THE EFFECTS OF KINESIO TAPE ON ANKLE PROPRIOCEPTION IN ATHLETES WITH FUNCTIONAL ANKLE INSTABILITY

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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By

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Keywords: Kinesio Tape, Ankle Instability, Proprioception

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List of Abbreviations

- CAI- Chronic Ankle Instability
- FAI- Functional Ankle Instability
- KT- Kinesio Tape
- SEBT- Star Excursion Balance Test
- NT- No Tape
- ZT- Zonas Tape
- KT-72- Kinesio Tape applied for 72 hours
- A- Anterior
- AL- Anterolateral
- L- Lateral
- PL- Posterolateral
- P- Posterior
- PM- Posteromedial
- M- Medial
- AM- Anteromedial

Introduction

Lateral ankle sprains are one of the more common injuries in an athletic population. It is estimated that 30% of those injured will develop chronic ankle instability (CAI) following the first ankle sprain and in some athletes that rate can be as high as 70%-80%[1]. Chronic ankle instability can be defined as either mechanical ankle instability or functional ankle instability (FAI)[2]. Mechanical instability refers to the ankle physiologically moving past its limits, clinically called laxity[2]. Functional instability differs in that it is the subjective feeling of frequently "giving away" and sensations of instability[3,4]. These proprioceptive deficits as well as decreased sensory input from mechanoreceptors following the initial sprain leads to reduced motor control and balance deficits resulting in FAI [2-4,17].

Input for proprioception, the body's awareness of the limb or joint position and movement without visual assistance[5], is received from muscle spindles, sensorimotor receptors, mechanoreceptors, cutaneous receptors, and golgi tendon organs[3-5]. Proprioception is used in regulation of total posture, postural equilibrium, segmental posture, joint stability, as well as initiating several conscious peripheral sensations or ''muscle senses''[6]. It is believed that cutaneous mechanoreceptors have a role in detecting joint movement and position resulting from the stretching of skin at extremes of motion[11]. In other words, applying pressure to and stretching the skin can stimulate cutaneous mechanoreceptors and possibly influence the afferent proprioceptive information of the joint movement.

Kinesio Tape (KT), developed by Dr. Kenzo Kase in 1980[7], was theorized to improve joint function by enhancing "sensory" mechanisms[7, 11]. In contrast to traditional white athletic tape, KT can be worn for up to five days because it is porous allowing for evaporation of sweat and water and can be stretched up to 140% of its original length[10-12]. This stretch provides a constant pulling force on the skin[11] providing sensory feedback without restricting joint range of motion. These properties make KT unique compared to structurally supportive taping or bracing techniques.

Previous research on the effects of KT on joint position sense and proprioception has focused on static testing and has been inconclusive [8]. Most of these studies focused on immediate effect on KT therefore, the effect of KT on dynamic balance testing and its cumulative effects are unknown. The star excursion balance test (SEBT) is a dynamic test consisting of standing on one leg while reaching as far as possible with the contralateral leg toward eight different directions. This reaching motion during the

SEBT challenges the subjects' postural control, strength, range of motion, and proprioceptive abilities[9]. Kinzey and Armstrong[8] have found the SEBT to be a moderately reliable test for dynamic balance (ICC= .87)[8]. Hertel et al[9] specifically utilized subjects with CAI compared to healthy controls, and found significant differences between the groups. Subjects with CAI had significantly lower reach distances compared to subjects with healthy ankles, specifically reaches in the direction of anteromedial, medial and posteromedial[9].

The purpose of this study was to examine the effects of KT on proprioception in athletes with FAI. Proprioception was measured using SEBT. It was hypothesized that the application of KT on the FAI group would increase the reach distance on the SEBT when compared to a healthy control group.

Methods

Research Design

This study utilized a randomized experimental repeated measures design. Subjects participated in four separate data collection sessions with 72 hours between sessions. The independent variables were the taping conditions: No tape (NT), KT acute (KT), KT 72 hours (KT-72), and Zonas tape (ZT), and the group: FAI or control. The dependent variables were the reach distances of subjects on SEBT.

Subjects

Subjects recruited for this study were college age individuals from the University of Hawai'i at Manoa and the surrounding community. The FAI group included 12 ankles from eight subjects (6 female, 2 male), and the control group included eight healthy ankles from eight subjects (6 female, 2 male) (Table 1). Inclusionary criteria for the FAI group consisted of a history of recurrent lateral ankle sprains, three or more episodes of the ankle giving away in the last 12 months and the Cumberland Ankle Instability Tool (CAIT) score of less than 27 (appendix 2). Inclusionary criteria for the control group consisted of no history of lateral ankle sprain and a CAIT score of greater than 27. Subjects were excluded from the study if they had an ankle sprain within the last month, ankle surgery, fracture (current or previous) in the involved lower extremity, or any medical problem affecting balance such as inner ear disorder, vertigo or concussion.

Table 1. Descriptive Statistics FAI Group and Control Group

FAI			Control		
N=12 ankles	Mean	Std. Deviation	N=8 ankles	Mean	Std. Deviation
Age (yrs)	21.33	0.89		23.00	1.31
CAIT Score	20.25	3.55		29.13	1.36
Height (mm)	1680.92	64.58		1664.75	78.08
Leg Length (cm)	88.38	3.02		85.39	4.79
Weight (kg)	73.19	18.09		62.28	7.22

Instruments

Star excursion balance test was used to determine the dynamic balance ability of the subjects. The SEBT was set up with eight lines extending at 45 degrees from the center of the star. A goniometer was used to ensure each line was 45 degrees from the center point. A tape measure was placed on the ground at the corresponding line in each of the eight directions: Anterior (A), Anterolateral (AL), Lateral (L), Posterolateral (PL), Posterior (P), Posteromedial (PM), Medial (M), and Anteromedial (AM).

Star excursion balance test was performed with the head of the second metatarsal of the involved foot on the center of the star. For the control group, the involved ankle was matched for injured side and dominance of FAI group. All FAI and control subjects were right leg dominant. The FAI group consisted of six right ankles and six left ankles; the control group consisted of four right ankles and four left ankles. Subjects were instructed to place their hands on their hips and gain balance on the involved foot. When comfortable, the subjects were directed to reach with the uninvolved leg as far as possible on the designated line. The uninvolved foot lightly touched the ground before returning to the starting position next to the involved foot. Subjects were allowed to regain balance between trials with a rest period between reaches. All subjects completed the SEBT in the same order of directions (A, AL, L, PL, P, PM, M, and AM). Each direction was completed three times consecutively before moving to the next direction.

The CAIT is a questionnaire with nine Likert Scale questions with a maximum score of 30. Lower scores indicated more severe instability. The CAIT has excellent test-retest reliability with an ICC of .96 and has been validated against FAI questionnaire and ankle joint functional assessment tool with strong correlations[13]. The discrimination score was 27.5, with subjects scoring less most likely indicating FAI[13]. Subjects who scored less than 27 were placed in the FAI group for this study.

Taping

The KT ankle stability taping technique was applied with a full stretch. The area was cleaned with an alcohol wipe to remove dirt, oils and lotions from the skin to ensure proper contact with the skin. Excess hair was removed with a razor if necessary. Three strips of tape were cut according to each subject's measurements. A first measurement was taken from lateral malleolus along the base of the calcaneus to the medial malleolus. A second measurement was taken from the navicular tubercle, around the posterior calcaneus to the base of the fifth metatarsal and back to the navicular tubercle; this measurement was used for two strips of tape. To determine the KT length needed with an appropriate stretch, two thirds of the measured length was calculated and an additional four inches, two on either end, were added for anchors.

The first strip of KT's anchor was placed above the lateral malleolus with no stretch applied to the tape. A stretch was applied to the tape as it was laid across the bottom of the calcaneus, ending at the medial malleolus with the last two inches of tape having no stretch applied above the medial malleolus. The second strip began with the anchor placed distal to the base of the navicular tubercle on the medial side of the foot. The active portion of the tape was stretched around the posterior calcaneus to the base of the fifth metatarsal then back to the navicular tubercle with the remaining anchor placed with no tension. The third strip anchor started distal to the base of the fifth metatarsal then stretched around the posterior calcaneus to the navicular tubercle and back to the base of the fifth metatarsal with the remaining anchor placed with no tension. Zonas tape (ZT), a high tensile strength cotton athletic tape, was applied using the same technique as the KT with two-inch anchors on either end with no inherent stretch. A Certified Athletic Trainer (ATC) who had completed all three levels of the KT training applied all of the taping conditions.

Procedures

Prior to the study, subjects signed a consent form and completed the CAIT. At each data collection session anthropometrics of height, body mass, and leg length were recorded. Leg length was measured from the anterior superior iliac spine to the medial malleolus. The order of the taping conditions was randomized. Between each session, there was a 72-hour washout period to minimize any lingering proprioceptive effects of tape. All subjects performed up to six practice trials of the SEBT to familiarize themselves with the movements and to minimize the learning effect, as suggested by Hertel et al[9]. Each reach was marked by the same ATC throughout the study and measured from the center of the star in centimeters. The trial began when the subject started to reach in the designated direction. The trial was considered complete when the reach foot returned to the starting position. After three successful trials in a direction, the subject proceeded to the next direction, maintaining the same order. Trials were discarded if the subject lost balance indicated by the involved foot's second metatarsal moving off the center of the star, the reach foot resting on the ground to regain balance, or the subject lifting their hands off of their hips. In the case of unsuccessful trial, the subject repeated the trial until they achieved three successful trials in each of the eight directions.

Statistical Analysis

All reach distances were normalized to subject's leg length[9]. Descriptive statistics were calculated for each subject. Independent *t* tests were conducted to compare the SEBT reach distances between groups under NT condition to examine the difference in balance ability between groups. Multiple Repeated Measures One Way Analysis of Variance (ANOVA) was conducted to compare between tape conditions (NT, KT, KT-72, ZT) within each group. Post hoc analyses with LSD adjustment were conducted to compare each tape condition to NT condition within group. Dependent variables were reach distance for each SEBT directions (A, AL, L, PL, P, PM, M and AM). Data were analyzed using SPSS version 23.0 with an alpha level set at $P<.05$.

Results

No significant difference was found between the FAI and control groups under NT condition for SEBT reach distance in all directions (A: P=.54, Power=.606; AL: P=.329, Power=.497; L: P=.543, Power=.597; PL: P=.706, Power=.722; P: P=.684, Power=.705; PM: P=.875, Power=.876; M: P=.890, Power=.891; AM: P=.744, Power=.757). Significant differences within the FAI group between KT-72 and the NT conditions were found in SEBT distance in the directions of PM, M, and AM, indicating significant increase in reach distance under KT-72 condition (Table 2). There was no significant difference within the control group between conditions in any direction of SEBT.

Table 2. Star Excursion Balance Test Reach Distances (cm) Within Group Comparison of Tape Conditions to NT for Functional Ankle Instability and Control Groups (Mean ± SD)

Tape Condition	FAI Group	*P* Value	Power	Control Group	*P* Value	Power
Anterior						
NT	78.17 ± 11.7	--		82.13 ± 16.7	--	
KT	76.40 ± 11.8	.39	.999	83.69 ± 16.7	.67	.991
KT-72	79.03 ± 11.0	.69		84.59 ± 14.2	.29	
ZT	74.15 ± 12.2	.08		79.78 ± 17.5	.60	
Anterolateral						
NT	83.99 ± 9.1	--		90.13 ± 18.1	--	
KT	83.59 ± 12.2	.85	.999	90.29 ± 16.0	.97	.994
KT-72	85.24 ± 10.5	.43		91.86 ± 15.2	.52	
ZT	82.02 ± 12.2	.22		86.69 ± 14.9	.24	
Lateral						
NT	88.83 ± 7.3	--		92.63 ± 19.4	--	
KT	87.14 ± 11.7	.42	.994	93.64 ± 19.2	.75	.997
KT-72	90.59 ± 9.0	.43		96.91 ± 19.5	.12	
ZT	86.93 ± 9.8	.31		91.58 ± 17.4	.67	
Posterolateral						
NT	97.42 ± 7.9	--		99.69 ± 18.3	--	
KT	96.30 ± 9.6	.51	.994	101.54 ± 19.9	.56	.972
KT-72	99.39 ± 7.9	.19		101.29 ± 20.0	.47	
ZT	95.52 ± 10.7	.56		100.71 ± 17.3	.65	
Posterior						
NT-P	94.40 ± 11.5	--		97.34 ± 20.3	--	
KT-P	92.19 ± 12.2	.35	.968	93.69 ± 19.6	.10	.982
KT-72-P	96.96 ± 11.5	.13		96.98 ± 19.4	.90	
ZT-P	92.52 ± 12.6	.44		96.81 ± 18.7	.88	
Posteromedial						
NT	89.94 ± 8.0	--		90.87 ± 17.6	--	
KT	86.86 ± 11.7	.32	.999	93.84 ± 17.3	.15	.995
KT-72	93.71 ± 9.8*	.02		90.65 ± 18.9	.84	
ZT	88.28 ± 12.0	.59		90.44 ± 16.3	.86	
Medial						
NT	77.49 ± 9.2	--		76.66 ± 17.3	--	
KT	76.04 ± 12.1	.52	.999	76.65 ± 15.1	.99	.995
KT-72	82.08 ± 8.4*	.01		77.82 ± 19.2	.67	
ZT	75.19 ± 11.5	.81		81.23 ± 19.2	.34	

Anteromedial						
NT	71.33 ± 8.3	--		72.88 ± 12.7	--	
KT	71.47 ± 9.1	.93	.987	74.21 ± 11.7	.47	.989
KT-72	73.28 ± 9.5*	.04		73.71 ± 13.3	.68	
ZT	71.48 ± 9.4	.91		76.32 ± 15.0	.16	

Note: NT, no tape; KT, kinesio tape acute; KT-72, kinesio tape applied for 72 hours; ZT, zonas tape
*Statistical significant difference compared to NT at $P<.05$

Discussion

Our study's results indicated that the KT was effective in improving the SEBT reach distance in the direction of PM, M, AM at 72 hours post KT application; this effect was not indicated under KT acute and sham (ZT) conditions. Additionally, this effect was only indicated in the FAI group, suggesting that the KT is only effective in those who have ankle instability, indicated by CAIT, and does not improve balance ability for those who have healthy ankles. These results support the findings of Simon et al[10], who reported that KT improved proprioception at 72 hours after KT application and not immediately after KT application. They included 14 healthy control and 14 FAI subjects, and measured force sense error, how well subjects could reproduce the plantarflexion force, with and without the KT compared to untaped control. The results indicated that there was significantly increased error in FAI group compared to control under no tape and KT acute conditions; however, the proprioceptive deficit was diminished in the FAI group after wearing KT for 72 hours as indicated by no significant difference in force sense error between FAI and control groups. Similarly, when KT effects were measured immediately after application, Bicici et al[12] reported no significant difference on SEBT performance between KT and no tape conditions, while Briem et al[14] reported no significant difference in muscle activation of peroneus longus during unexpected ankle inversion between KT and no tape conditions[14]; both studies utilized subjects with FAI. Simon et. al[10] have pointed out that KT should be applied at least 30 minutes prior to athletic activity, as recommended by KT manual[18], and explained that this might have caused the lack of KT effect when measured immediately after the application. For the KT acute condition in the current study, the time between KT application and the start of SEBT was approximately five to ten minutes.

Mechanoreceptors, abundantly found in cutaneous and fascial tissues, respond to various stresses placed on them[15]. There are two types of mechanoreceptors: quick adapting Pacini receptors and slow adapting Ruffini receptors[14]. Pacini receptors are dynamic in nature due to their low threshold and respond to rapid pressure changes but not to constant steady pressure[16]. The quick adapting Pacini receptors decrease their firing rate at the onset of continuous stimulus and are thought to affect joint motion sensation[16]. Ruffini receptors are considered static and dynamic because of their low threshold[6,14]. The slow adapting Ruffini receptors maintain their firing rate with continuous stimulus and are thought to affect joint position and sensation of changes in joint position[14]. Stecco et. Al[17] reported that alterations to the extensor retinacula due to ankle sprains were believed to play a role in the decreased proprioceptive activity associated with FAI as the histological examination indicated that the extensor retinacula were rich in proprioceptors. It is plausible that damage to mechanoreceptors caused by injuries results in decreased ability to provide feedback to the central nervous system. The KT application augments the stimuli to the Ruffini receptors through continuous pressure resulting in increased firing rate, subsequently providing enhanced proprioceptive feedback to the central nervous system. The improved balance ability could be explained by adjustments made by motor control system based on the improved afferent feedback; however, this adjustment seems to require some time. Simon et. al,[10] who reported the KT effect after 72 hours of continuous wear, and not immediately after application, theorized that it required some practice for the body to incorporate the increased afferent input, which was accomplished through daily activity such as walking with KT[10]. Another important finding of our study was that there seemed to be no lingering effect of KT after removal, indicated by nonsignificant findings under KT acute and ZT conditions, given the randomized order of condition with a 72-hour washout period. Based on the results of current and previous studies, it could be theorized that the improvement in balance ability was induced by increased afferent stimuli provided by KT in conjunction with motor control improvements occurring sometimes between 10 min to 72 hours, and not by changes in the mechanoreceptors themselves; the prerequisites requirement for the motor control improvements is increased afferent stimuli, which explains why the balance improvement did not last after tape removal.

Interestingly, our results did not indicate SEBT differences between FAI and control groups. Conversely, Lui et al[2] reported that subjects with frequent ankle sprains demonstrated decreased passive and active joint reposition sense, while Hertel et al[9] reported that subjects with CAI demonstrated decreased balance ability indicated by SEBT; both comparing to healthy controls. Lack of balance deficits indicated in our FAI group could be due to the difference in subjects' fitness level between groups. As a result of ankle sprains being one of the most common sports related injury, a majority of FAI group consisted of collegiate athletes who currently participate in NCAA Division I sports, while all control group consisted of active college age individuals who did not participate in college level sports. Although we did not assess subjects' fitness level, it is possible that the inherent balance ability of the highly trained FAI subjects' was higher than that of control subjects, which was negatively influenced by FAI resulted in no difference between groups. In the current study, the FAI group demonstrated significant improvements in the SEBT reach distance with KT application in the directions of PM, M, and AM. Interestingly, Hertel et. al[9] indicated that the CAI group demonstrated decreased reach distance in the directions of PM, M and AM, suggesting that CAI is associated with the balance deficits in these directions. These directions coincide with the directions of improvement with KT-72 demonstrated by our FAI subjects, further supporting the possibility that there were deficits in above mentioned directions in our FAI group, which was counterbalanced by the difference in fitness level between groups.

Although the KT application for 72 hours indicated positive effect on balance ability, the effect on sham (ZT) condition for 72 hours remains unknown. According to our theory of increased mechanoreceptor stimulation that lead to motor control adjustment after 72 hours, application of ZT could have similar effects if left in place for extended period of time. However, this effect was unable to be examined due to the properties of ZT not being conducive to long term wear or to withstand the activities of daily living. In summary, the current study demonstrated that the KT was effective in improving dynamic balance ability when worn for 72 hours, while the effect was not indicated immediately after the KT application suggesting that the effectiveness of KT occurs some time within 72 hours. This positive effect of KT was only indicated in the FAI subjects, and not in healthy control subjects. Based on these findings, when applying KT for proprioceptive enhancement for those with FAI, it is recommended to allow ample time prior to the targeted activity.

Appendix 1

Tables

Table 1. Descriptive Statistics FAI Group and Control Group

FAI			Control		
N=12 ankles	**Mean**	**Std. Deviation**	**N=8 ankles**	**Mean**	**Std. Deviation**
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Anterolateral						
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ZT-P	92.52 ± 12.6	.44		96.81 ± 18.7	.88	
Posteromedial						
NT	89.94 ± 8.0	--		90.87 ± 17.6	--	
KT	86.86 ± 11.7	.32	.999	93.84 ± 17.3	.15	.995
KT-72	93.71 ± 9.8*	.02		90.65 ± 18.9	.84	
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Anteromedial						
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Note: NT, no tape; KT, kinesio tape acute; KT-72, kinesio tape applied for 72 hours; ZT, zonas tape
*Statistical significant difference compared to NT at *P*<.05

Appendix 2

The 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
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
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 3

Data Collection Form

Subject ID# ________________ Date____________

Tape Condition: NT KT KT-72 ZT Data collections session: 0 1 2 3 4

Age: ____ Height: _________ Weight: __________ Leg Length: __________

Ankle Width: ________ Knee Width: ________ Dominant Foot: L R Injured Ankle: L R

Total Trials

Direction	Trial 1	Trial 2	Trial 2
A			
AL			
L			
PL			
P			
PM			
M			
AM			

Appendix 4

Consent Forms

INFORMED CONSENT FORM - Involved

I. **INVESTIGATORS**

Principle Investigators: Nicolle Johnson, ATC; Kaori Tamura, PhD, ATC; Portia B Resnick, MA, ATC, LMT

II. TITLE

The Effects of Kinesio Taping on Ankle Proprioception in Athletes with Functional Ankle Instability

III. INFORMED CONSENT

The purpose of this consent form is to provide you with information about this research to help you decide if you would like to participate in this study. Please take your time to review this consent form. If there are any words or sections in this consent form that you do not understand or want to clarify, please do not hesitate to ask the research staff at anytime.

IV. **WHY IS THIS STUDY BEING DONE?**

This study will examine the effectiveness of Kinesio Tape on proprioception (balance ability) in the ankle. Kinesio Tape is applied in a manner to facilitate skin receptors and enhance sensory mechanisms. However, studies are inconsistent with their findings and no study has been done with dynamic balance to evaluate this property of Kinesio Tape. It is important for the allied medical professional to have evidence of the effects of Kinesio Tape in order to provide quality medical care.

V. VOLUNTARY PARTICIPATION

A total of 60 participants will take part in this study. You are being asked to participate because you are between the ages of 18 and 25 years old and have recurrent ankle sprains or the feeling of instability. It is important to understand that participation in this study is completely voluntary. You may decide not to participate, or withdraw at any time, and it will not affect you in any way. Upon clearance, you will be scheduled for the data collection sessions.

VI. **STUDY PROCEDURES**

If you decide to participate in this study, you will be asked to attend 4 data collection sessions over a consecutive 12 day period. At each data collection session, you will be asked to perform a dynamic balance test called Star Excursion Balance Test (SEBT), which involves standing on one foot and reaching as far as you can on the opposite foot in 8 different directions. You will be asked to perform this task under 4 different taping conditions on 4 separate days. You will be recorded using infrared cameras, which only capture the reftroreflective markers placed on your body; therefore, yourself including face will not appear on the recorded data. You will also be asked to complete a questionnaire for ankle instability at the initial data collection session.

Data collection will take place at the University of Hawaii at Manoa's Human Performance Lab. At each of the visits, we will measure your height, body mass, lower limb lengths and the widths of knee and ankle, and place 27 reftroreflective markers on various locations on your body. Your involved ankle will be measured and marked with a permanent marker to determine the location of the tape. Then the taping intervention will be applied.

At the first visit, you will have up to six practice trials to be familiar with the SEBT, and then complete three successful trials. You will be asked to come back 3 more times for the next data collection 72 hours following each one. For the Kinesio Tape 72-hour intervention you will be asked to leave the tape on for an additional 72 hours until the next data collection. During this 72 hours, you may bathe normally and perform activities of daily living, however you will be asked to refrain from any vigorous physical activity, such as but not limited to, heavy weight lifting, swimming, surfing or contact sports that may cause Kinesio Tape to come off. Should you have any redness or itching at the site of tape, you may remove it carefully and report your symptoms to the investigator immediately. For the rest of the 12 consecutive days during the data collection period, you will be allowed to perform normal daily activities.

VII. RISKS

There is minimal risk of an allergic reaction to the Kinesio Tex Tape. Should any redness, swelling, discomfort or irritation occur while wearing the tape, please remove it immediately and contact the research team. Incorrect removal of the tape may lead to some minor skin irritation and redness. The researchers will instruct you on how to remove tape safely on the first day, or may remove the tape for you at the end of the study to help minimize these risks.

VIII. BENEFITS

You may not receive any direct or immediate benefits. Kinesio Taping has been theorized to increase joint and cutaneous sensory mechanisms in the tissues, decrease pain and increase range of motion. You may feel these effects while being taped. In addition, your participation will help to further understand the effects of Kinesio Taping.

IX. COSTS

All clinic and professional testing fees will be provided at no cost to you. Parking fees will be reimbursed to you.

X. COMPENSATION

No compensation will be given for your participation. You will receive a Kinesio Tape treatment for the ankle instability during the study, and also be provided with information regarding self-treatment and rehabilitation exercise for ankle instability.

XI. CONFIDENTIALITY

All information about you will be held confidential to the extent allowed by state and federal law. Your personal information will not be given to anyone outside of the research team without your written permission. A code will be used as identifier instead of your name for this study. Research records that contain personal information, including code key, will be kept in a secure locked file in the Department of Kinesiology and Rehabilitation Science at the University of Hawaiʻi at Mānoa. These documents will be permanently destroyed no later than 5 years after the completion of the study.

Information gathered in this research study may be published or presented in public forums, however your name and other identifying information will not be disclosed. Agencies with research oversight, such as The University of Hawaiʻi Committee on Human Studies Program, have the right to review research records. You would be asked to sign an authorization form to allow the researcher to release any of your personal information obtained through the research process

XII. INJURY RELATED TO THE STUDY

Should any injury or medical emergency occur during the data collection, first responder care (first aid and CPR) is available, and appropriate referral will be made. First responder care will be provided for free of charge, however, you will be responsible for the cost associated with referral thereafter. If your insurance will not pay for these costs, it will be your responsibility. The University of Hawaiʻi has no program to pay or compensate you in any way for your injuries. Should any injuries occur during the study participation outside of data collection, please contact your physician for assistance, and inform research personnel as soon as possible.

XIII. QUESTIONS

If you have any questions related to the study participation, please contact **Nicolle Johnson at (502) 262-1668 or nicollej@hawaii.edu**. If you have questions or concerns about your rights as a research participant, please contact the Human Studies Program at (808) 956-5007.

XIV. STATEMENT OF CONSENT

I have read the above information, or it has been read to me. I have had the opportunity to discuss this research study with research staff, and I have had my questions answered by them in language I understand. I take part in this study of my own free will, and I understand that I may withdraw from participation at any time and this will not affect me in any way. My consent to participate in this study does not take away any of my legal rights in the event of negligence or carelessness of anyone working on this project. A copy of this consent form has been given to me.

XV. SIGNATORIES

I agree to take part in this study.

____

Print Name

____

Signature **Date**

____

Researcher Name (print)

____

Researcher Signature **Date**

INFORMED CONSENT FORM – Control Group

I. **INVESTIGATORS**

Principle Investigators: Nicolle Johnson, ATC; Kaori Tamura, PhD, ATC

II. TITLE

The Effects of Kinesio Taping on Ankle Proprioception in Athletes with Functional Ankle Instability

III. INFORMED CONSENT

The purpose of this consent form is to provide you with information about this research to help you decide if you would like to participate in this study. Please take your time to review this consent form. If there are any words or sections in this consent form that you do not understand or want to clarify, please do not hesitate to ask the research staff at anytime.

IV. **WHY IS THIS STUDY BEING DONE?**

This study will examine the effectiveness of Kinesio Tape on proprioception (balance ability) in the ankle. Kinesio Tape is applied in a manner to facilitate skin receptors and enhance sensory mechanisms. However, studies are inconsistent with their findings and no study has been done with dynamic balance to evaluate this property of Kinesio Tape. It is important for the allied medical professional to have evidence of the effects of Kinesio Tape in order to provide quality medical care.

V. VOLUNTARY PARTICIPATION

A total of 60 participants will take part in this study. You are being asked to participate because you are between the ages of 18 and 25 years old and are physically active and have no history have lower extremity injury. It is important to understand that participation in this study is completely voluntary. You may decide not to participate, or withdraw at any time, and it will not affect you in any way. Upon clearance, you will be scheduled for the data collection sessions.

VI. **STUDY PROCEDURES**

If you decide to participate in this study, you will be asked to attend 4 data collection sessions over a consecutive 12 day period. At each data collection session, you will be asked to perform a dynamic balance test called Star Excursion Balance Test (SEBT), which involves standing on one foot and reaching as far as you can on the opposite foot in 8 different directions. You will be asked to perform this task under 4 different taping conditions on 4 separate days. You will be recorded using infrared cameras, which only capture the reftroreflective markers placed on your body; therefore, yourself including face will not appear on the recorded data. You will also be asked to complete a questionnaire for ankle instability at the initial data collection session.

Data collection will take place at the University of Hawaii at Manoa's Human Performance Lab. At each of the visits, we will measure your height, body mass, lower limb lengths and the widths of knee and ankle, and place 27 reftroreflective markers on various locations on your body. Your involved ankle will be measured and marked with a permanent marker to determine the location of the tape. Then the taping intervention will be applied.

At the first visit, you will have up to six practice trials to be familiar with the SEBT, and then complete three successful trials. You will be asked to come back 3 more times for the next data collection 72 hours following each one. For the Kinesio Tape 72-hour intervention you will be asked to leave the tape on for an additional 72 hours until the next data collection. During this 72 hours, you may bathe normally and perform activities of daily living, however you will be asked to refrain from any vigorous physical activity, such as but not limited to, heavy weight lifting, swimming, surfing or contact sports that may cause Kinesio Tape to come off. Should you have any redness or itching at the site of tape, you may remove it carefully and report your symptoms to the investigator immediately. For the rest of the 12 consecutive days during the data collection period, you will be allowed to perform normal daily activities.

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VIII. BENEFITS

You may not receive any direct or immediate benefits. Kinesio Taping has been theorized to increase joint and cutaneous sensory mechanisms in the tissues, decrease pain and increase range of motion which may occur in this situation. In addition, your participation will help to further understand the effects of Kinesio Taping.

IX. COSTS

All clinic and professional fees testing will be provided at no cost to you. Parking fees will be reimbursed to you.

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Research records that contain personal information, including code key, will be kept in a secure locked file in the Department of Kinesiology and Rehabilitation Science at the University of Hawaiʻi at Mānoa. These documents will be permanently destroyed no later than 5 years after the completion of the study.

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XV. SIGNATORIES

I agree to take part in this study.

____

Print Name

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Signature **Date**

____

Researcher Name (print)

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Researcher Signature **Date**

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Literature Review

Simoneau et al[8] studied the effects of strips of athletic tape placed on the ankle on proprioception. The purpose was to examine a person's ability to perceive joint movement and placement of the ankle with athletic tape on the skin. The authors justified this study by the lack of studies investigating the effect of taping and bracing on balance and no study has directly examined the effects of joint movement and proprioception. The study used twenty healthy males ages 19-25 years old with a mean age of 20.3+-1.5 years and were recruited from Marquette University through fliers, advertisement boards and the student newspaper. All subjects were cleared of any ankle injury (current or chronic) and had normal ligamentous stability. The ankle joint movement and position perception device used to measure joint position sense and proprioception consisted of two individually movable foot platforms. Each platform was made up of a 12-by-7-inch metal plate where the subject placed their foot. Each plate moved individually at velocities of 0.1-4.0 degrees/second. This tested joint position perception and joint movement perception. Both of which were tested in weight bearing and non-weight bearing positions. Two strips of tape were placed on the subjects' ankle. One strip was placed on the anterior ankle, the other over the Achilles tendon to the bottom of the foot. The results showed no statistical difference for joint position perception while weight bearing (1.13° ± 0.54° [T] and 1.31° ± 0.670 [NT]), but a significant difference during non-weight bearing (1.53° ± 0.840[T], 2.310 ± 1.220[NT]). The use of tape did not have a significant difference on joint movement perception in either condition (WB 0.600 ± 0.470 vs 0.670 ± 0.500 and NWB 0.780 ± 0.570 vs 0.930 ± 0.670). There was a subjective questionnaire after each testing session. When asked, 16 of 20 subjects stated that the tape helped with position perception, while only 5 of 18 subjects stated that the tape helped with movement perception. Two subjects did not complete the movement perception questionnaire. [8]

Conversely, Refshauge et al[15] studied the effects of tape on the perception of inversion-eversion movements in subjects with recurrent ankle sprains. They justified this study based on the ideas that close contact between the tape and the skin increases afferent traffic arising from the cutaneous receptors, as well as the tape may increase cutaneous input that converges on muscle afferents and increase excitability of the motor neuron pool. Sixteen participants with recurrent ankle sprains volunteered for this study. 14 were female, 2 male with an average age of 22 ± 3 years, height 166 ± 7 cm and weight 62 ± 7 kg[15]. The authors defined a recurrent sprain as sustaining 3 sprains within the past 2 years and participants whom had injured their ankle in the past 3 weeks were excluded from the study. Movement detection was tested with and without tape. The ankles were taped with Leuko tape in a typical ankle tape job with the same evaluator completing each tape job. The subjects were tested in a seated position and the test foot was placed on a metal plate. The foot was placed midway between plantar/dorsiflexion and inversion/eversion. The footplate was moved into inversion and eversion up to 5 degrees in each direction. Movement detection was measured at 3 velocities: 0.1 deg/s, 0.5 deg/s, and 2.5 deg/s[15]. The order of testing velocity was randomized. Each subject was instructed to report the direction of the perceived movement. The results showed a significant difference in taping and velocity ($F = 6.387, P = .023$) but not in direction ($F=0.015$, $P = .905$) [15]. These results showed that tape did not help with motion sense rather is hindered the performance[15].

Briem, et al[1] studied the effects of Kinesio Tape compared to other sports tape and the untaped on sudden ankle inversion in male athletes. They justified this study based on the fact that Kinesio Tape's elastic properties make the effects on ankle stability proprioceptive and muscle activation rather than support. Therefore, the purpose of this study was to examine the effect of taping on the activation of the fibularis longus muscle during sudden inversion. 30 male athletes were recruited from soccer, basketball, and handball teams at a sports club in Iceland. The 30 participants had a mean age of 24.5 □ 5.0 (range, 18-37) years and a body mass index of 24.6 □ 3.1 (range, 19.6-31.6) kg/m2. All of the athletes were evaluated with the star excursion balance test. The scores were calculated by the distance reached divided by leg length and ranged from 70 to 115. The mean score on the SEBT was 102 □ 5 for the more stable group, which was significantly greater than the score of 81 □ 4 for the less stable group (P<.001). The 30 participants were tested under 3 conditions presented in randomized order, 2 taped conditions and a non-taped condition. Leukotape P non- elastic sports tape (BSN Medical, Ham- burg, Germany) and Kinesio Tex Gold elastic sports tape (Kinesio USA, LLC, Albuquerque, NM) were used for the 2 taping conditions and was applied by a single athletic trainer. KT was applied directly to the skin (subjects were shaved and cleaned prior to application) at the origin to the insertion of the fibularis longus muscle. During each trial, the participant stood on 1 foot on a balance board, as a 10-kg weight was dropped down a slot onto the backside of the lateral side of the board, without warning, creating an inversion perturbation of 15°. Muscle activity was measured through electromyography. The results showed that only the Leukotape had an effect on muscle activation while KT seemed to have no significant difference.[1]

Halseth, et al[10] studied the effects of Kinesio Tape on ankle proprioception. They hypothesized that the application of Kinesio Tape would decrease the absolute and constant error of reproduction joint position sense (RJPS) when compared to the untapped ankle. Thirty healthy (15 women and 15 men) were screened for this study. Volunteers with any previous history of ankle injury or surgery were excluded from this study. RJPS was measured with the subject's ability to actively recreate a randomly selected target position. These ankle measures were taken for both plantar flexion and inversion with 20º plantar flexion before and after the application of Kinesio tape. Ankle position data was measured using an instrumented platform with a moveable footplate with motion sensors. The footplate was stabilized throughout testing with the use of counterbalance system. Attached to the platform was a precision potentiometer (Spectrol, Type 157, Ontario, CA), which allowed a measure of specific angular position digitally, displaying the position to the nearest tenth of a degree on a digital liquid crystal display and computer data collection system. Ankle measures were taken for both plantarflexion and inversion at 20 degrees before and after Kinesio Tape application. Examiners passively placed the subjects' dominant ankle in a random target angle and then asked the subject to actively reposition their ankle in the target angle from neutral. Half of the subjects performed 10 trials with the ankle untapped before applying the Kinesio Tape while the other half performed the trials with the ankle taped first. This was decided randomly. The tape was done in accordance with the lateral ankle sprain tape in Kenzo Kase's Kinesio Tape manual. This study used a pretest-posttest design with the independent variable being the KinesioTM taping procedure, and the dependent variable being the reproduction of joint position sense. Results were evaluated for statistical significance ($p < 0.05$). The results showed no significant differences of absolute error between the no-tape condition (M=2.19° ± 1.20°) and the taped condition (M=2.07° ± 0.98°) in plantar flexion, nor were any significant differences seen between the no-taped condition (M=1.87° ± 0.89°) and the taped condition (M=1.95° ± 0.90°) in the combined motion of inversion with 20° of plantar flexion. [10]

Simon, et al[9] studied the effects of Kinesio Tape on force sense in subjects with functional ankle instability (FAI). Since Kinesio Tape has the ability to be worn for 3 to 5 days they hypothesized that this aspect of the tape would increase proprioception after being worn for a few days. The purpose is to directly study the effect of Kinesio tape on proprioception. The control group was composed of 14 subjects (2 men and 12 women; age, 21.2 +- 2.6 years; height, 170.1 +- 9.9 cm; weight, 67.0 +- 13.7 kg) who had healthy ankles with no history of ankle injury. The FAI group was composed of 14 subjects (9 men and 5 women; age, 20.8 +- 1.4 years; height, 177.3 +- 9.0 cm; weight: 78.5 +- 12.9 kg) who had a history of an ankle sprain, reported their last giving way episode as 1 to 6 months from the testing date, and felt unstable during sports or recreational activity. All completed the ankle instability instrument to determine their group assignments. Those who scored a 5 or greater were in the FAI group; control group had a score of zero. All subjects had an initial maximal voluntary isometric contraction test followed by a force sense test. After the initial testing the FAI group received KT application while the control group rested for 5 minutes. After the taping/rest both groups completed a second force sense test. The KT application was done following the manual for kinesio taping for lateral ankle sprains. A third force sense trial was completed 3 days after the initial trial day. The baseline mean force sense error for the control group was 0.9 +- 0.3 N; immediately after the rest period, 1.0 +- 0.3 N; and 72 hours later, 1.1 +- 0.8 N. For the FAI group, the baseline force sense error was 2.6 +- 1.0 N, immediately after tape application was 2.2 +- 1.8 N, and 72 hours after tape application was 1.8 +- 1.2 N. Results revealed a significant time by group interaction ($F_{2,52} = 3.7$;$P = 0.03$; effect size = 0.13; power = 0.65). Results of post hoc testing revealed that at both baseline ($t_{1,26} = 6.1$;$P = 0.01$; effect size = 0.58; power = 0.99) and immediately after tape application ($t_{1,26} = 2.4$;$P = 0.02$; effect size = 0.18; power = 0.64), the FAI group had significantly more errors than the control group. However, after wearing the tape for 72 hours, no significant differences were identified between the groups($t_{1,26} =1.7$;$P=0.12$;effectsize= 0.09; power = 0.37). This means that after the tape was worn for 72 hours, they had less force sense errors. This also showed that the number of errors were similar to the control group meaning that the use of KT over a few days enhanced their proprioceptive responses. [9]

Kinzey , et al[5] studied the reliability of the star excursion balance test in detecting proprioceptive deficiencies. Many balance tests are static and therefore do not accurately depict a person's ability to balance considering daily activities are mostly dynamic. They had twenty subjects (nine male, 11 female) between the ages of 18-25 volunteer for this study. Subjects were excluded from the study if they had received an ankle injury in the last two years, a history of dizziness, an inner ear disorder, nervous system problems, bone or joint abnormalities, a history of loss of consciousness, or any uncorrected visual problems. The test was set up with four strips of tape, two running horizontal and vertical and two at 45 degree angles in respect to the horizontal and vertical strips. There was a rectangle in the middle of the strips to indicate the starting point for the subjects' feet. Each subject completed two testing sessions seven days apart. The subjects' started the test by standing with both feet in the box and began to reach in one of four diagonal directions. The balance foot was the foot opposite of the direction the subject was reaching. The length of the reach was visually measured by the testing administrator without the subject touching the reach foot to the ground. The distance was measured in centimeters. Five consecutive trials were completed for each direction. The researchers used a pretest-posttest design to assess the four dependent measures. Intraclass correlation coefficient and the Spear- man Brown prophecy were used to estimate the reliability. The results showed only moderate estimates of reliability with the left posterior and anterior results being most reliable (0.87). [5]

Hertel, et al[4] studied the performance outcomes of subjects with and without chronic ankle instability (CAI) on the star excursion balance test (SEBT). They also looked at which directions of the SEBT were affected by CAI. Forty-eight subjects with self-reported CAI participated in the study. The demographics of the subjects were: mean ± SD age, 20.9 ± 3.2 years; mean ± SD height, 173.6 ± 11.1 cm; mean ± SD mass, 80.1 ± 22.1 kg. They also had 39 subjects (mean ± SD age, 20.7 ± 2.4 years; mean ± SD height, 174.1 ± 12.9 cm; mean ± SD mass, 75.1 ± 18.6 kg) without CAI participate in the study. The researchers defined CAI as having at least one ankle sprain that required medical attention and experiencing three or more episodes of the ankle giving away in the last year. The CAI group must not have a history of ankle fracture or surgery nor having any injury to the uninvolved limb. In this study, subjects performed the SEBT barefoot. The test was set up the same and completed the same as previous mentioned studies in this review. However, the reach distances were normalized according the subject's leg length, measured from the anterior iliac spine to the medial malleolus. Each subject completed three trials and the mean of the trials were used in statistical analysis. The researchers performed three different analyses', one on the involved limb of the CAI group, the second on the uninvolved limb of the CAI group and both limbs of the control group, and lastly, both limbs of both groups. They used Pearson product moment correlation coefficients to look at the data. A series of 8 mixed-model 2 × 2 analyses of variance (ANOVAs) were also performed to examine potential differences in reach performance in each of the 8 directions related to the between-factor (group: CAI, control) and the within-factor (limb: involved, uninvolved) effects. For the limbs with CAI, a 1-factor model was identified with the factor having an eigenvalue of 6.1. The second best factor had an eigenvalue of 0.9. The loading of each reach direction to the 1-factor model revealed that the PM reach was the most strongly related (a = .95). However, all 8 directions had alpha values of greater than .67, suggesting considerable redundancy among the 8 directions. For the healthy limbs, a 1-factor model was also identified with the factor having an eigenvalue of 6.2. The next best factor had an eigenvalue of 0.7. The PM reach again loaded highest (a = .97) and all 8 directions had alpha values of greater than .79. For each of these directions, post hoc testing revealed that the reach distances of the involved limbs of the CAI group were significantly less than those of their contralateral limbs and the side-matched sham-involved limbs of the control subjects ($P<.05$). [4]

Olmstead[16], et al studied whether or not SEBTs could detect reach deficits in subjects with unilateral CAI. They had twenty subjects with unilateral CAI volunteer for the study. The subjects were 10 men, 10 women; age 19.8 +- 1.4 years; height 176.8 +- 4.5 cm; mass 82.9 +- 21.2 kg; leg length 93.3 +- 7.1 cm[16]. The control group consisted of 20 uninjured subjects (10 men, 10 women; age 20.2 +- 1.4 years; height 178.7 +- 4.1 cm; mass 82.7 +- 19.9 kg; leg length 95.5 +- 5.2 cm) [16]. For this study CAI was defined as recurrent episodes of ankle instability. Again, the design of the SEBT was set up and conducted the same as previous mentioned studies. A 2x2x8 repeated measure analysis was used to analyze the data. The between-subjects factor was group with two levels (CAI, control), while the within-subjects factors were side with two levels (injured, uninjured) and direction with eight levels (eight directions of reach) with the alpha level set at $P<0.05$. The results showed a significant difference between the CAI group and the control group ($P=0.05$) [16]. The reaches in all directions for the CAI group were shorter. [16]

Bicici[17], et al studied the effects of ankle tape and kinesiotape (KT) on functional performance in basketball players with chronic inversion ankle sprains. Fifteen players between the ages of 18 and 22 (mean age: 20.33 ± 1.4 yrs) [17] participated in the study. They must have had recurrent ankle sprains defined as at least three sprains and be diagnosed with functional ankle instability (FAI) by the Cumberland Ankle Instability Tool (CAIT). CAIT is a questionnaire with 30 questions, a score of greater than or equal to 27 is considered to be a diagnosis of FAI. The subjects completed a series of functional tests in four different taping conditions. The conditions were: placebo tape, athletic tape, KT, and no tape. The first functional test completed was the hopping test. The hopping test tests single leg agility and motor control. It consists of four squares with a 15 degree incline in different directions. The next test subjects did was the single limb hurdle test which involved ten squares with three hurdles in the middle that were about 15cm high[17]. Subjects completed two lateral jumps and one medial jump. Thirdly, they performed a vertical jump test. After that the subjects did a standing heel rise test in which they did heel rises until fatigue. The next test they completed was the SEBT again as described earlier in this review. Lastly, the subjects performed the SportKAT test which measures kinesthesia tilt sensors on a platform. Statistical analyses performed consisted of one way ANOVA tests to examine difference in measurements between conditions. Bonferroni correction was applied to correct for use of multiple tests. The mean performance time for the hop- ping test was fastest in the athletic tape condition (6.56 seconds) followed by the KT condition (6.62 seconds) as compared to placebo tape (7.01 seconds) and non-taped condition (7.21 seconds) [17]. The only statistically significant difference was found between the athletic tape and non-taped conditions (p=0.035). In the single limb hurdle test fastest performance was measured in KT® condition (5.17 seconds) then in athletic taping condition (5.26 seconds), followed by placebo tape (5.41 seconds) and non-taped condition (5.50 seconds) [17]. The mean number of heel rises performed was the most in the KT condition (30.6) followed by placebo tape (28.8). While in vertical jump test results greatest height was measured in KT condition (33.4 cm). No significant differences were observed among all the trials of the SEBT. The SportKAT 3000 showed that in static balance assessments, subjects who had KT applied demonstrated statistically significant lower balance index scores (the lower balance score, the better success) than those who wore either placebo taping or no tape, while dynamically there were no significant differences. [17]

Karlsson and Frykberg[18] studied the correlation between force plate measures for assessment of balance. The purpose of the study was to compare different types of force plate measures. They compared the standard deviation of the horizontal ground reaction force components, the standard deviation of the center of pressure, the mean velocity of the center of pressure, movement strategy measures, and the standard deviation of the vertical ground reaction force[18]. As well as being compared to each other the researchers also compared the results to the Berg Balance test. They recruited 20 post stroke patients from Upsaala University hospital. Twelve males and 8 females, mean age: 50 years (range: 21±65 years) [18], paretic side: 12 right and 8 left, mean time from stroke: 2 years and 4 months (range: 6 months±13 years) [18]. Data were collected for 30 s, with a sampling frequency of 50 Hz[18]. "The mean and S.D. for 19 CVA patients were for the different measures as follows: S:D:…Fx=m†ˆ15:7 (S.D. 5.7) mm=s2; S:D:…Fy=m†ˆ10:6 (S.D. 4.1) mm=s2; S.D.…CoPx†ˆ3:5 (S.D. 1.1) mm, S.D.…CoPy†ˆ2:4 (S.D. 1.4) mm, CoPxvelˆ13.0 (S.D. 6.1) mm/s, CoPyvelˆ8.3 (S.D. 3.1) mm/s, qmodel ˆ 0:36 (S.D. 0.08), rmodel ˆ 0:95 (S.D. 0.03), and S.D.…Fz=m†ˆ14:3 (S.D. 4.7) mm=s2. [18]" These results found a positive correlation between horizontal force measures and CoP meaning this is related to the movement of CoM[18].

Gribbel and Hertel[6] studied the role of gender, foot type, height, leg length, and lower extremity ROM measurements during the star excursion balance test and determined the need for normalization of the test. Thirty (12 men, 18 women) recreationally active participants volunteered for this study. Prior to testing the participants' foot type, height, leg length, hip internal and external ROM, and ankle dorsiflexion ROM was measured. They then performed the SEBT, and were allowed up to six practice trials. Three trials were completed in each direction. A series of eight independent t tests was used to examine the differences in normalized excursion distances in the eight directions as a function of gender. Eight separate analysis of variance (ANOVA), with one between-groups factor (foot type), were computed; one for each excursion direction. Pearson product–moment correlations were calculated to explore the bivariate relations between excursion distance and height, leg length, hip internal ROM, hip external rotation ROM, and ankle dorsiflexion ROM. A significant correlation ($p < .05$) was found between height and excursion distance, and leg length and excursion ($p < .05$) distance in six of the eight directions: anterior, anteromedial, medial, posteromedial, posterior, and anterolateral. With these results they normalized the excursion distances to leg length. Men were initially found to have significantly ($p < .006$) greater excursion distances than women in three directions (posterior, posteriomedial, medial); however, after normalizing the excursions for leg length no significant differences between genders were found. The results show that height and leg length are strongly correlated to excursion distances suggesting that when completing the SEBT results should be normalized to leg length of the participants. [6]

Earl and Hertel[7] the lower extremity muscles that are activated during the star excursion balance test. The purposes of the study were to identify differences in (1) muscle activity and (2) ROM of the knee and ankle among the different excursion directions[7]. Ten recreational athletes were used as subjects (5 men, 5 women, age = 24.9 ± 4.2; mass = 72.2 ± 17.2kg; height = 152.6 ± 7.9 cm[7]). Surface EMG was collected from the vastus medialis obliquus (VMO), vastus lateralis (VL), medial hamstrings (MH), biceps femoris (BF), anterior tibialis (AT), and gastrocnemius using 10-mm-contact-area Ag-AgCl disposable electrodes (Biopac) [7]. The Cybex II Isokinetic Dynamometer (Cybex Inc, Bay Shore, NY) was used to facilitate the maximal voluntary isometric contractions (MVICs) [7]. During the SEBTs EMG an ROM was collected on the stance leg only. Subjects performed 5 trials in each direction. Six 1-within-factor ANOVAs were run to compare the normalized EMG values during the 8 excursion directions. A separate ANOVA was run on each muscle tested. Two 1-within-factor ANOVAs were run to compare the knee-flexion and ankle dorsiflexion angles during the 8 directions. Post hoc comparisons were again made to identify significant differences in ROM between specific directions of excursion. The level of significance was preset at .05 for all analyses. Significant differences in EMG activity among the different excursion directions were found for all muscles except the gastrocnemius ($P = .08$) [7]. VM activity was found to be greater during the anterior excursion than during any other direction ($P = .037$) [7]. MH activity was significantly higher during the anterolateral excursion than during the lateroanterior, anteromedial, and medial excursions ($P < .005$) [7]. The BF activity was higher during the posterior, posterolateral, and lateral excursions than during the anterior and anteromedial excursions. AT activity was significantly higher during the posteromedial, posterior, posterolateral, and lateral excursions than during the anterior (not significantly different than lateral), anteromedial, medial, and anterolateral. The highest knee flexion occurred during the anteromedial excursion, which was significantly greater than the anterior excursion. The anterior, anteromedial, and medial directions produced greater ankle dorsiflexion than all other directions. [7]

Liu, et al[2], studied the effects of ankle sprains on proprioception. The purpose of the study was to examine total active and passive reposition sense, for a detailed understanding of ankle proprioception. Another purpose of this study was to examine the influences of ankle injury on proprioception. The subjects were 16 healthy male college students. Eight were in the functional instability group while the other eight were the control group[2]. To be classified as FI, the subjects needed to satisfy the following criteria: they experienced at least one significant lateral-inversion ankle sprain of either the right or left ankle but not both, and the subject was unable to bear weight or was placed on crutches within the last year; there was no reported history of fracture to either ankle; subjects sustained at least one repeated injury or the experience of feeling of instability or “giving way” in either the right or left ankle but not both; the subject was not undergoing any formal or informal rehabilitation of the unstable ankle; and that there was no evidence of mechanical instability, as assessed by a physician using an anterior drawer test. For this study proprioception was defined as the ability to match reference joint angles without visual feedback[2]. Active and passive joint repositioning occurred at the following three test positions: 10° eversion, 0° subtalar neutral, and 15° eversion from maximum inversion[2]. Subtalar neutral served as the 0° neutral position. These positions were visually displayed in volts by the internal goniometer of the Biodex System III Dynamometer and exported by BioPac System MP150 to Acqknowledge, Ver. 3.7.1[2]. The investigator passive moved the subject’s foot through its entire inversion and eversion range of motion. The foot was then passively moved into the preselected test position where it was held for 15 seconds and passively moved back to the starting position. The subjects were requested to use a hand-held switch to make a trigger signal when they reached the pre-selected position. The active ankle joint reposition test was performed at 500°/s, to avoid additional resistance in the Biodex System III isokinetic dynameters[2]. The results showed subjects with frequent ankle sprains (FAS) demonstrated significantly lower passive reposition sense than subjects with the healthy ankle (HA), and the LA and RA in NH subjects ($p < 0.05$) [2]. Furthermore, the active reposition sense was significantly lower in FAS ankle than LA or RA in NH subjects ($p < 0.05$) [2].

Tropp[3] wrote about the differences between mechanical ankle instability (MAI) and functional ankle instability (FAI) to more clearly define FAI. The differentiated between mechanical instability and functional instability stating that, “Mechanical instability (MI) is defined as ankle movement beyond the physiologic limit of the ankle’s range of motion. The term ‘‘laxity’’ is often used synonymously with MI. Functional instability (FI) is defined as the subjective feeling of ankle instability or recurrent, symptomatic ankle sprains (or both) due to proprioceptive and neuromuscular deficits.” [3] Tropp points out that the subtalar joint is critical in the mechanics of ankle instability. Ground reaction forces create moments at the subtalar joint. Corrections at the ankle occur around this joint through inversion and eversion to keep the ankle under the center of gravity. It is suggested that, “sensory information arising from the ankle ligaments provides most of the proprioceptive information necessary to allow the body to produce appropriate motor responses to prevent or minimize injury.” [3]

Garn and Newton [11] studied the kinesthetic awareness in subjects with multiple ankle sprains. They state that proprioceptive defects as a result of trauma to receptors have been suggested as a cause of chronic ankle instability. It was also said that the greater the injury to the ligaments is directly correlated to the amount of loss of joint position sense. Therefore, the purpose of their study was to determine whether kinesthetic deficits existed in the injured ankle joints of athletes with multiple ankle sprains. Another purpose was to replicate another study to determine whether subjects demonstrated a greater balance deficit when standing on the injured leg as compared with the uninjured leg. Subjects consisted of 24 men and six women, ages 18-24, who were staff members or midshipmen at the US Naval Academy. Subjects had a history of two or more unilateral lateral ankle sprains. The amount of ankle sprains per subject on the injured side ranged from two-twenty. Individuals were excluded from the study if they had effusion or pain in either ankle joint or if less than 30 days had elapsed since the last ankle sprain. Researchers used a kinesthesiometer to detect passive motion. Thirty trials per ankle were preformed in which 15 trials had no movement occurring and the other 15 had movement that occurred from neutral to five degrees of plantar flexion at 0.3 degrees per second. Subjects' responded with yes or no answers to whether the ankle moved or not. A one-legged standing balance test was performed to compare balance when the subject stood on the uninjured ankle and then on the sprained ankle[11]. The obsever looked for the number of times the subject lost balance, and the amount of trunk and upper body movement required to maintain balance. The yes/no responses were used to calculate choice theory measurements of hit rate, false-alarm rate, sensitivity, and response bias. They used a two-tailed t test to compare sensitivity and response bias. "Results of the test of proportion demonstrated a significant difference in hit rate ($z = 3.24$, $p < .001$) and false-alarm rate ($z = 1.68$, $p < .05$) when comparing the data from the sprained and uninjured ankles. Results of the statistical analysis using a two-tailed t test indicated statistical significance in sensitivity measurements ($t = 2.42$, $p < .025$) and no significant difference in response bias for uninjured and sprained ankles ($t = 0.114$, $p > .05$)[11]." These results show that the subjects were less likely to detect movement of the injured ankle compared the uninjured side. They also found that balance was significantly worse on the injured ankle[11].

Santos and Lui[12] studied the possible factors related of functional ankle instability. They cited that many studies recently have found that factors include, "ankle proprioceptive deficit, muscular weakness, impaired balance control and increased neuromuscular reaction time, which may or may not be accompanied by joint laxity.[12]" The purpose of this study was to classify subjects with FAI into deficit and no deficit groups from the evaluation of the most common causes of FAI listed above. Subjects conisited of a total of 37 individuals, 21 with unilateral FAI (15 women, 6 men; mean SD age, 30 11 years; height, 1.72 0.10 m; body mass, 78 15 kg) and 16 healthy subjects (12 women, 4 men; age, 31 11 years; height, 1.68 0.08 m; body mass, 68 16 kg). The inclusion criteria for the experimental group were a history of two or more ankle sprains in one of their ankles and at least one ankle sprain in the past six months, sensation of ankle instability or giving-way, no symptoms of an acute injury, and no history of fracture or surgery in either ankle. AMTI force was used to measure balance in a single leg stance. Biodex was also used to measure proprioception, evertor response time, passive ankle stiffness, and evertor strength. Both ankles were tested in a random order. Subjects performed a single le stance on the force place. Once they felt balance was stable data collection began. Five trials on each ankle were performed. For proprioception testing, the subject was passively put into 30 degrees of ankle inversion then back to neutral. A platform moved the subject's ankle into inversion at five degrees per second and the subject reported when they believed the ankle was in 30 degrees of inversion. Biodex was used to test evertor response time, ankle stiffness and peak torque. Researchers used paired t tests to analyze the data. Results showed that only balance control and evertor peak torque had a significant difference[12].

Gross[13] looked at the effects of recurrent lateral ankle sprains on active and passive joint position sense. They had three null hypothesis': "1. Recurrent lateral ankle sprain injuries have no significant effect on judgments of joint position. 2. Active judgments of joint position do not differ significantly from passive judgments of joint position. 3. No significant interaction between recurrent lateral ankle sprain injury and active-passive testing condition exists that affects judgments of ankle joint position.[13]" The study had an injured group of 14 subjects (11 men, 3 women) and a control, healthy, group of seven subjects (two men, five women). Subjects were tested with six active and six passive trials for each ankle. The researchers used two electromyographic biofeedback units for the passive trials as well as a Cybex isokinetic dynamometer. The researchers passively moved the ankle into either ten degrees of eversion, ten degrees of inversion or 20 degrees of inversion which was maintained for 15 seconds. The researcher then moved the ankle into extreme range of motion and the subject was instructed to say when they believed it was in the same position. They were tested twice at each test position. Data was analyzed using an ANOVA. Post hoc comparisons of means were accomplished with a Scheffe multiple comparison test. The results found a significant difference between passive judgments and active judgments. The results suggest that the first null hypothesis should be accepted and that the second null hypothesis should be rejected. [13]

Shields, et al[14] studied the effects of elastic taping on postural control in subjects with healthy ankles, Copers, and FAI. The purpose of the study was to assess static postural control differences between subjects with healthy ankles, those with functionally unstable ankles, and those designated as copers and to investigate immediate and prolonged effects of Kinesio Taping in these subjects. Each group had 20 subjects in it. They used the Cumberland Ankle Instability Tool to classify subjects into groups. An AMTI force plate was used to track the subject's location and velocity of center of pressure during static balance. Each subject performed three baseline 20 second single leg balance tests. Kinesio tape was then applied according to the lateral ankle sprain tape job with 115%-120% stretch applied. Once the tape was applied the subjects performed the test again. They returned 24 hours later and completed one final test. "Separate two-way repeated-measures analyses of variance (ANOVA) were used to test for overall main effects of group (3 levels) and tape conditions (3 levels) for each COP and TTB variable as well as the potential interaction effects between group and tape condition[14]." Alpha level was set at $P<0.05$. "There were significant group main effects for 2 variables: COP SD ($F_{2,57} = 4.309$, $P = .018$) and range ($F_{2,57} = 4.918$, $P = .011$) in the AP plane. Significant condition main effects were observed for 3 variables: TTB absolute minima in the ML plane ($F_{3,159} = 3.610$, $P = .015$) and TTB SD in both ML ($F_{3,138} = 5.710$, $P = .002$), and AP ($F_{3,141} = 3.318$, $P = .029$) planes. Post hoc analysis revealed that unstable ankles had a higher COP SD than healthy ankles ($P = .027$, ES = 0.56) and a higher COP range in the AP plane than both healthy controls ($P = .021$, ES = 0.83). There was a significant improvement in the ML plane for TTB absolute minima ($P = .025$, ES = 0.15) from pretest to 24 hours after taping, a significant improvement in TTB SD ($P = .002$, ES = 0.14) from immediately following tape application to 24 hours, and a significantly higher TTB SD ($P = .009$, ES = 0.06) at posttest than at 24 hours. [14]" The results show that there was impaired balance in subjects with unstable ankles. Improvements in balance were seen after having the KT on for 24 hours. However the limitations being the lack of control or sham tape and a small effect size of this warrant more research.

Lin, et al[19] studied the with-in and between day reliability of several COP measurements of postural sway between younger and older subjects. They had 16 younger and 16 older subjects participate in the study.

Center of pressure was measured 4 different days on quite upright stance. The dependent variables were mean velocity, RMS distance, mean power frequency, sway area, Hurst rescaled range analysis and detrended fluctuation analysis. With-in day results were better than between day results. They used intra class correlation and standard error of measurement for statistical analysis. Mean velocity (ICC=.86; SEM=1.0) and RMS distance (ICC=.80; SEM= 1.6) had the highest reliability of all measures in the younger subject group.

Ross, et al[20] studied which force plates could discriminate between ankles with FAI and stable ankles as well which force plate measure was the most reliable. They had 22 healthy subjects, mean age 21yr and 22 subjects with FAI, mean age 20yr. The subjects performed a single leg static balance test and a single leg jump landing balance test on a force plate. Force plate measures were analyzed in anterior-posterior (AP) and medial-lateral (ML) directions. The dependent variables for the static balance test were ground force reaction SD, COP SD, mean, maximum, and total COP excursion and mean and maximum COP velocity. AP and ML time to stabilization was the dependent variable for the dynamic balance test. The results showed that the FAI group had greater values than the control group. Medial-lateral ground force reaction SD and AP time to stabilization were found to be the most accurate with scores of .73 and .72. Medial-lateral COP excursion also showed significant differences (P= .014).

Ross and Guskiewicz[21] used COP and time to stabilization numbers to determine static and dynamic balance differences in subjects with FAI and healthy subjects. They 14 subjects in each group. The subjects performed a static single leg balance test and a single leg jump landing test on a force plate. The dependent variables were AP and ML COP mean sway for the static balance and time to stabilization for the dynamic balance. The results showed that there were no significant differences in either AP or ML mean sway (AP: P=.28; ML P=.65). Time to stabilization however was significant in both directions (AP: P<.001; ML: P= .04).

Lephart el al[22] wrote about the Proprioception in the knee and ankle and the mechanisms that contribute to that proprioception. They state that proprioception and its neuromuscular feedback provide a major role in joint stability. This is primarily controlled by the Central nervous system. Through sensory input signals sent to the brain through the central nervous results in conscious awareness of joint position and motion as well as unconscious joint stability and maintenance of posture and balance. There are two types of mechanoreceptors: slow adapting and quick adapting. Qiuck adapting receptors will decrease their discharge at the on the onset of continuous stimulus while the slow adapting receptors continue a steady discharge. Quick adapting is thought to control joint motion sensation and slow adapting is thought to control joint position sense and sensation changes in joint position.

Schleip and Muller[23] wrote about the training principles for fascial connective tissue. Fascia is a body wide tensional network that consists of connective tissue that is dominantly shaped by tensional strain. This connects all muscles and organs. Connective tissue, when regularly put under strain will adjust their matrix so that the tissue can better meet the demands placed on it. They typically adapt to regular strains of changes in length, strength and ability to shear. However, in order to adapt to these changes the strain magnitude should exceed the value that normally occurs. This fascia contains a rich supply of sensory nerves which includes proprioceptive receptors. There has be a mutually antagonistic relationship between myofascial pain and proprioception which with an increase in local proprioception can significantly lower myofascial pain.

Schleip[24] also wrote about fascial plasticity and described certain mechanoreceptors that provide feedback to the body. He states that the transmission of impulses in our nervous system often happens through messenger substances through neural pathways, blood, lymph and spinal fluid. A detailed histochemical study has found that fascia is highly populated with mechanoreceptors. There are three groups of these receptors. First the Pacini corpuscles and the Paciniform corpuscles which respond to rapid change in pressure but not constant unchanging pressure. The other group are the Ruffini corpuscles which do not adapt as quickly and respond to long term pressure. Both of which are found in fascia, tendons, ligaments, aponeurosis and joint capsules.

Stecco et al[25] studied the ankle retinacula and its proprioceptive role in the fascial tissue. They did a macroscopic study, microscopic study, and radiological study. The microscopic and macroscopic studies were done on 12 cadavers and 3 amputated legs resulting in 27 total ankles. These cadavers were not embalmed or frozen and had no evidence of lower extremity lesions. The radiological study was done through MRI and included seven volunteer subjects without a history of lower limb injury and 17 subjects with a history of ankle sprains. The MRI was also done on two of the three amputated limbs prior to dissection. The MRI results showed that the retinacula of the foot and ankle are part of the fascia while the histological study of the cadaver revealed that the retinacula is rich in proprioceptors. Based on the amount of lesions and thickening of the retinacula in subjects with a history of ankle sprains the results conclude that alterations of the retinacula in turn alter the proprioceptive feedback which leads to frequent outcomes of ankle sprains.

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