fatigue). Primary dependent variables will be normalized SEBT reach distance (anterior, posterior-lateral, and posterior-medial directions) and COP and TTB measurements taken during a single limb stance on a force plate. Secondary dependent variables will consist of VAS (to measure perceived instability) and plantar flexor strength measured via a handheld dynamometer to quantify fatigue. All outcomes will be compared at baseline, post-tape application, and post-fatigue among and within groups.

3.2 Participants

The participants included in this study were college-age students from the University of North Carolina at Charlotte. The participants were required to fill out the IdFAI and score 11 or higher[40] to be considered as having CAI. The participants also had to meet the inclusion/exclusion criteria set forth by the International Ankle Consortium.[60] The inclusion criteria consist of a history of at least 1 significant lateral ankle sprain (initial must have occurred at least 12 months prior to study); a history of ankle joint "giving way," and/or recurrent sprain, and/or "feelings of instability" (participants should report at least 2 episodes of giving way in 6 months prior to study); and a IdFAI score of at least 11.[60] The exclusion criteria consist of a history of either lower extremity musculoskeletal surgeries; a history of fracture in either lower extremity requiring realignment; or an acute injury within the past 3 months to musculoskeletal structures of the lower extremity resulting in at least 1 interrupted day of desired physical activity.[60] Participants were 18-35 years old and able to complete the duration of the study. This study was approved by the Institutional Review Board (IRB) of the University of North Carolina at Charlotte.

3.3 Instruments

Assessing participants' dynamic balance will be done using the SEBT. Instead of using all 8 directions in the SEBT, we will be using the anterior, posterior-lateral, and posterior-medial directions because studies have shown these 3 directions to be sufficient in identifying deficiencies in dynamic postural control in participants with CAI.[2,4-6] Before conducting the trials, verbal instructions will be given to each participant as outlined in Table 1. To create the appropriate "Y," three measuring tapes are placed on the floor in the shape of a "Y" with the intersection starting at "0 cm."[61] A study conducted by Bastien et al.[62] compared visual estimation to a motion-capture system and revealed an intraclass correlation coefficient (ICC) value of 0.991 (ICC > 0.75 represents excellent reliability) for measuring SEBT reach distance. Along with this study, Olmsted et al.[63] and Hertel et al.[64] state the SEBT is a valid and reliable tool to discriminate between populations. Other ranges of ICC values were reported by Gribble et al.[65] and

Munro and Herrington[61] between 0.84 to 0.94, which support the excellent reliability values reported in previous studies.

Using a force plate (Advanced Mechanical Technologies Inc, Watertown, Massachusetts), three 10-second test trials of a single-limb stance will be completed. For the ground reaction forces captured from the force plate, COP and TTB measurements will be generated. The COP is the point at which the pressure of the body over the soles of the feet would be if it were concentrated in one spot.[66] The COP data were sampled at 50 Hz and were used to calculate the COP excursion in the anteroposterior (AP-COP) and mediolateral (ML-COP) directions as well as the average anteroposterior sway (AP-sway) and mediolateral sway (ML-sway).[67] The COP data were used to compare before and after taping and after fatigue to show changes in AP-COP, ML-COP, AP-sway and ML-sway. TTB is an estimation of the time it would take for the COP to reach the boundary of the foot at a given velocity if it continued on its path without change.[33,37,68,69] The TTB data were calculated by processing COP data files using a custom MATLAB (Mathworks Inc., Natik, MA) program. More specifically, TTB was calculated by identifying the valleys generated by changes in direction of COP. A study conducted by Hertel et al.[69] found comparable ICC values for TTB compared to COP measurements. This study also showed a weak correlation between TTB and COP, which may indicate TTB measurements identify deficits in postural control differently than COP. Several other authors[33,37,68] have noted the significance of TTB measurements in identifying deficits in postural control traditional COP measurements were not able to detect. The TTB data was used to compare before and after taping and after fatigue to show changes in mean of minimum samples and standard deviation of minimum samples in the ML and AP directions.

The visual analog scale (VAS) will also be used to assess changes in perceived instability after taping and fatigue. Table 4 represents the 10 cm line the participant will use to make a mark in relation to how they are feeling at the various assessment points. The VAS has been shown to be a valid and reliable tool when assessing pain.[9] However, our aim in using the VAS is to show changes in the participants' perception of stability and, therefore, the VAS may not be as reliable in this situation.

Questionnaires are commonly used to identify participants with CAI. A study conducted by Simon et al.[40] showed the IdFAI questionnaire to be 91.7% accurate in identifying CAI when participants scored at least an 11 out of 37 points, with an overall accuracy of 89.6% in identifying CAI and non-CAI. Another common questionnaire used is the FAAM (Foot and Ankle Ability Measure), which is comprised of the ADL (activities of daily living) scale and Sport subscale (FAAM-S). The FAAM is a valid and reliable tool when used to measure differences overtime.[70,71]

A MicroFET (Hoggan health industries, Inc., Draper, UT) hand-held dynamometer will be used to quantify fatigue and show changes in strength of the ankle plantar flexors before and after the fatigue protocol. The hand-held dynamometer has been shown to have good inter-tester reliability for plantar flexion (ICC = 0.82–0.86).[72]

3.4 Procedures

Each participant completed the IdFAI and other eligibility questionnaires to identify whether or not CAI was present. Once eligible, participants were then randomly assigned to group orders by counterbalancing them in the order they appeared in the study. First, participants performed a session to estimate strength according to Reimer and Wikstrom.[42] This session and the fatigue protocol will be conducted on a Nautilus (Nautilis Inc., Vancouver, WA) Smith machine and required participants to stand on aerobic steps (Nantong Ruilin International Co., Jiansu, China). Participants began the exercise with self-selected weight, which progressed by a range of 10-20% until participants could no longer complete 5-7 repetitions. A one-repetition maximum was calculated using the Brzycki one repetition maximum (1RM) equation (1RM=Repetition weight kg /(1.0278 – 0.0278 x [# reps])). Next, participants rested for at least 15 minutes before completing the baseline test session as outlined below.

Each participant will complete baseline measurements of static and dynamic postural control, plantar flexion strength, and perceived stability. As previously stated, the SEBT was completed in the anterior, posterior-lateral, and posterior-medial directions. Each participant performed 4 practice trials and then measurements were recorded during 3 trials that were performed in each direction. The order of the directions performed were self-selected by the participants. After the 3 trials are recorded the results are normalized to the participants leg length.[73] Leg length was measured as the distance from the anterior superior iliac spine to the center of the ipsilateral medial malleolus. The excursion distance from the SEBT is then divided by the participant's leg length and then multiplied by 100.[73]

To assess plantar flexion strength, we will use the methods reported by Plante and Wikstrom[72] which required participants to ramp into a 3-5 second maximal effort a total of 3 times. Between each effort, at least a 15-second rest period was given. Testing position was chosen to offer the tester the greatest mechanical advantage. All tests were performed with the participants in a supine position with hips and knees extended and the lower limb stabilized proximal to the ankle joint. The dynamometer, was secured to the participant's foot just proximal to the metatarsal heads and then pressed against a wall by the participant. The maximum force (N) produced during each of the three trials was then normalized to the participant's body mass (kg) and averaged across the trials. Verbal encouragement was given during each effort.

Next, three 10-second test trials of a single-limb stance were completed. Prior to the start of each trial participants were instructed to remain as still as possible and to keep his or her hands on the hips and the non-test limb in a position of approximately 45^{o} of knee flexion and 30^{o} of hip flexion. Failed trials, defined as a participant touching down with the non-test limb were discarded and repeated.

Following baseline testing, the application of KT tape was replicated from Halseth et al.[55] (Figure 1). The Traditional tape application was applied as outlined by Prentice and Arnheim.[74] Participants in the control condition, sat quietly for 5 minutes. After the control or tape application, participants completed the assessments for static and dynamic balance, plantarflexion strength, and perceived instability. Following the post-tape assessment session, participants underwent an ankle fatigue protocol consisting single leg calf raises to a computerized metronome (Virtual Metronome 2.0) set to 45 beats per minute while lifting 65% of their estimated one repetition maximum until fatigue. Participants are to perform one complete repetition to one beat of the metronome until they are unable to complete 2 successful consecutive repetitions to the metronome or unable to complete the exercise with proper form.[13] Once fatigue was reached, post-test measurements were collected immediately in a counter-balanced order. Participants were scheduled at least 7 days from their previous data collection to ensure recovery from fatigue was achieved. Participants will complete the 2nd and 3rd test sessions in an identical manner except that the initial one repetition maximum testing will not be performed. The order of intervention received during subsequent test sessions will follow the counterbalanced order established upon study entry.

3.5 Statistical Analysis

Sample size estimates were based on sample sizes from several investigations examining the effects of fatigue on SEBT performance.[2,12,13] These investigations consistently showed balance impairments post fatigue using 14-16 CAI subjects per group. Calculated effect sizes from Salvati et al.[45] (0.82) and Reimer and Wikstrom[42] (1.2) indicate a total sample size of 4 is needed to observe the effects of fatigue on postural control but they evaluated postural control using a Biodex stability system. Finally, Delahunt et al.[25] evaluated the effects of various taping techniques on SEBT performance. Based on the average effect size of those taping procedures (Ant: 0.29, PM: 0.18, PL: 0.27), a sample size of 18, 46, and 22 is needed to determine significant differences, with a power of 0.80 and a Type I error of 5%. Therefore, we aim to recruit 24 CAI participants and plan on a 10% drop out rate so that at least 22 participants will complete the study.

To determine if KT tape is more effective than Johnson and Johnson Coach Athletic Tape at improving static and dynamic postural control in those with CAI, dynamic postural control (SEBT reach distance) and static postural control (COP and TTB outcomes) will be assessed using separate Group [baseline, control, KT, standard]

MANOVAs. Plantar flexion strength and balance perception will be assessed using separate Group [baseline, control, KT, standard] ANOVAs.

To determine if KT tape is more effective than Johnson and Johnson Coach Athletic Tape at mitigating the effect of fatigue on static and dynamic balance in those with CAI, dynamic postural control (SEBT reach distance) and static postural control (COP and TTB outcomes) will be assessed using separate Group [control, KT, standard] x Time [pre-fatigue, post-fatigue] Repeated Measures MANOVAs. Plantar flexion strength and balance perception will be assessed using separate Group [control, KT, standard] x Time [pre-fatigue, post-fatigue] ANOVAs. An alpha level of 0.05 will be used on all statistical analyses and post-hoc testing will be performed as needed to identify the exact location of differences.

CHAPTER 4: RESULTS

4.1 Demographics

A total of 24 subjects with CAI volunteered to participate in this investigation. Table 4-1 shows their demographic information and Table 4-2 shows injury history information as well as their self-reported function.

Table 4-1: Participant demographics

	IdFAI	FAAM (%)	FAAM-S (%)	Age (years)	Height (cm)	Weight (lbs)	Leg Length (cm)
Mean ± SD	20.29± 4.27	85.66 ± 11.92	76.3 ± 15.69	21.25 ± 3.34	173.14 ± 9.64	149.13 ± 28.3	89.85 ± 5.62

Abbreviations: SD, standard deviation

Table 4-2: IdFAI self-reported levels of function and injury information.

Last sprain	1-6 months	7-12 months	13-18 months	19-24 months
# of Subjects	12	6	2	3
Last “giving way”	<1 month	1-6 months	6-12 months	1-2 years
# of Subjects	5	13	5	1
Last “giving way” sensation	Never	Once a year	Once a month	Once a week
# of Subjects	1	4	12	7
During Sport/Recreational activity how often does your ankle feel UNSTABLE?	Never	Once a month	Once a week	Once a day
# of Subjects	1	12	8	3

4.2 Primary Outcomes

Specific Aim: To determine if KT Tape is more effective than Standard Tape at improving static and dynamic postural control in those with CAI

Time to Boundary

The MANOVA for TTB revealed significant tape main effects [$F_{(12,159)}$=1.935, p=0.034] indicating that the KT Tape condition resulted in better postural control relative to the Standard Tape and Control conditions. However, the follow-up univariate ANOVAs failed to identify any individual variables that changed between conditions (p>0.05) suggesting that the MANOVA was the result of small changes in each outcome rather than a large shift in a particular outcome. Table 4-3 contains the means and standard deviations of TTB variables across the different tape conditions.

Table 4-3: Means±SD for the effect of Tape on TTB postural control outcomes

	Baseline	KT Tape	Standard Tape	Control
ML TTB Mean	1.94±0.63	1.94±0.45	2.18±0.63	1.93±0.63
AP TTB Mean	4.98±1.59	5.21±1.68	5.13±1.52	5.08±1.73
ML TTB SD	1.63±0.98	1.41±0.50	1.79±0.90	1.55±0.73
AP TTB SD	3.30±1.97	3.11±1.22	3.21±1.40	3.11±1.22

Abbreviations: TTB, Time to Boundary; SD, standard deviation; ML, medial-lateral; AP, anterior-posterior

Center of Pressure

The MANOVA for COP revealed a significant tape main effect [$F_{(12,159)}$=3.055, p=0.001]. The follow-up univariate ANOVA identified a difference between conditions for ML COP velocity [$F_{(3,63)}$=4.200, p=0.009]. The pairwise comparisons identified a statistically significant difference between the Baseline and KT Tape conditions (p<0.05, d=0.39) indicating that the KT Tape condition resulted in better postural control in the mediolateral direction relative to Baseline. Table 4-4 contains the means and standard deviations of COP variables.

Table 4-4: Means±SD for the effect of Tape on COP postural control outcomes				
	Baseline	KT Tape	Standard Tape	Control
ML COP SD	0.53±0.11	0.53±0.11	0.57±0.12	0.55±0.11
AP COP SD	0.75±0.19	0.79±0.23	0.77±0.12	0.83±0.21
ML COP VEL	2.41±0.60	2.20±0.47*	2.09±0.61	2.36±0.61
AP COP VEL	2.28±0.99	2.06±0.85	2.05±0.59	2.12±0.70
Abbreviations: COP, Center of Pressure; SD, standard deviation; VEL, velocity; ML, mediolateral; AP, anteroposterior				

* Indicates a statistically significant difference (p<0.05) from the Baseline condition.

Star Excursion Balance Test

The SEBT MANOVA revealed a significant tape main effect [$F_{(9,163)}$=10.197, p<0.01]. The follow-up univariate ANOVA identified changes between conditions for the Anterior direction [$F_{(2,49)}$=40.688, p<0.01] and PL direction [$F_{(3,69)}$=5.187, p=0.003]. The pairwise comparisons identified a statistically significant difference in the Anterior reach direction resulting in a reduction in reach in the Standard Tape condition relative to the KT Tape condition (p<0.01, d=1.17), Baseline condition (p<0.01, d=1.36), and the Control condition (p<0.01, d=1.24). In the PL reach direction, the Standard Tape condition also resulted in a statistically significant reduction in reach relative to the Baseline (p<0.05, d=0.35) and the KT Tape condition (p<0.01, d=0.47). Table 4-5 shows the means and standard deviations of SEBT variables.

Table 4-5: Means±SD for the effect of Tape on SEBT postural control outcomes				
	Baseline	KT Tape	Standard Tape	Control
SEBT Ant	68.94±5.54§	67.76±5.47*	60.52±6.80	68.10±5.36†
SEBT PM	93.31±9.56	95.25±9.59	91.99±11.33	93.49±12.00
SEBT PL	99.34±10.23§	100.56±10.34*	95.56±11.05	98.58±10.98
Abbreviations: SEBT, Star Excursion Balance Test; SD, standard deviation; Ant, anterior; PM, posterior-medial; PL, posterior-lateral				

* Indicates a statistically significant difference from the Standard condition in the Ant. (p<0.01) and PL (P<0.01) direction.
§ Indicates a statistically significant difference from the Standard condition in the Ant. (p<0.01) and PL (p<0.05) direction.
† Indicates a statistically significant difference from the Standard condition in the Ant. (p<0.01) direction.

Specific Aim: To determine if KT tape is more effective than Standard Tape at mitigating the effect of fatigue on static and dynamic balance in those with CAI

Time to Boundary

The MANOVA for TTB revealed significant time main effects [$F_{(4,18)}$=3.822, p=0.020], but no significant condition main effect [$F_{(8,78)}$=1.992, p=0.058] or condition x time interaction [$F_{(8,78)}$=0.931, p=0.496] indicating that the pre-fatigue postural control relative to the post-fatigue postural control scores. The follow-up univariate ANOVAs failed to identify any individual variables that changed over time (p>0.05) suggesting that the MANOVA time main effect was the result of small subtle changes in all of the individual TTB variables. Table 4-6 illustrates the means and standard deviations of TTB variables.

Table 4-6: Means±SD for the effect of Fatigue on TTB postural control outcomes						
	KT Tape		Standard Tape		Control	
	Pre	Post	Pre	Post	Pre	Post
ML TTB Mean	1.94±0.45	2.03±0.61	2.18±0.63	2.22±0.73	1.93±0.63	2.00±0.61
AP TTB Mean	5.21±1.68	4.94±1.33	5.13±1.52	5.13±1.40	5.08±1.73	5.21±1.65
ML TTB SD	1.41±0.50	1.56±0.59	1.79±0.90	1.70±0.77	1.55±0.73	1.48±0.50
AP TTB SD	3.11±1.22	3.07±0.92	3.21±1.40	3.27±1.26	3.11±1.22	3.28±1.22
Abbreviations: TTB, Time to Boundary; SD, standard deviation; ML, medial-lateral; AP, anterior-posterior						

Center of Pressure

The COP MANOVA revealed a significant condition main effect [$F_{(8,78)}$=2.772, p=0.009], but not a significant time main effect [$F_{(4,18)}$=1.185, p=0.351] or condition x time interaction [$F_{(8,78)}$=1.216, p=0.301]. The follow-up univariate ANOVA identified a change between conditions for ML COP velocity [$F_{(2,42)}$=4.573, p=0.016]. Pairwise comparisons failed to identify any statistically significant differences between conditions. The Standard Tape condition showed better postural control relative to the Control condition (p=0.052) indicating that the ANOVA finding was driven by this difference. Table 4-7 contains the means and standard deviations of COP variables.

Table 4-7: Means±SD for the effect of Fatigue on COP postural control outcomes						
	KT Tape		Standard Tape§		Control	
	Pre	Post	Pre	Post	Pre	Post
ML COP SD	0.53±0.11	0.55±0.11	0.57±0.12	0.53±0.10	0.55±0.11	0.55±0.11
AP COP SD	0.79±0.23	0.80±0.18	0.77±0.12	0.88±0.20	0.83±0.21	0.88±0.18
ML COP VEL	2.20±0.47	2.23±0.56	2.09±0.61	2.09±0.55	2.36±0.61	2.26±0.65
AP COP VEL	2.06±0.85	2.09±0.54	2.05±0.59	2.06±0.53	2.12±0.70	2.06±0.59
Abbreviations: COP, Center of Pressure; SD, standard deviation; VEL, velocity; ML, mediolateral; AP, anteroposterior						

§ Indicates a statistical trend from the Control condition in ML COP VEL (p=0.052).

Star Excursion Balance Test

The SEBT MANOVA identified a significant condition main effect [$F_{(6,88)}$=11.405, $p<0.01$] and condition x time interaction [$F_{(6,88)}$=2.423, p=0.03], but no significant time main effect [$F_{(3,21)}$=2.876, p=0.06]. The follow-up univariate ANOVAs identified differences between conditions in the Anterior [$F_{(2,35)}$=39.216, $p<0.01$], PM [$F_{(2,46)}$=5.939, p=0.005], and PL [$F_{(2,46)}$=10.321, $p<0.01$] directions. There were also differences identified in the univariate ANOVA between the condition x time in the Anterior [$F_{(2,46)}$=7.867, p=0.001] direction. For the condition main effect, the Standard Tape condition resulted in significantly less anterior reach distances relative to the KT Tape ($p<0.01$, d=1.02) and Control conditions ($p<0.01$, d=1.05). The KT Tape condition also resulted in a statistically significant farther PM ($p<0.01$, d=0.18) and PL ($p<0.01$, d=0.41) reach distances relative to the Standard condition. In the PL reach direction the Control condition resulted in a statistically significant farther reach distance relative to the Standard Tape condition ($p<0.05$, d=0.24). In the condition x time interaction, the Standard Tape condition improved in the Anterior reach direction post-fatigue relative to pre-fatigue. Table 4-8 contains means and standard deviations for SEBT postural control variables.

Table 4-8: Means±SD for the effect of Fatigue on SEBT postural control outcomes						
	KT Tape*		Standard Tape		Control[†]	
	Pre	Post	Pre	Post	Pre	Post
Ant	67.76±5.47	67.99±4.85	60.52±6.80[§]	63.03±6.52[§]	68.10±5.36	67.99±5.04
PM	92.25±9.59	95.30±10.30	91.99±11.33	91.65±11.83	93.49±12.00	94.09±11.03
PL	100.56±10.34	100.40±9.68	95.56±11.05	96.67±11.14	98.58±10.98	98.93±10.04
Abbreviations: SEBT, Star Excursion Balance Test; SD, standard deviation; Ant, anterior; PM, posterior-medial; PL, posterior-lateral						

* Indicates a statistically significant difference from the Standard condition in the Ant, PM, and PL (p<0.01) direction.
[†] Indicates a statistically significant difference from the Standard condition in the Ant (p<0.01) and PL (p<0.05) direction.
[§] Indicates a statistically significant difference from pre-fatigue to post-fatigue (p<0.01).

4.3 Secondary Outcomes

Specific Aim: To determine if KT Tape is more effective than Standard Tape at improving static and dynamic postural control in those with CAI

Plantar Flexion

The ANOVA for PF identified differences between conditions [$F_{(3,69)}$=5.996, p=0.001]. The pairwise comparisons identified significantly higher PF values for the Standard Tape (p<0.05, d=0.54) and the Control conditions (p<0.01, d=0.63) relative to the Baseline condition. Table 4-9 illustrates the means and standard deviations for PF postural control variables.

Table 4-9: Means±SD for the effect of Tape on PF postural control outcomes				
	Baseline	KT Tape	Standard Tape	Control
Mean±SD	33.99±8.32	37.08±9.23	38.87±9.63[§]	39.15±8.09[†]
Abbreviations: PF, Plantar Flexion; SD, standard deviation				

[§] Indicates a statistically significant difference from the Baseline condition (p<0.05).
[†] Indicates a statistically significant difference from the Baseline condition (p<0.01).

Visual Analog Scale

The ANOVA for perceived stability using the VAS identified changes between conditions $F[_{2,69)}=15.869$, $p<0.01$]. The pairwise comparisons identified statistically higher perceived stability in the KT Tape condition relative to the Baseline ($p<0.01$, $d=1.14$) and Control conditions ($p<0.01$, $d=0.72$). The Standard Tape condition also had higher perceived stability relative to the Baseline ($p<0.01$, $d=1.15$) and Control conditions ($p<0.01$, $d=0.82$). Table 4-10 shows the means and standard deviations for the perceived stability variable.

Table 4-10: Means±SD for the effect of Tape on VAS postural control outcomes				
	Baseline	KT Tape	Standard Tape	Control
Mean±SD	4.78±1.72	6.70±1.65*	7.21±2.45§	5.38±2.02
Abbreviations: VAS, Visual Analog Scale; SD, standard deviation				

*, § Indicates a statistically significant difference from the Baseline and Control conditions ($p<0.01$).

Specific Aim: To determine if KT tape is more effective than Standard Tape at mitigating the effect of fatigue on static and dynamic balance in those with CAI

Plantar Flexion

The ANOVA for PF failed to identify changes between conditions [$F_{2,46)}=0.641$, $p=0.531$], time [$F_{(1,23)}=1.999$, $p=0.171$], and condition x time [$F_{(2,46)}=1.728$, $p=0.189$]. Table 4-11 contains the means and standard deviations for the PF outcome.

Table 4-11: Means±SD for the effect of Fatigue on PF postural control outcomes						
	KT Tape		Standard Tape		Control	
	Pre	Post	Pre	Post	Pre	Post
Mean±SD	37.08±9.23	37.03±9.26	38.87±9.63	37.88±8.33	39.15±8.09	36.88±8.19
Abbreviations: PF, Plantar Flexion; SD, standard deviation						

Visual Analog Scale

The ANOVA for perceived instability as measured by the VAS identified a condition [$F_{(2,46)}$=16.487, p<0.01] and time main effect [$F_{(1,23)}$=4.884, p=0.037], but no condition x time interaction [$F_{(2,46)}$=1.994, p=0.148]. The condition pairwise comparisons identified lower perceived stability in the Control condition relative to the KT Tape (p<0.01, d=0.70) and Standard Tape conditions (p<0.01, d=0.94). Over time, perceived stability decreased (p<0.05, d=0.17) after the fatigue intervention. Table 4-12 shows the means and standard deviations for the perceived stability variable.

Table 4-12: Means±SD for the effect of Fatigue on VAS postural control outcomes

	KT Tape*		Standard Tape[§]		Control	
	Pre	Post	Pre	Post	Pre	Post
Mean±SD	6.70±1.65	6.20±1.69	7.21±2.45	7.15±2.10	5.37±2.02	4.92±2.10

Abbreviations: VAS, Visual Analog Scale; SD, standard deviation

* Indicates a statistically significant difference from the Control condition (p<0.01).

§ Indicates a statistically significant difference from the Control condition (p<0.01).

CHAPTER 5: DISCUSSION

5.1 Summary of Findings

The purpose of this study was to determine if KT tape could improve postural control and mitigate the effects of fatigue. The KT tape condition demonstrated better SEBT scores relative to Standard tape condition, however the Baseline measurements were also better than the Standard tape condition and no different than the KT Tape condition. This would likely suggest that the Standard tape hinders SEBT rather than KT tape improving dynamic postural control. Postural control was also equally impaired after fatigue while wearing KT tape and no-tape at all. These results fail to support our initial hypotheses.

5.2 Demographics

The mean IdFAI score of our subjects was 20.29±4.27, which is well above the cut off score of 11 indicating ankle instability is present.[40,75] Thus we believe that our sample is representative of the CAI population. Further supporting this belief are the FAAM ADL and FAAM Sport subscale scores of our sample. Our findings, relative to current literature (FAAM ADL 86.7-91.5%; FAAM Sport 78.9-80.9%), suggest that our sample is representative of the larger CAI population.[67,71]

5.3 Kinesio Tex Tape

One of the specific aims of this study was to determine if KT Tape was more effective than Standard Tape at improving static and dynamic postural control in those with CAI. The current results for static postural control do not completely satisfy this aim. Although the TTB values were comparable (ML mean=1.67-2.15, ML SD=1.08-1.61; AP mean=4.26-6.45, AP SD=3.23-4.35) to previous CAI studies[37,68,69] that used single leg stance measurements, we failed to identify differences in postural control when comparing the different tapes. This could suggest the KT Tape did not elicit enough of a response to alter sensory input or improve mechanical instability. Our COP means (ML SD=0.55, AP SD=0.79, ML Vel=2.27, AP Vel=2.13) were also comparable to other CAI studies.[16-18] We did observe better mediolateral COP velocity measurement in the KT Tape condition relative to the Baseline condition (d=0.39). However, the Standard Tape condition showed better mediolateral COP velocity measurement despite having more variability relative to the other conditions (i.e. a statistical trend). Our results are consistent with the study conducted by Shields et al.[57], who failed to identify significant COP or TTB results after application of KT tape. The lack of significant findings in COP and TTB measurements in this study cannot be completely dismissed. This study can be part of bridging the gap between CAI and KT tape along with providing a basis of data for other studies to compare to.

Our findings for SEBT outcome measures were also comparable (Anterior 77.01-78.05, PM 80.9-93.9, PL 73.31-87.95) to other CAI studies[25,62,73] for anterior, posteromedial and posterolateral directions. These findings are not surprising as the Standard tape was expected to have some range of motion restriction due to the non-elastic nature of the material. As previous studies[76-78] have identified, non-elastic tape provides a more rigid support that in turn will limit range of motion. Our results are similar to studies investigating KT tape and ankle instability.[2,8,16,17,43] Similarly, Nunes et al.[56] found no difference between a KT tape and placebo condition in SEBT reach distances in healthy athletes. Nakajima et al.[51] had similar findings with a lack of significant results in SEBT measurements. Although the KT Tape condition had significantly greater reach distances relative to the Standard Tape condition in the anterior and PL reach direction, so did the Baseline as well as the Control condition (only in the anterior reach direction).

The results of the VAS outcome measurement identified significantly higher perceived stability in the KT Tape condition relative to the Baseline (d=1.14) and Control (d=0.72) conditions. However, there were also higher perceived stability scores in the Standard Tape condition relative to the Baseline (d=1.15) and Control (d=0.82) conditions. The increase in perceived stability with Standard tape was expected due to the rigid nature of a traditional ankle tape application. Our results are consistent with Myo-Hla et al.,[34] who noted that subjects' perceived stability increased after mechanoreceptors, that are likely to be damaged after a lateral ankle sprain, were deafferentated by being anesthetized. Their explanation was that a prolonged peroneal reaction time was likely caused by mechanoreceptors and/or nociceptors becoming impaired due to trauma during ankle sprains. The prolonged reaction time then causes impairment in the reflexes that normally would have occurred as a protective mechanism. While our study did not inhibit mechanoreceptors or have an application of any kind of tape, it is possible that the application of any tape to the lower leg could stimulate surrounding receptors providing a sense of stability. Further supporting the evidence on higher perceived stability, Ridder et al.[79] and de la Domingo et al.[80] studied the effectiveness of standard athletic tape and KT tape, respectively, and found after application of tape the subjects' feelings of stability improved.

Our findings of PF strength did not show any significant results with the use of KT tape. However, the Standard Tape condition and Control condition were statistically better relative to the Baseline. Our lack of statistical significant findings are consistent with Gomez-Soriano et al.[54] and Grindstaff et al.[81] who state that the use of KT tape does not increase muscle activation. This is contrary to Chou et al.[82] whose study showed an increase in muscle activation after the application of KT tape to the distal lower leg. However, the effect sizes claims, although his results show small effect sizes, their study.

5.4 Fatigue

Our second specific aim was to determine if KT tape is more effective than Standard tape at mitigating the effect of fatigue on static and dynamic balance in those with CAI. Our TTB and COP findings demonstrated main effects but no meaningful differences among the conditions. The lack of significant findings in static postural control may allude to the fact that our fatigue protocol itself was not challenging enough to elicit fatigue or a difference between conditions following fatigue. Our fatigue protocol was based off of the protocol by Reimer and Wikstrom,[42] however due to equipment limitations, two different fatigue protocols were used during the investigation. Several other studies also used equipment to add resistance[43-45] or conducted a fatigue protocol involving the entire lower body,[42,43] such as lunges. This may lead to the conclusion that adding external resistance by way of some device could be a contributor to identifying results during a single limb fatigue protocol.

Our dynamic postural control measurement showed no real meaningful results. Although we identified a significant condition main effect between the KT Tape condition relative to the Standard Tape condition, after interpreting the results this is likely due to the differences observed in the pre-fatigue test condition. The lack of differences over time again suggest that the fatigue protocol was not effective. Unfortunately, there are no other investigations that have examined the effect of KT tape at mitigating fatigue, so it is difficult to contextualize our results.

Perceived stability of the ankle decreased after fatigue (d=0.17) indicating that while the fatigue protocol may have not induced postural control impairments, participants did not feel as stable while completing the postural control tasks. The KT Tape condition resulted in a higher perceived stability relative to the Control condition (d=0.70) when collapsed over time. The subjects' perception of better stability may be due to a psychological aspect of having tape on their ankle and knowing the purported benefits. It is interesting to observe the large effect size indicating there is some aspect of wearing KT tape that is beneficial to the subject, however we did not observe any differences in static postural control outcomes as hypothesized which may suggest that the mechanism is psychological and not physiological (i.e. stimulation of sensory receptors).

Plantar flexion strength also failed to reduce following the fatigue protocol. Although subjects appeared to be fatigue, the PF data does not support their actions. It is a possibility that having the subject long sit on the floor and plantar flex their ankle with the hand held dynamometer between them and a wall is not an appropriate measure of PF strength. However, it is also possible that the lack of differences was due to an ineffective fatigue protocol.

5.5 Clinical Implications

The exact clinical implications of our results remain unclear. Applying KT tape to athletes may be appropriate in certain situations. The current study does support the use of KT tape to improve a person's perceived stability. However, other studies have shown evidence that supports wearing KT tape for longer periods of time may be more beneficial to the individual.[52,58] Thus, our immediate assessment of the effects of KT tape may not accurately capture the true impact of the product. Furthermore, if an athlete feels better and perceives their performance is better with the application of KT tape, this therapeutic modality may be an option to consider.

However, several studies have shown little to no improvements in balance[51,56,57], muscle activation[53,54], and jump performance[51,56] in those with CAI. For a clinician it is important to provide the best evidence based practice when treating their patients. Given the results of this study, along with the current literature, it may be better practice to explore other therapeutic modalities when treating CAI.

5.6 Limitations

The fatigue protocol may have not been robust enough to observe the desired results. Further, the change made half way through the study, which required the fatigue protocol to be manipulated may have impacted the effectiveness of the fatigue protocol. The use of the equipment to test and fatigue subjects was no longer available for use after 10 subjects had completed the study. Although subjects were encouraged to exert themselves until they could not complete another repetition, the revised protocol may not have been appropriate for this study.

Future Research

Future studies with the CAI population are important to provide clinicians the best evidence based research. The application of KT tape for longer periods of time may prove to benefit subjects as it has been seen in previous studies. Another approach could be to study the effectiveness of other similar elastic tapes relative to KT tape. Other possible research studies could explore different application techniques as well. In the current investigation, we used an application technique suggested by the vendor, but there is no empirical evidence to support the use of this technique.

5.7 Conclusion

Overall, this study showed KT tape to be beneficial in the subjects' perception of stability, but not postural control. Whether or not KT tape is effective in mitigating the effects of fatigue is still inconclusive given the current data due to the overall lack of fatigue. However, the higher perceived stability an athlete may gain from the simple application of KT tape may warrant clinicians to explore this as a possible therapeutic modality. If the same benefits can be gained through the use of the Standard tape an Athletic Trainer already uses, it could become a burden to have to maintain a supply of KT tape, which is more expensive and lacks empirical evidence regarding its ability to reduce the risk of ankle sprains.

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APPENDIX A: SEBT INSTRUCTIONS

Table 1. Oral Instructions Given for Star Excursion Balance Test Performance
1. Keep your stance foot flat on the floor with your hands on your hips
2. Make a reach with your other leg as far as possible and make a light tap on the measuring tape
3. Without pushing off the ground with your reaching leg, return it back to the center of the testing grid and place this foot on the ground next to the foot of the stance leg
4. You may make any movements you wish to reach as far as possible, as long as you keep your stance foot planted, your hands on your hips
5. If you tap more than once or slide the reaching foot during the reach, miss the tape measure with your tap, push off the floor with the reaching foot, lift your heel or your hands from the testing position, or are unable to return the reaching foot back to the starting position, we will repeat that trial

APPENDIX B: IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY QUESTIONAIRE

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:

"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? ________

2.) When was the last time you sprained your ankle?

❑Never ❑ > 2 years ❑ 1-2 years ❑ 6-12 months ❑ 1-6 months ❑< 1 month

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

❑Have **not** seen someone ❑Mild (Grade I) ❑Moderate (Grade II) ❑Severe (Grade III)

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

❑Never used a device ❑1-3 days ❑4-7 days ❑1-2 weeks ❑2-3 weeks ❑>3 weeks

5.) When was the last time you had ***"giving way"*** in your ankle?

❑Never ❑> 2 years ❑1-2 years ❑6-12 months ❑ 1-6 months ❑< 1 month

6.) How often does the ***"giving way"*** sensation occur in your ankle?

❑Never ❑Once a year ❑Once a month ❑Once a week ❑Once a day

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?

❑Never rolled over ❑Immediately ❑Sometimes ❑Unable to stop it

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?

❑Never rolled over ❑Immediately ❑ < 1 day ❑1-2 days ❑> 2 days

9.) During "Activities of daily life" how often does your ankle feel ***UNSTABLE****?*

❑Never ❑Once a year ❑Once a month ❑Once a week ❑Once a day

10.) During "Sport/or recreational activities" how often does your ankle feel ***UNSTABLE****?*

❑Never ❑Once a year ❑Once a month ❑Once a week ❑Once a day

APPENDIX C: IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY QUESTIONAIRE SCORING

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? ________

2.) When was the last time you sprained your ankle?

❑Never	❑ > 2 years	❑ 1-2 years	❑ 6-12 months	❑ 1-6 months	❑< 1 month
0	1	2	3	4	5

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

❑Have **not** seen someone	❑Mild (Grade I)	❑Moderate (Grade II)	❑Severe (Grade III)
0	1	2	3

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

❑Never used a device	❑1-3 days	❑4-7 days	❑1-2 weeks	❑2-3 weeks	❑>3 weeks
0	1	2	3	4	5

5.) When was the last time you had ***"giving way"*** in your ankle?

❑Never	❑> 2 years	❑1-2 years	❑6-12 months	❑ 1-6 months	❑< 1 month
0	1	2	3	4	5

6.) How often does the ***"giving way"*** sensation occur in your ankle?

❑Never	❑Once a year	❑Once a month	❑Once a week	❑Once a day
0	1	2	3	4

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?

❑Never rolled over	❑Immediately	❑Sometimes	❑Unable to stop it
0	1	2	3

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?

❑Never rolled over	❑Immediately	❑ < 1 day	❑1-2 days	❑> 2 days
0	1	2	3	4

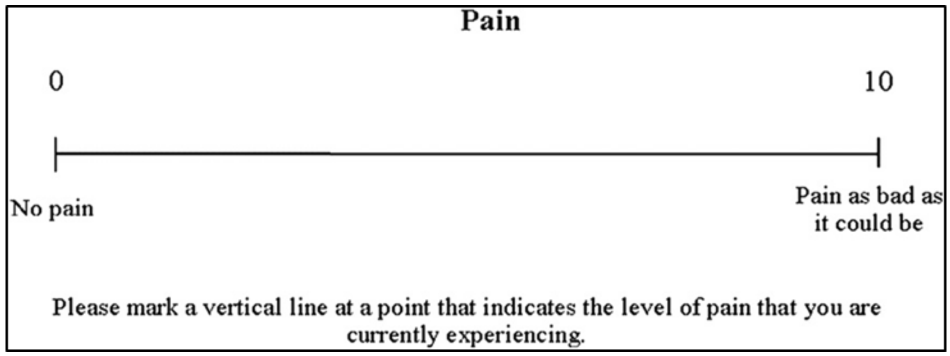
9.) During "Activities of daily life" how often does your ankle feel ***UNSTABLE****?*

❑Never	❑Once a year	❑Once a month	❑Once a week	❑Once a day
0	1	2	3	4

10.) During "Sport/or recreational activities" how often does your ankle feel ***UNSTABLE****?*

❑Never	❑Once a year	❑Once a month	❑Once a week	❑Once a day
0	1	2	3	4

APPENDIX D: VISUAL ANALOG SCALE



APPENDIX E: TAPING APPLICATIONS

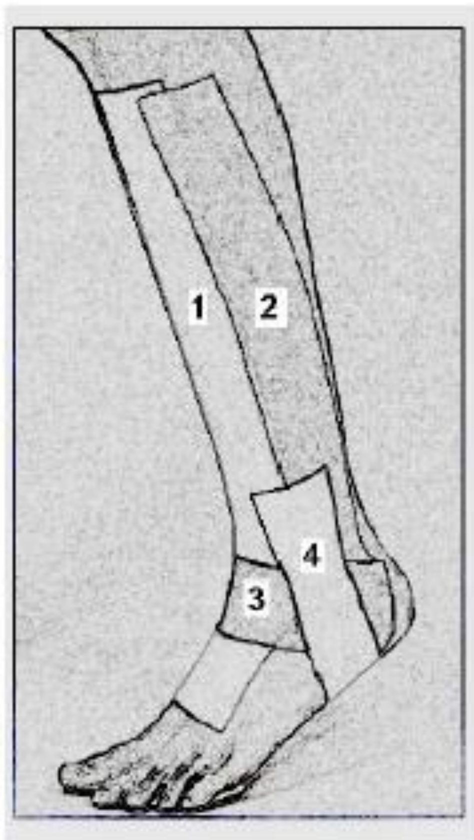


Figure 1. Tape strips comprising Kinesio Tex tape application. Numbers indicate order of application.

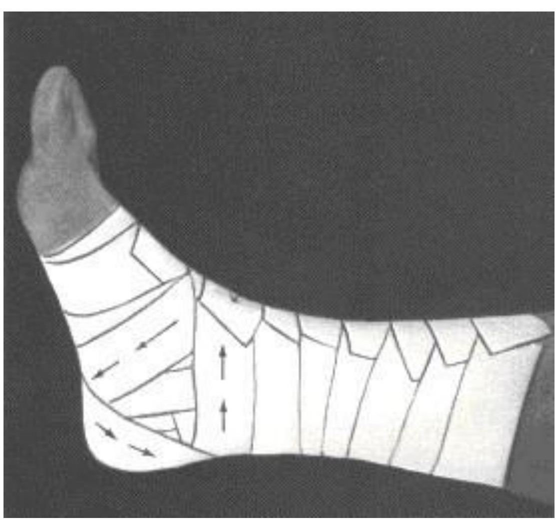


Figure 2. Application of Standard tape.