

THE EFFECT OF KINESIO TAPING ON BALANCE IN INDIVIDUALS WITH CHRONIC  
ANKLE INSTABILITY

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## DEDICATION

I would like to dedicate this manuscript to my family. Specifically, thanks to my mom for listening to my daily freak outs and knowing how to calm me down. Thank you mom, for always being there for me through my whole graduate school journey. Thank you dad, for being there for me in person these past two years. To my sister, no matter what you can always make me laugh and cheer me up. Thank you for being more than my sister, and being my best friend. Most importantly, to my fiancé. Thank you for being my rock through these two years. I wouldn't have been able to finish this without you always being there for me.

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## ABSTRACT

The purpose of this study was to evaluate the effect of a Kinesio tape (KT) technique on balance performance in subjects with chronic ankle instability <sup>1</sup>. Thirty participants with CAI (12 males, 18 females, 20.4±2.0 yrs; 170.8±10.9 cm; 73.4±14.9 kg) from a large Division I institution participated in this study. The Identification of Functional Ankle Instability (IdFAI) questionnaire was used to measure ankle instability. A score of 11 or higher was used to identify who had CAI. Balance was assessed using the Balance Error Scoring System (BESS). The BESS consists of instructing participants to stand unassisted with eyes closed and hands on their hips for 20 seconds during six different conditions. There are two test surfaces, a hard flat surface, and a foam surface. There are also three stances, a double leg stance, a single leg stance, and a tandem stance. The participants were instructed to remain motionless during the balance tasks. The number of BESS errors were counted by the same clinician. All subjects participated in four days of testing. On the first day, participants filled out the informed consent and health history questionnaire, and completed two practice trials of the BESS. The next session was the first day of actual data collection. The participants completed the BESS as a pretest and were randomly assigned to one of two groups: control and KT. Subjects in the control group received no tape application while subjects in the KT group received a tape application. The KT technique consisted of 4 strips of tape pulled at approximately 20 to 35% of full stretch from origin to insertion of the tibialis posterior, tibialis anterior, peroneus longus, and across transverse arch. Subjects were instructed to leave the tape on their lower leg if they were in the KT group, and all subjects returned in 48 hours to complete the BESS again. The tape was then removed and the subjects returned 72 hours later to complete the BESS for a final time. Three repeated measures analysis of variance (RMANOVA) were used to determine if the use of KT had an effect on total

BESS scores, flat total BESS scores, and foam total BESS scores. Each analysis included one within subjects factor (time at 3 levels: pretest, 48 hours post application of the tape, and 72 hours post removal of the tape) and one between subjects factor (KT group and control group). Alpha was set at  $p < .05$ . We found a significant group by time interaction in total BESS scores ( $F_{2,56} = 6.16$ ,  $p = .01$ ,  $\eta_p^2 = .18$ , power = .87). Specifically, we found a significant improvement in balance in the KT group between the pretest and 48 hours post application of the tape (mean difference:  $5.9 \pm 0.9$  errors,  $p < .01$ , 95% CI: 3.7 to 8.2 errors) and between the pretest and 72 hours post removal of the tape (mean difference  $4.7 \pm 1.0$  errors,  $p < .01$ , 95% CI: 2.3 to 7.2 errors). There was no significant difference in the control group at any of the time periods ( $p > .05$ ). Therefore, the application of KT for 48 hours can be beneficial in improving balance impairments in people with CAI. The results of this study are very different than most of the previous literature that has evaluated the effects of KT on balance. One of the reasons for the difference could be that we left the tape on for 48 hours which is significantly longer than all of the other research. All previous studies kept the tape on for 24 hours or less. One of the most clinically important findings of this study is that balance improvements were retained even after the tape was removed for 72 hours.

## TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS.....	iv
ABSTRACT.....	v
TABLE OF CONTENTS.....	vii
MANUSCRIPT.....	1
Introduction	
Methods	
Results	
Discussion	
References	
Tables	
Legend of Figures	
APPENDICES.....	29
APPENDIX A: Operational Definitions, Assumptions, Delimitations, Limitations, Statement of the Problem, Dependent and Independent Variables, Hypothesis.....	30
APPENDIX B: Review of Literature.....	37
APPENDIX C: Data Procedures.....	67
APPENDIX D: Data Collection Forms, Health History Questionnaire, IdFAI Questionnaire.....	72
APPENDIX E: Reliability.....	77
APPENDIX F: Power Analysis.....	82

Lateral ankle sprains are one of the most common injuries in athletics today. They can hinder athletic performance, as well as activities of daily living.<sup>2</sup> After sustaining a lateral ankle sprain, some people are predisposed to having recurrent injuries. People with repetitive ankle sprains can often develop chronic ankle instability or CAI.<sup>1-10</sup> People with CAI can have postural control deficits because of a decrease in neuromuscular control in the ankle.<sup>11</sup> Having these deficits can hinder athletic performance and can lead to an increased risk of injury.<sup>2,6,12,13</sup> There are many factors that can influence postural control including sensory information obtained from somatosensory, visual, and vestibular and motor responses that affect coordination, joint range of motion, and strength.<sup>14</sup>

There are numerous treatment strategies that can be employed to improve balance, including whole body vibration training<sup>15</sup>, taping<sup>16,17</sup>, bracing<sup>18</sup>, orthotics<sup>19-21</sup>, and joint mobilizations.<sup>22</sup> Kinesio tape, or KT, is a new type of clinical tape that was made popular by the athletes at the 2008 Olympics in Beijing, China. KT was developed in the 1970s by chiropractor Dr. Kenzo Kase.<sup>23-30</sup> The creators of KT claim that the tape can improve proprioceptive awareness.<sup>30</sup> To date, there has only been limited research evaluating the effects of KT on balance. Specifically, one study evaluated KT on a sample of individuals with multiple sclerosis.<sup>24</sup> These researchers applied KT to both calves and kept it on for two days to see if stability would improve in quiet standing with both eyes closed. They found that the use of KT reduced sway in the antero-posterior axis only.

KT has the potential to improve balance by providing feedback to the mechanoreceptors of the ankle, which can increase proprioceptive awareness. The KT might also assist in activating weak muscles that might have been damaged during the previous ankle sprains.<sup>31</sup> If proprioception can increase, it allows the person to have a better sense of where their foot or



ankle is positioned on uneven surfaces and in space, thus improving balance as well as overall quality of life. KT could also provide stability to the ankle thereby improving balance. So, the purpose of this investigation is to determine the effects of KT application on postural stability in people with CAI.

## METHODS

### **Subjects**

There were 30 subjects included in this study. All subjects were physically active which is defined as a person who does cardiovascular activity for at least 30 minutes 3 times per week. Subjects were recruited from the School of Public Health, Student Recreational Sports Center, and the Bloomington, IN community to participate in this study. Subjects were between the ages 18-50 years old. All subjects had CAI which was determined by the Identification of Functional Ankle Instability (IdFAI) questionnaire.<sup>32</sup> It has been previously determined that a score of 11 or more on the IdFAI indicates that a subject has CAI, therefore, the same criteria was used for inclusion in this study.

Additional inclusion criteria for participation in the study are as follows: (1) history of at least one lateral ankle sprain, (2) experience the sensation of “giving way” at least once within the last six months, and (3) have a baseline BESS score of 14 or greater. The exclusion criteria for the study are as follows: (1) no lateral ankle sprain within the last two weeks, (2) no recently diagnosed concussion or head injury, (3) no other foot or lower leg pathologies, (4) no previous lower leg surgery, (5) have used KT on the ankle, and (6) no symptoms of a head cold.

Before participating in the study, all subjects read and signed an informed consent form and the study was approved by the University’s Institutional Review Board for the Protection of Human Subjects.

## **Procedures**

On the first day, subjects completed the health history questionnaire, the informed consent, and the IdFAI. Subjects then completed two practice trials of the balance test to get comfortable with the procedures. On day two, subjects completed the balance test as a pre-test and then were randomly divided into two groups: the KT group or the control group. If they were in the KT group, they then received the taping intervention to the ankle. If they were in the control group, they received no intervention. All subjects, both KT and control, were asked to return 48 hours later. Those in the KT group were instructed to keep the tape on their ankle until they returned. If the tape would happen to fall off, the subjects were instructed to contact the primary examiner for instructions. Subjects were instructed to shower, exercise, and complete activities of daily living as normal. All subjects came back in 48 hours for the next day of testing where they repeated the balance test and, if they were in the KT group, the tape was removed. All subjects were then instructed to come back 72 hours later for the final day of testing. On the final day, subjects completed the balance test for the final time. Figure 1 provides an overview of the study design.

### Balance Error Scoring System

The study used the Balance Error Scoring System (BESS) to measure the amount of postural sway (balance) in all subjects. The BESS consists of the participants standing unassisted with eyes closed and hands on their hips during six different conditions (Figure 2). There are two test surfaces: a hard flat surface, and a foam surface. A foam pad that is 50.8 x 41.7 x 6.4 centimeters was used (Perform Better, Airex Balance Pad, Craston, RI). There are also three stances: a double leg stance, a single leg stance, and a tandem stance. The test was completed by doing the flat ground surface first then the foam surface second. The three stances were

completed on each surface in double leg, single leg, and tandem order. With each condition, the participants were instructed to try and remain motionless with their hands on their iliac crest for 20 seconds with their eyes closed. The examiner counted the errors as the participant balances. The errors consist of: (1) lifting hands off their iliac crest, (2) opening eyes, (3) stepping, stumbling, or falling, (4) moving the hip more than 30 degrees of flexion or abduction, (5) lifting the forefoot or heel, (6) and remaining out of the testing position for more than five seconds.

The BESS has been used in previous research in evaluating postural sway.<sup>2</sup> The reliability of the BESS according to Bell et al<sup>33</sup> ranges from  $ICC_{(2,1)}=0.60$  to  $ICC_{(2,2)}= 0.92$ . Bell et al<sup>33</sup> also looked at the validity of the BESS and found that it has a criterion-related validity that has moderate to high levels depending on testing conditions. The BESS also has a high content validity in identifying balance deficits. We required all participants have a baseline BESS score of 14 or more errors. This value is supported by Linens et al<sup>34</sup> who identified a score of 14 or more when determining if a subject had CAI or not. The BESS test was evaluated by the same researcher for all conditions.

### Kinesio Tape

The study used Kinesio Tex Tape (Albuquerque, NM). The taping technique consists of 4 I strips of varying lengths depending on the size of the subject. For the beginning of the taping technique, the subjects were asked to lay prone on a treatment table with their foot hanging off in a relaxed resting plantarflexed position. The first strip of tape was placed approximately from the origin to the insertion of the posterior tibialis muscle. This strip began around the inner posterior borders of the tibia and fibula and extended over the muscle to around the medial malleolus. The subjects then sat supine on the treatment table for the remainder of the taping procedure. The second strip was placed approximately from the origin to the insertion of the anterior tibialis

muscle. It extended from around the upper two thirds of the lateral surface of the tibia and extended to the dorsum of the foot around the first cuneiform and first metatarsal bones of the foot. The third strip was extended approximately from the origin to insertion of the peroneus longus muscle. This strip began around the head of the fibula, and ran on top of the lateral malleolus, then continue and wrap under the plantar aspect of the foot ending around the base of the first metatarsal. The fourth strip began just anterior to the lateral malleolus and extended under the plantar aspect of the foot and pulled up the transverse arch of the foot. The taping procedure was applied by the same certified athletic trainer to ensure consistency throughout the study. When applying the tape to the skin, the paper backing was removed at one end, causing that to be the anchor. The anchors at the beginning and end of each strip of tape were just laid on the skin with no tension at all. There was a moderate tension applied to the body of the tape which is a 20-35% tension when applying the tape to the subject's skin. After the tape is applied, it was rubbed creating friction and heat causing the adhesive to activate and properly adhere to the skin. (Figure 3)

### **Statistical Analysis**

Three Repeated Measures Analysis of Variance (RMANOVA) were used to determine if the use of KT had an effect on BESS errors, one for each dependent variable. The three dependent variables were: total of the flat conditions, total of the foam conditions, and the overall total BESS score. Each analysis included one within subjects factors: time at 3 levels: pretest (Day1), 48 hours post tape application (Day2), and 72 hours post tape removal (Day3), and one between subjects factors: KT group and control group. A Bonferroni post hoc test was conducted on all significant differences. A priori alpha level was set at  $p < .05$  for all analyses.

## RESULTS

Means and standard deviations for age, height, weight, IdFAI scores, gender, and leg used are reported in Table 1. Means and standard deviations of all BESS errors in each stance are reported in Table 2. For the overall total BESS scores, interpretation of the RMANOVA revealed a significant interaction between the KT group and control group during three different testing times of the BESS ( $F_{2,56}=6.16$ ,  $p=.004$ ,  $\eta_p^2=.18$ ,  $\text{power}=.87$ ). (Figure 4) Specifically, we found that there was a significant improvement in balance scores in the KT group between pretest and 48 hours post tape application (mean difference:  $5.9 \pm 0.9$  errors,  $p<.01$ , 95% CI: 3.7 to 8.2 errors) and between pretest and 72 hours post removal of the tape (mean difference  $4.7 \pm 1.0$  errors,  $p<.01$ , 95% CI: 2.3 to 7.2 errors). We also found no significant difference in total scores between the KT and control groups at pretest ( $p>.05$ ), but we did find a significant difference between the groups at 48 hours post application of the tape (mean difference:  $4.7 \pm 1.4$  errors,  $p<.01$ , 95% CI: 2.0 to 7.5 errors) and at 72 hours post removal of the tape (mean difference:  $2.3 \pm 1.1$  errors,  $p=.04$ , 95% CI: 0.1 to 4.6 errors). There was no significant difference in total BESS scores between any of the test times in the control group ( $p>.05$ ).

For the total of the flat condition, we found no differences in balance performance between groups or test times ( $F_{2,56}= 2.75$ ,  $p=.07$ ,  $\eta_p^2=.09$ ,  $\text{power}=.52$ )(Figure 5). For the total of the foam condition, we identified a significant interaction between the KT group and the control group during the three testing times. ( $F_{2,56}=4.5$ ,  $p=.02$ ,  $\eta_p^2= .14$ ,  $\text{power}=.75$ )(Figure 6). Specifically, we found that there was a significant improvement in balance scores in the KT group between pretest and 48 hours post application of the tape (mean difference:  $4.0 \pm 8.4$ errors,  $p<.01$ , 95% CI: 2.3 to 5.7 errors) and between pretest and 72 hours post removal of the

tape (mean difference:  $3.2 \pm 8.4$  errors,  $p < .01$ , 95% CI: 1.7 to 4.5 errors). There was no significant differences between the test times in the control group ( $p > .05$ ).

## DISSCUSSION

The primary finding of this study was that there was a significant improvement in balance scores after KT was applied to participants with CAI for 48 hours. Potentially one of the most clinically important findings of this study is that balance improvements were retained even after the tape was removed for 72 hours. This is the first study that has looked at the effects of KT on balance in subjects with CAI when the tape was applied for an extended period of time. This is also the first study which conducted a follow up test after the tape was removed to see if the balance improvements were retained.

The results of this study are very different than most of the other literature that has evaluated the effects of KT on balance. In fact, only one other article to date has shown positive effects with KT and balance.<sup>24</sup> They investigated a very different sample, subjects with multiple sclerosis, and employed a very basic taping technique. Investigators simply applied one strip of tape on the posterior leg. However, following 48 hours after tape application, subjects had decreased sway in the antero-posterior axis.

Most of the studies that evaluated the effects of KT on balance used healthy, uninjured subjects. These subjects probably had 'normal' balance abilities making it difficult for any intervention to facilitate an improvement. Subjects with CAI, which were those used in the current investigation, are known to have balance deficits.<sup>2,35-40</sup> Therefore, it is more appropriate to investigate mechanisms to improve balance in this sample of participants. In our study, we made certain all CAI participants had balance deficits by requiring all subjects to have at least 14 BESS errors at baseline testing. This value was based on two previous studies.<sup>2,34</sup> Linens et al<sup>34</sup>

identified two BESS criteria to determine the presence of CAI. First, a total score of 14 or more errors, and second, having a single limb flat surface score of 3 or more errors. Both double leg stances on a flat surface and foam surface were too easy for subjects with CAI and healthy subjects and they recommended that they could be taken out of the testing procedures. In another study completed by Docherty et al,<sup>2</sup> they determined that subjects with CAI scored a  $15.7 \pm 6.0$  on the BESS. By having subjects with balance deficits to start, there is room for the subject's balance to improve. This is another distinguishing aspect of the current study compared to previous CAI investigations.

### Difference in Balance Testing

Previous research used balance tests that were performed on an even surface, instead of using an unstable surface like the foam surface in the BESS. Previous studies used Time To Boundary<sup>41</sup>, Center Of Pressure<sup>41</sup>, Star Excursion Balance Test<sup>42,43</sup>, and the Kinesthetic Ability Trainer<sup>42</sup> to measure balance. These were all completed on a flat stable surface. Most athletics and activities of daily living are completed on an unstable surface which is where the most of the ankle injuries occur, so it is appropriate to measure balance deficits on an unstable surface. Also, in this study, the significant improvements only occurred on the unstable foam surface condition of the BESS, and not on the flat surface of the test. This implies that the more challenging balancing tasks were the ones which created the greatest improvement with the KT application. A reason that balance improvements might not have been seen in past studies was that they all used a balance test that was performed on a flat stable surface. Since unstable surfaces are more difficult to balance on, the proprioceptors and muscle fibers fire more. With the KT helping improve the firing of these systems, the improvements should show up more on the unstable surface measures. The BESS protocol also has the subjects eyes closed during testing which

eliminates spotting and visual cues during balancing and, therefore, increases the difficulty of the test.

### Studies Using CAI Subjects

A few studies<sup>41-44</sup> have looked at the effects of KT on balance in people with CAI, and surprisingly they all found no improvements in balance after the application of KT. One major difference between these studies and the current study is the length of time KT the applied KT remained on the skin prior to balance testing. A study completed by Bicici, Karatas, and Baltaci,<sup>42</sup> evaluated balance immediately after KT application, while Hettle et al,<sup>43</sup> left the KT on for 20 minutes. Both of these studies concluded that KT had no impact of balance. In a study done by Shields et al<sup>41</sup>, they left the tape on for 24 hours. What is interesting about that study is that authors identified minor balance improvements, but concluded that they were not clinically meaningful. This conclusion, in addition to the current study, suggests that KT needs to be left on for at least 48 hours to show improvement in balance. Based on manufacturer information, KT has been reported to be left on for up to five days.

In a study recently published by Simon, Garcia, and Docherty,<sup>44</sup> the KT was left on for 72 hours and measured changes in proprioception through ankle force sense testing. The two groups in this study were ankle instability and a healthy ankle group. They found that the KT improved proprioception in the ankle instability group. This improvement in the ankle instability group had similar proprioceptive function as in the healthy ankle group. This is further evidence to suggest that when KT is applied to the ankle for a longer period of time, improvements in ankle stability are seen.



## Specific Kinesio Taping Techniques

Another problem with prior studies involving KT at the ankle is they do not discuss the reason for their taping technique or why they applied the tape the way they did. We developed a new taping technique based on this KT theory instead of using an already identified technique used in previous studies. It is theorized by Kase et al<sup>31,45</sup> that when pulling the tape from the origin to the insertion of a certain muscle, it facilitates muscle activation and helps the muscle work. When you pull the tape from insertion to the origin of a muscle, it inhibits the muscles and tries to prevent the muscle from working. In this study, we determined the muscles in the leg that could affect balance, and we facilitated them. While other previous studies<sup>26,41,43,44</sup> used a technique that Kase et al<sup>45</sup> designed for stability after a lateral ankle sprains.

According to the Kinesio Taping Association,<sup>31</sup> facilitating the muscles that are weak from a chronic condition or injury, such as CAI, the muscle tension is increased. With the muscle fibers and spindles tension increased, they are firing more which might create an increase in proprioceptive function.<sup>31,45</sup> However, with the amount of skin, subcutaneous fat, and fascia between the tape and the muscle, it is still unclear if the pull of the tape can really impact the muscle fibers.

Conversely, we propose that the extended period of time that the KT is applied facilitates the receptors in the muscle and skin. Unlike other types of tape, KT can be worn for up to five days. By wearing this tape for several days, like 48 hours in this study, the stimulation of cutaneous receptors and mechanoreceptors are constantly occurring. According to a motor learning theory presented by Adams<sup>46</sup> call the closed-loop theory, a stimulus, which could be either tactile, pressure, or other sources of stimuli, when applied to the body provides immediate afferent feedback data from the limb. The body compensates and gets used to receiving that

afferent feedback from the stimulus even after the stimulus has been removed.<sup>44,46-48</sup> After a lateral ankle sprain, the ankle proprioceptors are damaged causing the body to not have that feedback data to know where the limb is in space.<sup>49</sup> With the KT being applied to the leg, the tactile stimulus from the tape provides that feedback that has been lacking from the damaged proprioceptors. With the tape being applied for a longer period of time, 48 hours in this study, the body is more aware of the afferent feedback and accepts that change even after the tape is removed from the skin which could be the reason why the balance improvements stayed even after the tape was removed for 72 hours.

There have been studies<sup>20,50-52</sup> that evaluated the effects of traditional white cloth tape on improving ankle proprioception. One study found that when tape strips are applied to the skin, there was an increase in cutaneous sensory feedback provided by the strips of tape that were applied to the ankle joint, but were completed in healthy individuals who did not have a decrease in proprioception to begin with.<sup>50</sup> Other studies<sup>49,51,53</sup> have looked at the effects of ankle braces on ankle proprioception. One article<sup>49</sup> used subjects with ankle instability and found that when wearing an ankle brace the threshold-to-detection of passive motion scores were higher when compared to a no tape and a tape only group. These findings also support that theory which might have been utilized to enhance balance when KT was applied for an extended period of time.

### **Clinical Implications**

The findings of this study can be used on athletes who have CAI that are having problems competing. Especially in sports that require balancing techniques including gymnastics, diving, baseball or softball pitching, or any other sport that CAI's balance deficits are hindering their athletic performance. Clinicians can also use this information on patients having trouble completing activities of daily living due to balance deficits from CAI. This could be used on all

age ranges and all sports since the tape is waterproof, hypoallergenic, moveable, and can be worn for long periods of time.

### **Limitations**

One limitation was that the tape cannot be applied in an identical form every time it is used although it was applied by the same clinician. Another limitation of the study was that there is a known learning effect with the BESS.<sup>54,55</sup> We attempted to prevent this from occurring by having two practice tests on the first day, so subjects could become completely comfortable with the task. We think this was accomplished because subjects in the control group did not improve balance over the length of the study.

### **Areas of Further Research**

Some areas of further research include having multiple applications of the KT to the same subjects and see if that can decrease balance more than just one application. Multiple applications could include putting the KT on the same subject after the 72 hours post application and waiting another 48 hours to see if the BESS score would improve even more. It would also be interesting to do a long term follow-up to determine how long the balance improvements were retained. Finally, since it is theorized that when the KT is pulled from origin to insertion, muscle activation is facilitated, would the results be changed if the tape is pulled from insertion to origin thus inhibiting the muscles?

### **Conclusion**

Postural sway can affect activities of daily living and sport performance in individuals with CAI. There have been many different techniques used to improve postural sway in people with ankle instability. It appears that KT can improve balance after being applied to the ankle for 48 hours. More importantly, those balance improvements were retained even after the KT had

been removed for 72 hours. Even though other articles have shown no improvement in balance in subjects with CAI, this article is the first one that has left the KT on for 48 hours. Further studies should follow these guidelines and see if these results can be reproduced.

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**Table 1: Means and standard deviations of demographics.**

	All Subjects (n=30)	KT Group (n=15)	Control Group (n=15)
Age (years)	20.4 ± 2.0	19.9 ± 1.7	20.9 ± 2.1
Height (cm)	170.8 ± 10.9	168.4 ± 11.2	173.2 ± 10.4
Weight (kg)	73.4 ± 14.9	69.8 ± 15.0	77.1 ± 14.4
Gender	12 male / 18 female	4 male / 11 female	8 male / 7 female
Leg Used	19 right / 11 left	6 right / 9 left	13 right / 2 left
IdFAI Scores	21.5 ± 4.3	21.6 ± 4.8	21.5 ± 3.9

**Table 2: Means and standard deviations of BESS Errors by stances.**

Stance	KT Group			Control Group		
	Pretest	48HrPostTape	72HrPostRemove	Pretest	48HrPostTape	72HrPostRemove
Flat Double	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Flat Single	3.0 ± 1.5	1.9 ± 1.3	1.9 ± 1.3	3.0 ± 1.7	2.9 ± 1.4	2.7 ± 1.3
Flat Tandem	1.1 ± 0.8	0.3 ± 0.6	0.6 ± 1.1	1.5 ± 1.5	1.5 ± 1.6	1.2 ± 1.2
Foam Double	.07 ± .3	.03 ± .2	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Foam Single	7.1 ± 1.1	4.5 ± 1.8	4.9 ± 1.4	6.9 ± 1.3	5.7 ± 1.1	5.1 ± 1.6
FoamTandem	3.6 ± 1.3	2.3 ± 1.4	2.7 ± 1.5	3.7 ± 1.7	3.5 ± 1.4	3.4 ± 1.2
Total Scores	14.9 ± 3.1	<b>8.9 ± 3.5*</b>	<b>10.1 ± 3.3*</b>	15.1 ± 4.8	<b>13.7 ± 3.9*</b>	12.5 ± 2.8

\*Significant difference located in total BESS scores in the KT group between pretest and 48HrPostTape and between pretest and 72HrPostRemove. Also, a significant difference was located between the KT group and control group at 48HrPostTape.

## LEGEND OF FIGURES

Figure 1. Procedure Flow Chart

Figure 2. BESS Testing Stances

Figure 3. Kinesio Taping Technique

Figure 4. Time by Total BESS Errors Line Graph

Figure 5. Time by Total Flat BESS Errors Line Graph

Figure 6. Time by Total Foam BESS Errors Line Graph

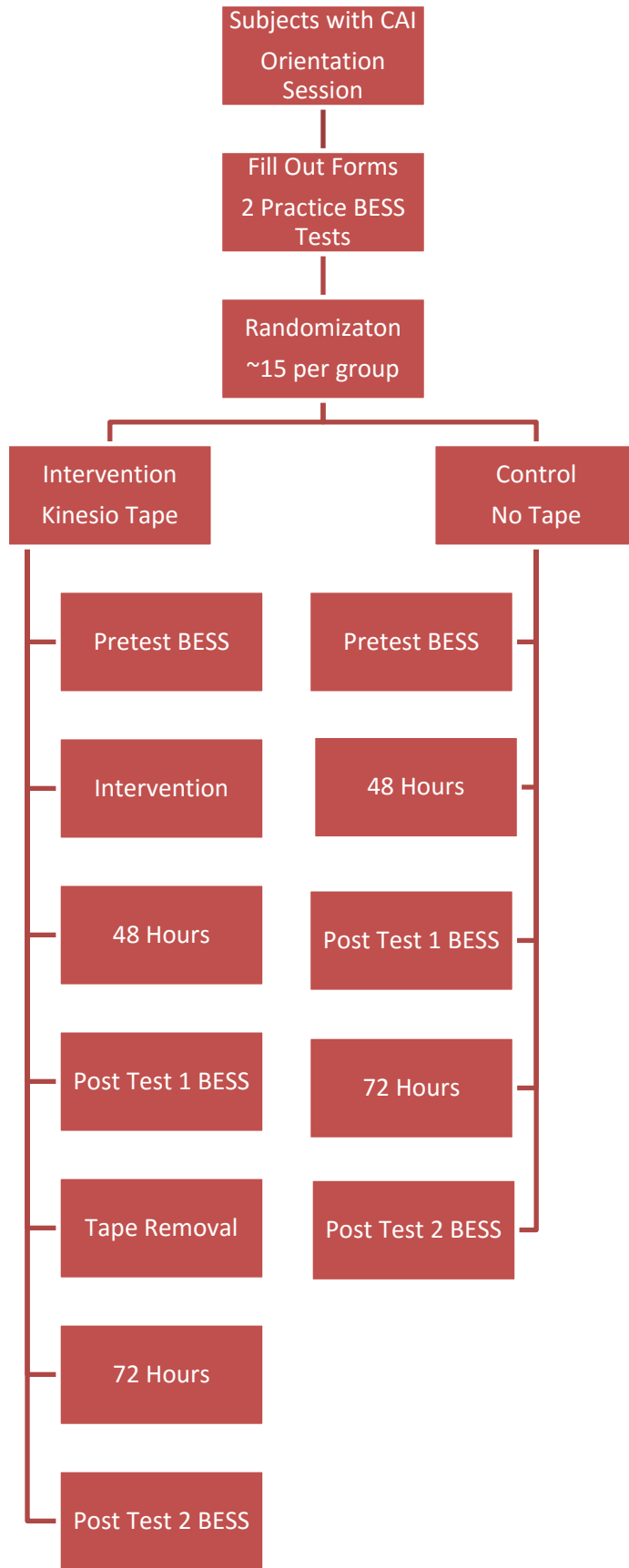


Figure 1: Procedure Flow Chart



a)



b)



c)



d)



e)



f)

Figure 2. BESS Testing Stances a) flat double leg stance, b) flat single leg stance, c) flat tandem stance, d) foam double leg stance, e) foam single leg stance, and f) foam tandem stance

a)



b)

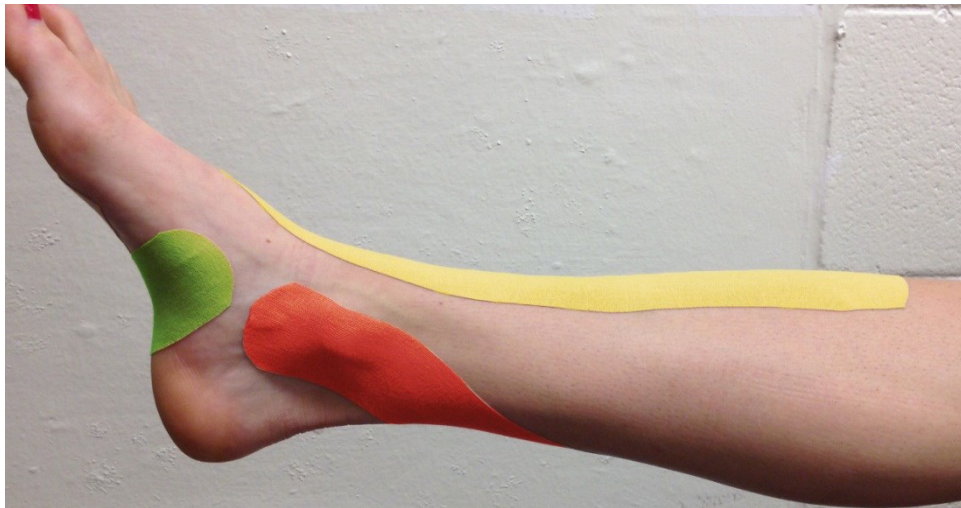


Figure 3. KT Taping Technique: a) lateral view, b) medial view

Red- Posterior Tibialis, Yellow- Anterior Tibialis, Purple- Peroneus Longus, Green- Transverse Arch



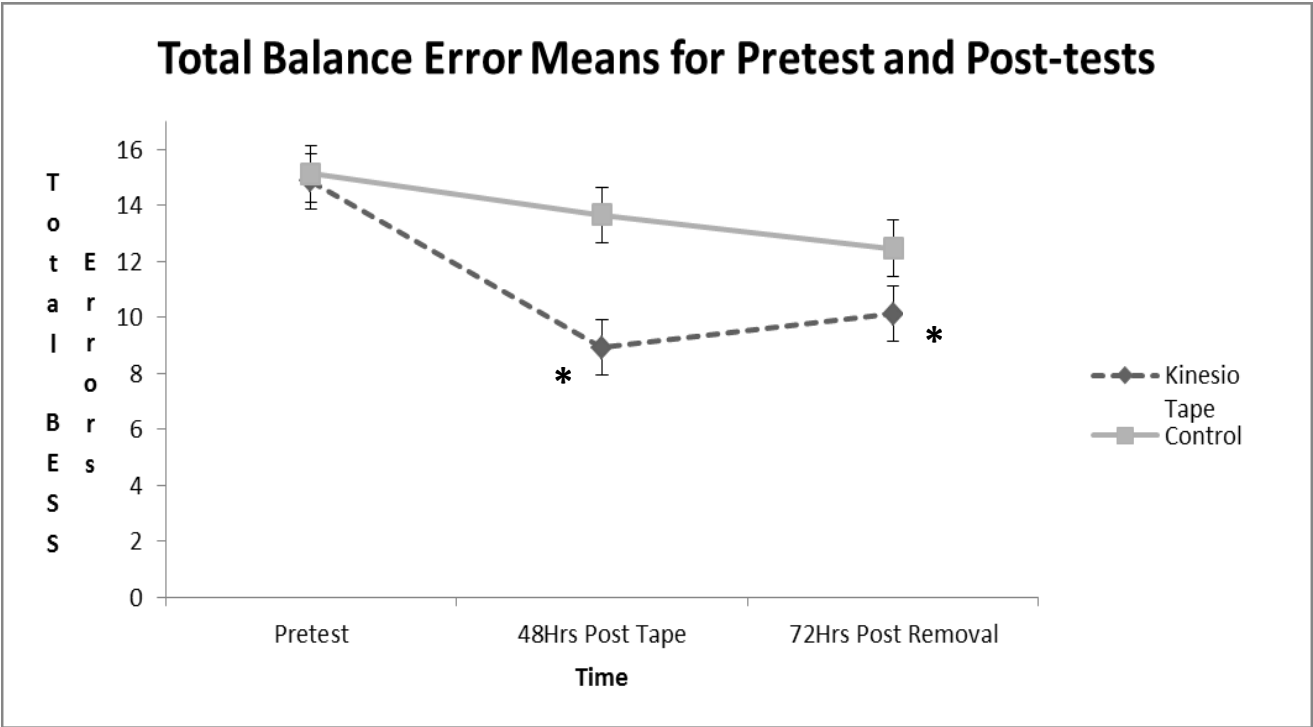


Figure 4. Time by Total BESS Errors Line Graph

\*Significant difference located in total BESS scores in the KT group between pretest and posttest1 and between pretest and posttest2. Also significant difference between the KT group and control group at 48 hours post tape application.

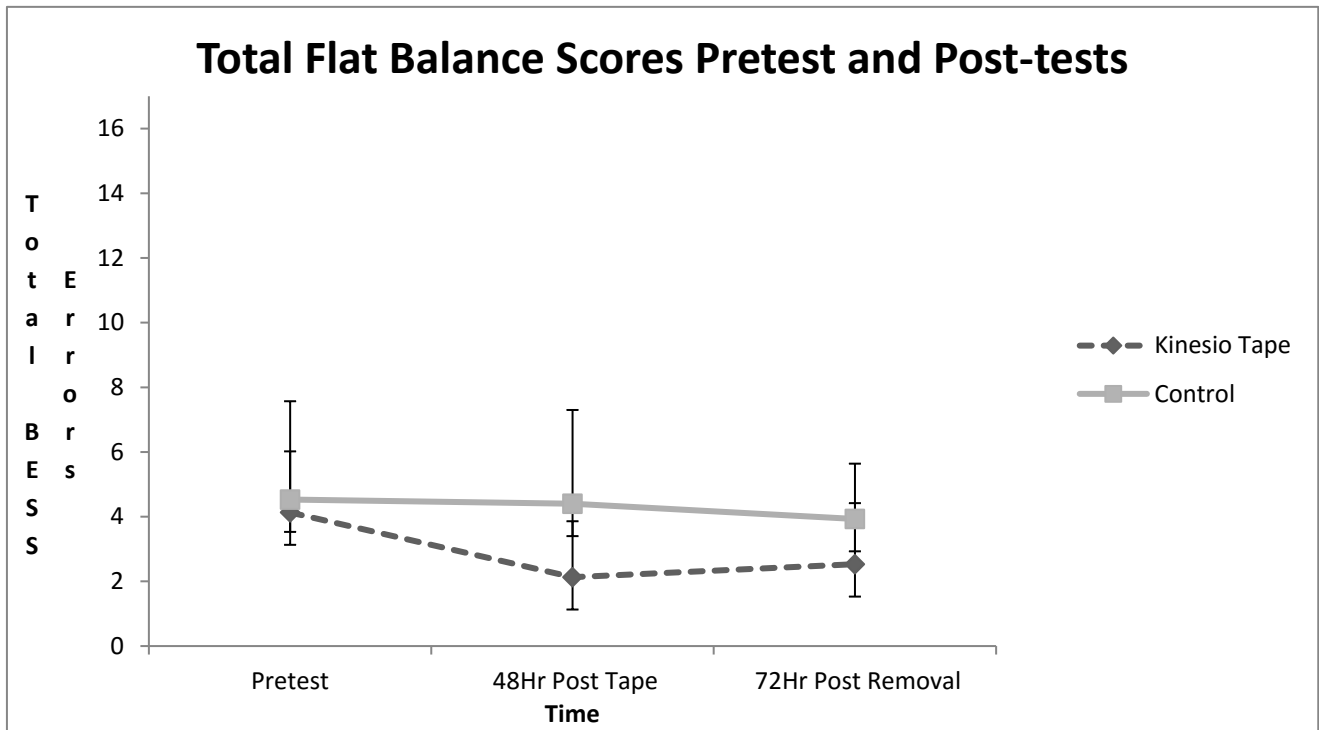


Figure 5. Time by Total Flat BESS Errors Line Graph

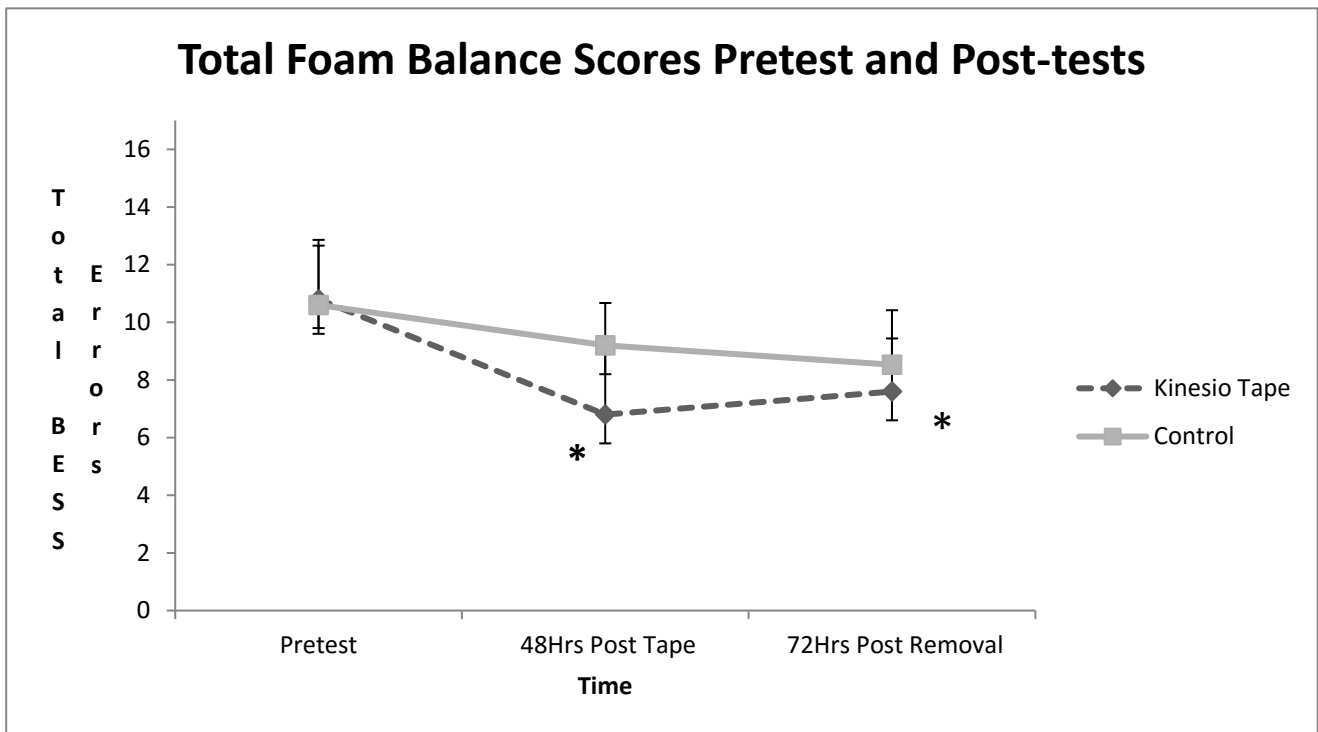


Figure 6. Time by Total Foam BESS Errors Line Graph

\*Significant difference located in the KT group between pretest and 48 hours post tape application and between pretest and 72 hours post tape application

## APPENDICES

APPENDIX A  
INTRODUCTION  
ASSUMPTIONS  
DELIMITATIONS  
LIMITATIONS  
STATEMENT OF THE PROBLEM  
DEPENDANT AND INDEPENDENT VARIABLES  
HYPOTHESIS

## **Operational Definitions**

Balance: The ability to remain in a stable position, during the Balance Error Scoring System.

Balance Error Scoring System (BESS): Traditionally used for the assessment of mild concussions where participants stand unassisted with eyes closed during six different conditions. The participants complete the tasks on 2 surfaces (flat and foam) and 3 stances (double leg, single leg, and tandem). The participants are instructed to remain motionless with their hands on their hips for 20 seconds. The clinician will count the amount of errors to make the BESS score.

BESS Errors: The BESS errors are the amount of movements from the base position. The amount of errors is the final score of the test. The errors consist of: lifting hands off iliac crests, opening eyes, stepping, stumbling, or falling, moving the hip into more than 30 degrees of flexion or abduction, lifting the forefoot or heel, and remaining out of the testing position for more than five seconds. Ten errors is the minimum that can be obtained during a single trial.

Chronic Ankle Instability: A score of 11 or more on the Identification of Functional Ankle Instability (IdFAI) questionnaire.

Identification of Functional Ankle Instability (IdFAI): The IdFAI is a self-reported questionnaire that is used to distinguish people who have CAI. A score of 11 or more on the IdFAI in this study will be the cut off to determine CAI.

Kinesio Tape or KT: Kinesio Tape (KT) was developed in the 1970s by chiropractor Dr. Kenzo Kase. It is an elastic tape that can stretch up to 100% of its original size that claims many therapeutic effects on the body including: (1) it corrects muscle function by strengthening weak muscles, (2) it improves circulation of blood and lymph through the body by limiting tissue fluid or bleeding underneath the skin, (3) it decreases pain through neurological suppression, (4) it repositions subluxed joints by relieving irregular muscle tension which helps to return the

function of fascia and muscle to normal, (5) it increases proprioception through an increase stimulation to cutaneous mechanoreceptors from the stretch of the tape on the skin.

Ankle KT Technique: The technique will consist of 4 strips according to the Kinesio Taping Perfect Manuel.<sup>1</sup> The subject will be sitting prone on a treatment table to start. The subject will have their foot placed in the relaxed plantarflexed position. The first strip will be placed approximately from the origin to the insertion of the posterior tibialis. This strip would begin at the inner posterior borders of the tibia and fibula then extend over the muscle to the medial malleolus. The subjects will then sit supine on the treatment table for the remainder of the taping procedure. The second strip will be placed approximately from the origin to the insertion of the anterior tibialis. It will extend from the upper two thirds of the lateral surface of the tibia and extend to the dorsum of the foot at the first cuneiform and first metatarsal bones of the foot. The third strip will extend approximately from the origin to the insertion of the peroneus longus. The strip will begin at the at the head of the fibula, then run on top of the lateral malleolus, and continue to wrap under the plantar aspect of the foot ending at the base of the first metatarsal. The fourth strip will begin just anteriorly to the lateral malleolus and extend under the plantar aspect of the foot and pull up the transverse arch of the foot. The taping procedure will be applied by the same certified athletic trainer to ensure consistency throughout the study. When applying the tape to the skin, the paper backing will be removed at one end, causing that to be the anchor. There will be a moderate tension applied to the tape which is a 25-30% tension when applying the tape to the subject's skin.

Postural Sway: The number of times the body moves “of center” where a correction is necessary in order to maintain balance as measured by the BESS test. A score of 14 or higher on the BESS at baseline was needed to participate in this study.<sup>2</sup>

Postural Stability: The ability to perform the BESS with few to no errors.

Physically Active Subjects: Physically active people are people who do cardiovascular activity for 30 minutes, 3 times per week.

### **Assumptions**

The following assumptions were applied to this study:

1. Subject's backgrounds were similar.
2. Subjects were truthful and followed directions.
3. Subjects gave their maximum efforts when completing the BESS.
4. The BESS was a valid assessment of balance.
5. Subjects answered the IdFAI questionnaire truthfully.
6. Subjects left the KT on the lower leg for 48 hours.
7. KT was applied on the ankle correctly.
8. The IdFAI determined CAI status.

### **Delimitations**

The following delimitations were applied to this study:

1. Thirty subjects with CAI, determined by the IdFAI questionnaire, were included in this study.
2. Fifteen subjects wore the KT applied to the ankle for 48 hours in this study.
3. Fifteen subjects wore no tape on their ankle for 48 hours in this study.
4. The condition the subjects receive was chosen at random.
5. The Balance Error Scoring System (BESS) was used to measure balance.
6. The BESS was observed and scored by the same clinician.



7. The subjects completed the BESS in the six conditions according to the operational definitions.
8. The BESS was tested on four occasions:
  - a. Pre-test
  - b. 48 hours after application of KT, sham taping, and no taping conditions
  - c. 72 hours after removal of KT, sham taping, and no taping conditions

### **Limitations**

The following limitations were applied to this study:

1. The tape could not be applied exactly the same for each subject.
2. There is a learning effect with the BESS.

### **Statement of the Problem**

After a lateral ankle sprain, a person is predisposed to having chronic ankle instability which can hinder athletic performance.<sup>3</sup> There are many deficits that can occur because of chronic ankle instability including postural control deficits.<sup>3</sup> If KT can improve the postural stability in people with chronic ankle instability, then healthcare providers could incorporate this technique into the rehabilitation process and possibly prevent or reduce further injury. The purpose of this study was to see the effect of the KT technique on balance performance in patients with chronic ankle instability.

### **Independent Variables**

Two independent variables were evaluated in this study:

1. Tape at Two levels
  - a. Kinesio tape (KT)
  - b. No tape (Control)

2. Time at Three levels
  - a. Pre-Test
  - b. 48 hours after application of KT and no taping conditions
  - c. 72 hours after the removal of KT and no taping conditions

### **Dependent Variable**

One dependent variable was evaluated in this study:

1. Balance Error Scoring System (BESS) errors

### **Research Hypotheses**

1. There will be a significant decrease in the number of BESS errors after the KT has been applied to the participant for 48 hours in people with CAI when compared to the pretest.
2. There will be a significant decrease in the number of BESS errors 72 hours after the removal of the KT in people with CAI when compared to the pretest.

### **Statistical Hypothesis**

1.  $H_A: \mu_{KT} \neq \mu_{Notape}$
2.  $H_A: \mu_{Pre-App} \neq \mu_{48Post-App}$
3.  $H_A: \mu_{48Post-App} \neq \mu_{72Post-Remove}$

### **Null Hypothesis**

1.  $H_o: \mu_{KT} = \mu_{Notape}$
2.  $H_o: \mu_{Pre-App} = \mu_{48Post-App}$
3.  $H_o: \mu_{48Post-App} = \mu_{72Post-Remove}$

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APPENDIX B  
REVIEW OF LITERATURE

This literature review will review the topics that are involved with the effects Kinesio tape on postural control in people with chronic ankle instability tested by the balance error scoring system. This review will cover: (1) ankle instability, (2) measuring CAI, (3) postural sway, (4) measure of postural sway, (5) improving postural sway, and (6) Kinesio tape (KT).

### **Ankle Instability**

Lateral ankle sprains are one of the most common injuries in athletics today. They can affect athletic performance and activities of daily life. Most people, after having a lateral ankle sprain, are predisposed to having another because of many reasons including neuromuscular deficits.<sup>1</sup> The common mechanism of injury for a lateral ankle sprain is extreme plantarflexion and inversion. The stress can cause damage to the ligaments, muscles, nerves, and mechanoreceptors on the lateral aspect of the lower leg.<sup>1</sup> People with repetitive ankle sprains can often develop chronic ankle instability or CAI.<sup>2-9</sup> In the past, CAI has been subdivided into mechanical ankle instability<sup>10</sup> and functional ankle instability (FAI). MAI has been defined as movement of the ankle beyond normal range of motion.<sup>5-7,11</sup> CAI has been defined as patients who have the feeling of their ankle “giving way” due to the contributions of proprioceptive and neuromuscular deficits.<sup>1-5</sup> FAI was first proposed by Freeman<sup>3</sup> in 1965. In a position statement of the International Ankle Consortium by Gribble et al,<sup>9</sup> they have shown that in peer-related literature that CAI is the most commonly used term to describe subjects that have ongoing symptoms after an initial lateral ankle sprain. The definition that Gribble et al<sup>9</sup> used to describe CAI is “an encompassing term used to classify a subject with both mechanical and functional instability of the ankle joint.” CAI can result in an array of deficits including proprioceptive, muscular, neuromuscular control and postural control.

## Measuring CAI

Chronic ankle instability can be measured through self-reported questionnaires. Some questionnaires that have been developed include Ankle Joint Functional Assessment Tool (AJFAT), Chronic Ankle Instability Scale (CAIS), Foot and Ankle Ability Measure (FAAM) which was developed from the Foot and Ankle Disability Index (FADI), Foot and Ankle Instability Questionnaire (FAIQ), and the Foot and Ankle Outcome Score (FAOS). The AJFAT, CAIS, FAAM, FADI, FAOS, and FAIQ are general foot and ankle questionnaires.<sup>12</sup> Three questionnaires were specifically designed to detect CAI, these include: the Ankle Instability Instrument (AII), the Cumberland Ankle Instability Tool (CAIT), and the Identification of Functional Ankle Instability (IdFAI).

### *The Ankle Instability Instrument*

The Ankle Instability Instrument (AII) was designed specifically for the detection of CAI. It is a 16-item questionnaire that has 9 yes or no questions, six multiple choice questions, and one open-ended question. Each question was designed to fit one out of three categories including severity of initial ankle sprain, history of ankle instability, and instability during daily living. Participants who answer yes to 5 or more of the yes or no questions are considered to have CAI.<sup>13</sup> The AII was proven to have a good test-retest reliability of ICC<sub>2,1</sub>=0.70 to 0.89.<sup>12</sup> The sensitivity of the AII is 0.73, and the specificity is 0.85.<sup>12</sup>

### *The Cumberland Ankle Instability Tool*

Another questionnaire that has been used to determine CAI is the Cumberland Ankle Instability Tool (CAIT). The authors of the CAIT specifically designed it to not require comparison between the limbs as other questionnaires require. The CAIT is a 9 item questionnaire that was intended to grade ankle instability.<sup>12,14,15</sup> Each answer to the questions has

a point value that ranges from 0 to 5 and the participants score both limbs separately. If a participant scores a 27 or less on a limb with a maximum score of 30, then they are likely to have CAI. The higher the score, the less likely you have CAI. The lower the score, the more likely you are to have CAI. The founding authors reported a test-retest reliability of  $ICC_{2,1}=0.96$ .<sup>12</sup> The overall validity of the CAIT compared to the visual analog scale is  $p=.76$ ,  $p<.01$ .<sup>14</sup> The sensitivity of the CAIT is 0.56 and the specificity is 0.86.<sup>12</sup>

### *The Identification of Functional Ankle Instability*

A new questionnaire, the Identification of Functional Ankle Instability (IdFAI), was developed to better define “giving way.” This questionnaire distinguishes between the right and left ankle.<sup>16</sup> The IdFAI revealed three specific factors; history of ankle instability, initial ankle sprain, and instability during activities of daily living. All of the ten questions fall into one of the three factors, and have a point value for each answer.<sup>16</sup> The cut off score for the IdFAI is an 11, so if a person has a score of an 11 or higher, then they could be classified as having CAI. The IdFAI had an accuracy of 89.6% in separating individuals with and without CAI.<sup>16</sup> The sensitivity of the IdFAI is 0.92 and the specificity is 0.67.<sup>16</sup>

### **Postural Sway**

The terms balance and postural stability ultimately have the same definition, so both can be interchangeable. There are two different types of balance; static and dynamic. Static balance can be defined as the ability to maintain a base of support with no movement while standing. Dynamic balance is the ability to perform a moving task while maintaining a stable base.<sup>17-19</sup> There are many factors that influence balance including sensory information obtained from somatosensory, visual, and vestibular systems and motor responses that affect coordination, joint range of motion, and strength.<sup>17,20</sup>

## Methods of Measuring Postural Sway

### *Romberg Test*

The Romberg test was originally introduced in 1853 and was one of the first static balance tests to be used in the clinical setting.<sup>21</sup> Most studies involving postural control have used a modified Romberg test with six variations.<sup>22-24</sup> The six test conditions altered the three sensory modalities that control posture including visual input, vestibular input, and proprioceptive input. In one study, they used a one-legged modified Romberg test. It consisted of the testing conditions: (1) eyes open and normal floor, (2) eyes closed and normal floor, (3) a visual-conflict dome and normal floor, (4) eyes open standing on foam, (5) eyes closed standing on foam, and (6) a visual conflict dome standing on foam. The visual conflict dome is worn over the head and face to provide a visual frame of reference.<sup>22</sup> The visual conflict dome was a Japanese lantern that had vertical lines painted on the inside. Force plates were used to collect data.

### *Force Plates*

Force plates or platforms have been used as a measure of balance in many different studies measuring ankle instability. Force plate systems have led to the ability to make quantitative balance assessments under both static and dynamic conditions.<sup>21</sup> They operate by measuring vertical forces at three or more points on the platform to determine postural sway and center of pressure.<sup>21</sup> Force plates are used to measure center of pressure velocity and have been used to measure balance impairments associated with CAI.<sup>25-27</sup> Another method that has used a force plate to detect CAI is through time-in-boundary or TTB. TTB is a measure that estimates the time it takes for the subject's center of pressure to reach the boundary of the base of support if the center of pressure was to continue on its same course at the same velocity.<sup>23,24,28</sup> The TTB



estimates the amount of time the sensorimotor system has to make a postural correction in order to maintain the body over its base of support. The less TTB indicated diminished postural control.<sup>24</sup> Another use of a force plate has been the amount of time it takes for a person with CAI to stabilize, called time-to-stabilization, when coming down from a jump.<sup>27,29,30</sup> Force plates have been used to assess center of pressure velocity and 95th percentile center of pressure velocity area ellipse. They have been proven to detect balance impairments associated with CAI.<sup>25</sup>

### *Star Excursion Balance Test*

One test that can measure balance is the Star Excursion Balance Test (SEBT). The SEBT can be administered quickly and easily to help the clinician determine if the patient possesses or has returned to normal and symmetrical levels of dynamic balance. The SEBT has been used as a rehabilitative tool where the patient does a series of single-leg squats using the non-standing limb to reach out maximally to touch along eight different directions, three anterior, two lateral, and three posterior, in the shape of a star on the ground.<sup>19,31-38</sup> The SEBT has been used as a tool in many studies to measure postural sway deficits in people that have CAI. Hertel et al<sup>35</sup> and Robinson and Gribble<sup>38</sup> believe that there is a redundancy in the eight reaching directions, leading to the conclusions that the test can be performed with greater efficiency using only one direction or a few directions without compromising the assessment of dynamic postural control. Hertel et al<sup>35</sup> found that doing the anteromedial, medial, and posteromedial reach tasks may be used clinically to test for functional deficits related to CAI instead of testing all eight directions. There are a few sources of error that can occur in the SEBT. One is whether the foot touches the floor when reaching, and the other is where the stance foot is aligned at the starting position.<sup>19</sup>

These sources of error are important to consider because some studies might not follow these errors in the SEBT when scoring the test, which can skew the results.

### *Y Balance Test*

Building onto the reduction in the number of reach directions of the SEBT, Plisky et al<sup>36</sup> proposed a new Y Balance Test to further improve the efficiency of the SEBT. This test comprises of three directions: anterior, posteromedial, and posteriolateral directions, in a Y shape. The patient reaches in each direction with one foot and the other is stationed in the middle of the Y.<sup>19</sup> In a study by Coughlan et al<sup>31</sup>, they compared performance of the SEBT and the Y Balance Test. They found that there is differing postural control strategies between the two tests that could be used to complete these tasks.

### *Balance Error Scoring System*

The Balance Error Scoring System (BESS) is another way that balance can be measured. The BESS is a tool that has been primarily used in the diagnosis of mild head injuries or a concussion because of the ease of assessment and it is cost effective. It was developed to use a battery of modified Romberg stances on different surfaces that assess the postural ability traditionally after a mild head injury.<sup>39</sup> The BESS consists of the participants standing unassisted with eyes closed during six different conditions.<sup>2,40-46</sup> There are two test surfaces, a hard flat surface, and a foam surface. There are also three stances, a double leg stance, a single leg stance, and a tandem stance. The participants are instructed to try and remain motionless with their hands on their iliac crest for 20 seconds with their eyes closed. To score the test, a clinician counts the amount of errors the patient makes. The errors consist of: (1) lifting hands off their iliac crest, (2) opening eyes, (3) stepping, stumbling, or falling, (4) moving the hip more than 30 degrees of flexion or abduction, (5) lifting the forefoot or heel, (6) and remaining out of the

testing position for more than five seconds.<sup>2,40-46</sup> The normative values for the BESS scores for ages 20 to 39 is 10.97, ages 40-49 is 11.88, and ages 50-54 is 12.73.<sup>47</sup>

Some learning effects have been noted in people with no previous exposure to the BESS. In a study done by Valovich, Perrin, and Gansneder,<sup>39</sup> they found that there was a slight practice effect with repeated administrations of the BESS, especially with the single-leg stance on foam. In another article, Valovich McLeod<sup>48</sup> found that serial administration of the BESS has a learning effect, and was more predominant during the tandem conditions. One study reported that the clinician should interpret the mean score of three BESS trials on a given occasion.<sup>41</sup> Some studies found that fatigue also has an effect on BESS scores<sup>42,45,46</sup> which is why it is important to complete the test before exercise. Although, in another study,<sup>45</sup> they found that after exertion, balance according to the BESS can return to baseline levels within 20 minutes of rest. To date, there have only been two known studies that have used BESS to measure balance in people with CAI.<sup>2,49</sup> One article found that postural control deficits were found in participants with CAI when completing the BESS.<sup>2</sup> This demonstrates that the BESS can be a useful screening tool for people with postural control deficits following a lower extremity injury including CAI. Practically speaking, it is low cost and quick test to complete, and is also reliable. The other article, which is the most recent, looked at the difference of balance between individuals with CAI and healthy participants to determine if balance scores can decipher if a person has CAI or not.<sup>49</sup> They used many different balance tests including the BESS. They found that the cutoff score for total BESS errors to be a 14 to determine if a person has CAI.

Finnoff et al<sup>43</sup> found that the inter-rater and intra-rater reliability ICCs for the total BESS scores were 0.57 and 0.74, respectively. This shows that the inter-rater reliability of 0.57 is poor. However, according to Bell et al<sup>40</sup> who did a review of inter-tester reliability of the BESS and

found that the reliability of the total BESS score ranged from 0.60 and 0.92, showing that reliability ranges from poor to great. Valovich McLeod et al.<sup>50</sup> also investigated the test-retest reliability of the BESS and they found that the reliability is ICC=0.70 which is found to be good. In the study done by Bell et al,<sup>40</sup> they also looked at the validity of the BESS. The BESS has a criterion-related validity of moderate to high depending on testing conditions. The criterion-related validity was established by correlating BESS scores with target sway.

### Postural Sway Deficits in Individuals with CAI

Postural sway deficits in individuals with CAI could be caused by many reasons, but it is suggested that it is because of diminished proprioception and evertor muscle weakness.<sup>51</sup> Other studies believe that it is because of joint position sense deficits,<sup>32,52-54</sup> delayed peroneal muscle reaction time<sup>55,56</sup>, decreased dorsiflexion range of motion<sup>55,57</sup>, or injured mechanoreceptors<sup>53</sup>. According to Hertel,<sup>1</sup> alterations of weight bearing in the foot may be the reason people are predisposed to recurrent ankle sprains. Many studies have looked at the possible factors related to CAI including postural control. The majority of studies have found that people with CAI have an increase in postural deficits compared to a non-injured ankle as measured by the SEBT<sup>32,33,58,59</sup> and force platforms<sup>26,30,60,61</sup> during functional movements. In two different studies that looked at postural sway in people with CAI, they found that people with CAI demonstrated deficits in landing stability, which is an example of dynamic postural stability.<sup>52,62</sup> Another study showed subjects with CAI had a greater anterior displacement of center of pressure and time to boundary measures during single limb static stance compared to the control group.<sup>63</sup> The authors believed these alterations may result from the CAI subjects because they are adapting a more dorsiflexed position so they can keep the ankle in a more closed packed and stable position. A study done by Brown and Mynark<sup>18</sup>, measured balance through time-to-stabilization on a force

plate, and they found that people with CAI took longer to return to a stable range of ground reaction forces than people with stable ankles in the anterior-posterior directions. Another study agrees in that people with CAI have dynamic postural control deficits when landing from a hop.<sup>60</sup> One article, a meta-analysis,<sup>64</sup> found through their analysis of outcomes measures that ankles with CAI exhibited poorer balance performance than stable ankles, but it is unclear if it is a result of the injury or if the problem preexisted. The study did not have baseline results of the subjects balance before the injury occurred, so it is unclear if the balance deficits were there before the injury or if they occurred because of the injury.

Some studies disagree by finding that there is no deficits in postural stability in people with CAI. One study found that postural sway and inversion and eversion strength measures had no difference in functionally unstable ankles compared to non-injured subjects, but they had a small sample size of 18.<sup>65</sup> Another study<sup>66</sup> found no difference in static balance between people with CAI compared to healthy subjects as measured with a single leg test on a force plate and on a compliant floor. Isakov and Mizrahi<sup>67</sup> agrees, in that the amount of postural sway is similar in the people with CAI and people with uninjured ankles, and during single leg standing with eyes open and closed. The discrepancy in the results from the studies looking at postural control difference in people with CAI could be from the lack of universally accepted operational definitions of functional, mechanical, and chronic ankle instability. Also, there is not universal way to determine if a subject has or does not have ankle instability.

### Methods of Improving Postural Sway

#### *Whole Body Vibration Training*

There are many different techniques that can improve balance or postural control. One technique is vibration training.<sup>68,69</sup> In a study done by Cloak et al<sup>69</sup> they used whole body

vibration technique to improve SEBT scores during a six-week training intervention in female dancers with self-reported CAI. There were significant reach improvements in the anterior, anteriomedial, medial, and anteriolateral directions in the SEBT, following training.

### *Ankle Taping and Bracing*

Ankle taping or bracing has constantly been used to treat the symptoms of ankle instability. One study investigated the effects of an ankle brace on dynamic postural stability in subjects with CAI.<sup>70</sup> The study measured time-to-stabilization. They found that the application of the ankle brace does not appear to have an influence on dynamic postural stability. Another study looked at two different taping techniques, the lateral subtalar sling and the fibular repositioning, on perceived dynamic postural stability in people with CAI.<sup>71</sup> They measured the dynamic postural stability by completing the SEBT. They found that both ankle tapings had no significant change in dynamic postural stability when completing the SEBT. Reach distance did not improve in the SEBT compared to a non-taped group. A different type of taping that has been studied on balance performance in subjects with CAI is the Mulligan technique.<sup>72</sup> This study looked at static balance, postural sway recovery patterns after hopping and dynamic balance tasks. They found that Mulligan taping did not impact balance during static or dynamic balance in people with CAI. All studies did not find improvement in balance while having their ankle taped or braced. Another study used a form of fibular taping on the ankle that wrapped around the posterior leg and assessed balance and ankle dorsiflexion ROM<sup>58</sup>. The subjects completed the SEBT over the course of two visits, and when compared to a sham control taping, there was no significant change in ankle dorsiflexion ROM. All of these conditions have been used to provide stability to the ankle after a lateral ankle sprain, but it does not help with postural stability.

### *Orthotics*

Another technique that has been used to treat balance deficits in people with CAI are orthotics. Studies<sup>73-75</sup> have found that the use of orthotics can decrease balance deficits in people with CAI compared to a control group. One study looked at whether orthotics would reduce postural sway in injured and uninjured subjects with inversion ankle sprains.<sup>73</sup> They found that custom-fit orthotics may aid in preventing undesirable movement to improve postural stability, or positively affect the balance, in people with lateral ankle sprains. Another study looked at orthotics effects on postural sway in people with and without CAI measured by center of pressure on a force platform. They found there were lower center of pressure parameters when wearing the orthotics in people with CAI.<sup>74</sup> Another study agrees with the aforementioned in that prefabricated orthotics improved postural stability in participants with CAI that was measured by force plates.<sup>75</sup> A more recent study that looked at the effect of foot orthotics and ankle rehabilitation exercises in helping balancing abilities and joint proprioception in athletes who have CAI.<sup>76</sup> The study looked at 41 athletes that were split up into two different groups, a rehabilitation group, and rehabilitation group with foot orthotics. They measured joint position sense of the ankle joint using an isokinetic exercise machine. Balancing abilities were measured using a computerized posturography. They were tested before and after a four week program. The study showed that athletes with CAI who had foot orthotics applied for four weeks improved their proprioceptive and balancing abilities, but it did not show any additional treatment effects when compared with the rehabilitation exercise treatment.

### *Joint Mobilizations*

Joint mobilizations have also been studied to see the effects on balance. In a study by Hoch and McKeon,<sup>77</sup> subjects with chronic ankle instability received a Maitland Grade III

anterior-to-posterior joint mobilization. After receiving the joint mobilization, the subjects completed the SEBT and a time-to-boundary test using a force plate. Results suggested that joint mobilization treatment had a beneficial effect in the SEBT scores and in the time-to-boundary time.

### **Kinesio Tape**

Kinesio Tape (KT) was developed in the 1970s by a chiropractor named Dr. Kenzo Kase.<sup>78</sup> KT came into the public eye after the 2008 Olympics in Beijing, China, when it was worn by many high profile athletes. KT is an elastic tape that is 100% cotton and is supposed to resemble the thickness of the epidermis, can stretch up to double of its original size causing a constant pull on the skin, can also be worn for up to 5 days, and is water resistant.<sup>79-81</sup> Since it is water resistant, it can be worn during aquatic sports, unlike other adhesive tapes. During manufacturing of the tape, the tape is applied to a substrate paper with a 10% stretch applied to the tape.<sup>81</sup> According to the manufacturers of the KT tape, the tape causes micro convolutions, or folds, in the skin which causes a lifting of the skin away from the tissue underneath.<sup>81</sup> This facilitates a release of pressure on tender tissues underneath and provides space for lymphatic fluid movement. KT is purported to have many physiological and biological effects on the body including: (1) it corrects muscle function by strengthening weak muscles, (2) it improves circulation of blood and lymph by lifting the skin and fascia, (3) it decreases pain through neurological suppression, (4) it repositions out of places joints by relieving irregular muscle tension and muscle imbalances which helps to return the function of fascia and muscle to normal, (5) it increases proprioception through an increase stimulation to cutaneous mechanoreceptors from the stretch of the tape on the skin.<sup>82,83</sup>



According to the Kinesio Taping Association International,<sup>84</sup> there are four different types of tape application strips available including: an I strip, a Y strip, an X cut, and a fan cut. There are also different tension guidelines that are used to have different biological effects on the body. There is the super light tension that is 0-10% which will affect the epidermis. Then there is the paper off tension at 10-15% which will affect the lymphatic system. Then there is light tension at 15-25% which has an inhibitory effect on muscle. Then there is moderate tension at 25-35% which is used to facilitate the muscle. Next is severe tension at 50-75% which is used for mechanical and functional corrections, then the full tension is 75-100% which is used for ligament corrections.<sup>84</sup> There are two basic KT muscle application concepts, inhibition and facilitation. Inhibition is used for overused muscles from acute conditions or muscle spasms. Facilitation is used for weak muscles from chronic conditions or for rehabilitation. For inhibition, the tape will be applied with 15-25% tension in the direction from the insertion of the muscle to the origin of the muscle. For facilitation, the tape will be applied with a 25-35% tension in the direction from the origin of the muscle to the insertion.<sup>84</sup> There have been studies that have looked at KT effects on proprioception<sup>82,85</sup>, pain<sup>83,86-90</sup>, range of motion<sup>83,88</sup>, strength<sup>91-93</sup>, functional performance<sup>79,94</sup>, and balance<sup>95</sup>, but this study will only focus on proprioception, functional performance, and balance.

### KT Effects on Proprioception

KT claims to increase proprioception, and research by Murray and Husk<sup>85</sup> has supported this finding. They used the Lido Active isokinetic machine with electrogoniometer and a dynamometer set at 300 degrees per sec, with the axis of rotation just inferior to the lateral malleolus. They set the target joint angle replication at 26 degrees and 10 degrees of plantarflexion, and 8 degrees of dorsiflexion. They tested ankle plantarflexion and dorsiflexion

motions when trying to replicate the certain amount of angle degrees. They compared white athletic taped ankle, a non-taped ankle, and an ankle taped with KT. They found no significant difference in ankle joint replication at 26 degrees of plantarflexion or in 8 degrees of dorsiflexion. However, in the KT condition, they found a significant difference at 10 degrees of plantarflexion. On the other hand, another article<sup>82</sup> has shown that there is no significant difference in increasing proprioception when applying KT to the anterior and lateral portion of the ankle. The article wanted to see if the KT would enhance the reduction in joint position sense (RJPS) when compared to a non-taped ankle, which was unsuccessful.<sup>82</sup>

One difference between the two studies is that Halseth et al<sup>82</sup> excluded subjects with ligament laxity and compared the KT group with a non-taped ankle. Murray and Husk<sup>85</sup> did not exclude participants with ligament laxity and compared the KT group with a white athletic taped ankle and a non-taped ankle. Another difference between the two studies was that Halseth et al<sup>82</sup> excluded subjects with any ankle or lower leg injuries, and Murray and Husk<sup>85</sup> only excluded subjects if they have a current ankle sprain or significant foot deformity. The positive of using subjects that have had an ankle injury is that they are most likely going to have a deficit in their ankle proprioception unlike someone who has a healthy ankle. This could be the reason there is the difference in the results.

#### KT Effects on Functional Performance

One study looked at functional performance tests. The patients with chronic inversion ankle sprains completed the tests while wearing white athletic tape, a placebo taping, or KT.<sup>79</sup> The tests consisted of a hopping test, a limb hurdle test, a standing heel raise test, and a vertical jump test. The study found that neither of the taping methods had a significant effect on

performance in most functional tests. The white athletic tape caused a decrease in performance in the vertical jump and in the standing heel raise while KT did not limit the performance.

### KT Effects on Balance

Recently, there have been many articles published that evaluated the effects of KT on balance.<sup>95-98</sup> The oldest study that was completed evaluated balance in people with multiple sclerosis.<sup>95</sup> The study applied KT to both calves and kept on for two days to see if body stability would improve in quiet standing with both eyes closed. They assessed static balance using the Berg Balance Scale. The study reported that the KT demonstrated a reduction in sway in the antero-posterior axis only. This possibly occurred because the application of the tape was on the posterior aspect of the lower leg.

In another study done by Fayson, Needle, and Kaminski,<sup>96</sup> they looked at the effects of KT on ankle stiffness and dynamic balance. This study did not use subjects that had ankle instability; they used only female subjects with no history of ankle injury. They measured passive ankle laxity and stiffness and TTB following forward, backward, medial, and lateral hops. The taping technique is the same technique used by Halseth et al.<sup>82</sup> The subjects were tested prior to tape application, immediately following application, and following 24 hours of use. The results showed that ankle stiffness increased following initial application and 24 hours post tape application. There was no observed change in ankle laxity and no change in TTB. The results show that KT may help restraining the ankle without altering balance.

### *KT Effects on CAI*

In a study completed by Shields et al,<sup>98</sup> they looked at the effects of KT on postural control deficits in healthy ankles, copers, and individuals with CAI. They had 60 subjects split up into the three groups determined by the CAIT questionnaire. They measured TTB and COP in

both the frontal and sagittal planes. They took measurements prior to the application of the tape, immediately after the application of the tape, 24 hours post application, and immediately after the tape removal. They found that there was a significant difference between the groups in COP in the sagittal plane specifically in the CAI group when compared to the healthy group and the copers group. The CAI group's path of COP was more unpredictable than the other groups. They also found that the KT did not have any effect on the improvement in postural control. However, they did start to see a positive effect on postural control after the KT was applied to the ankle for 24 hours, but didn't think it was significant because it was only in two dependent variables and the effect size was very low at 0.15 and 0.14, respectively.

In another study by Bicici, Karatas, and Baltaci,<sup>79</sup> they completed the SEBT, the Kinesthetic Ability Trainer (KAT) test, and other functional performance testing on male basketball players with chronic inversion ankle sprains. They looked at the effects they had on their performance in these tests while wearing white athletic tape, and placebo taping, no tape, and KT. The study found that there was not a significant difference in all four conditions either in the SEBT or the KAT. However, there was a faster performance time wearing the KT and the white tape in other functional tests including the single limb hurdle when compared to the placebo and the no tape groups.

A study done by Hettle et al<sup>97</sup> is closely similar to the study that I have completed. The article is a preliminary study on the effects of KT on functional performance in subjects with CAI. They only had 16 patients from university sports clubs that had CAI according to the CAIT. All 16 subjects completed a KT tape trial and a non-taped trial. The subjects completed the SEBT before the KT application, then received that ankle KT application, then waited 20 minutes. They then removed the tape and completed another SEBT. The study found that there

was no significant difference in reach distance in any direction of the SEBT between the taped and un-taped condition. However, they only kept the tape on for 20 minutes instead of the 48 hours like the study I completed.

### **Conclusion**

Postural sway is a problem that can occur because of many different injuries including CAI. Postural sway problems caused by the neuromuscular deficits in CAI can cause injury to the ankle or lower leg, or can hinder athletic performance. There are many techniques that can be used to improve postural sway in people with ankle instability injuries. KT has been shown to improve postural sway in people with multiple sclerosis,<sup>95</sup> but other articles show that there was no significant difference in subjects with CAI. The studies did not leave the KT on for longer than 24 hours, but could be left for up to 5 days. If KT is a tool that can be used to decrease postural sway in multiple sclerosis, then it can help athletic trainers get people with CAI if used for a longer period of time.

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APPENDIX C  
DATA PROCEDURES

## DATA PROCEDURES FORM/CHECKLIST

1. On the first day, subjects will come in and complete the informed consent, the health history questionnaire, and the IdFAI.
2. They will also have two practice sessions of the BESS.
3. The subjects will come back on another day to start data collection.
4. I will have the tape out, the foam pad out, and a stop watch ready for testing before the subjects arrive.
5. The subject will already be split into one of two groups before coming into the lab that day.
6. The data collection will be for five days in one of the two conditions:
  - a. KT taping
  - b. No tape (Control)
7. When the subjects arrive, I will have the BESS re-explained and the taping protocol explained. They will be able to ask any questions.
8. Each condition will complete the BESS before application of the tape as the pretest.
9. The subjects will then receive the taping intervention if in the KT group and if in the control group they will be done for the day.
10. After 48 hours with the application on the ankle, the subjects will come back in to the lab to perform the BESS again, and then get the tape removed if in the KT group.
11. The subjects will then be asked come back in 72 hours after the tape was removed to complete the BESS again for the final time.

### **Balance Error Scoring System (BESS) Procedures:**

1. The BESS consists of the participants standing unassisted with eyes closed during six different conditions
2. There are two test surfaces:
  - a. Hard flat surface
  - b. Foam surface
3. There are also three stances:
  - a. Double leg stance
  - b. Single leg stance
  - c. Tandem stance
4. The participants are instructed to try and remain motionless with their hands on their iliac crest for 20 seconds with their eyes closed
5. They will complete the three stances on the flat surface first
6. They will then complete the three stances on the foam surface
7. The errors consist of:
  - a. Lifting hands off their iliac crest
  - b. Opening eyes
  - c. Stepping, stumbling, or falling
  - d. Moving the hip more than 30 degrees of flexion or abduction
  - e. Lifting the forefoot or heel
  - f. Remaining out of the testing position for more than five seconds
8. The errors will be recorded by the same certified athletic trainer for consistency on a data collection form

### **Kinesio Taping Procedure:**

1. The technique will consist of 4 strips according to the Kinesio Taping Perfect Manuel <sup>99</sup>
2. The subject will have their foot placed in the relaxed neutral position
3. The subject will be laying prone on a treatment table with the foot hanging off the table to start
4. The first strip will be placed from the origin to the insertion of the posterior tibialis. This strip would begin at the inner posterior borders of the tibia and fibula then extend over the body of the muscle to the medial malleolus.
5. The subjects will then flip over and sit supine on the treatment table with the foot hanging off the edge of the table for the rest of the taping
6. The second strip will be placed from the origin to the insertion of the anterior tibialis. It will extend from the upper two thirds of the lateral surface of the tibia and extend to the dorsum of the foot at the first cuneiform and first metatarsal bones of the foot.
7. The third strip will extend from the origin to the insertion of the peroneus longus. The strip will begin at the at the head of the fibula, then run on top of the lateral malleolus, then continue and wrap under the plantar aspect of the foot ending at the base of the first metatarsal.
8. The fourth strip will begin just anteriorly to the lateral malleolus and extend under the plantar aspect of the foot and pull up the transverse arch of the foot.
9. The taping procedure will be applied by the same certified athletic trainer to ensure consistency throughout the study.

10. When applying the tape to the skin, the paper backing will be removed at one end, causing that to be the anchor. There will be a moderate tension applied to the tape which is a 25-30% tension when applying the tape to the subject's skin.
11. After the tape is applied to the skin, the tape will be rubbed creating friction and heat to the tape causing the adhesive to stick to the skin better.

APPENDIX D

DATA COLLECTION FORM

HEALTH HISTORY QUESTIONNAIRE

IDFAI QUESTIONNAIRE

IDFAI SCORING SHEET

# DATA COLLECTION FORM

## Data Collection Form:

<b><u>BESS Data Collection</u></b>									
Subject #	PMHx:	After App	48 hrs later	72 hrs tape remove	Condition				
Signed IRB:					Leg Used				
<b><u>Flat Surface</u></b>	Pre-Test					Height			
Both Leg						Weight			
Single Leg						Gender			
Tandem						Age			
<b><u>Foam Surface</u></b>									
Both Leg									
Single Leg									Have you exercise today?
Tandem									Day 1:
									Day 2:
									Day 3"
<b><u>Total</u></b>									



## Health History Questionnaire:

Please circle your response

Subject # \_\_\_\_\_

1. Did you have an ankle sprain within the last 2 weeks?

Yes No

If so please explain: \_\_\_\_\_

\_\_\_\_\_

2. Have you ever had the experience of your ankle “giving way” at least once within the last six months?

Yes No

3. Have you ever used Kinesio tape on the ankle before?

Yes No

If so, please explain why: \_\_\_\_\_

\_\_\_\_\_

4. Have you ever suffered a concussion before?

Yes No

If so, please specify when: \_\_\_\_\_

\_\_\_\_\_

5. Do you have any other foot or lower leg injuries besides ankle sprains within the last year? Yes No

If so, please specify what: \_\_\_\_\_

\_\_\_\_\_

6. Have you ever had previous lower leg surgery?

Yes No

If so, please explain on what? \_\_\_\_\_

\_\_\_\_\_

7. Do you have any symptoms of a head cold?

Yes No

What symptoms do you have and when did they start? \_\_\_\_\_

\_\_\_\_\_

8. Do you engage in physical activity for at least 30 minutes 3 times a week?

Yes No

## IdFAI Questionnaire:

### 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
- 

Version 1.0

## IdFAI Scoring Sheet:

### 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

Version 1.0

APPENDIX E  
INSTRUMENT RELIABILITY DATA

## INSTRUMENT RELIABILITY DATA

### Double Leg Stance Flat Surface Error Score

#### Reliability Statistics

Cronbach's Alpha	N of Items
.986	2

#### Intraclass Correlation Coefficient

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.968 <sup>b</sup>	.564	.993	41.667	4	4	.002
Average Measures	.999	.721	.997	41.667	4	4	.002

Two-way random effects model where both people effects and measures effects are random.

- a. Type A intraclass correlation coefficients using an absolute agreement definition.
- b. The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Double Leg Stance Flat Surface = **0.999**

Standard Error of Measurement <sup>100</sup>= **0.00**

n=5, largest standard deviation= **0.00**

### Single Leg Stance Flat Surface Error Score

#### Reliability Statistics

Cronbach's Alpha	N of Items
.976	2

#### Intraclass Correlation Coefficient

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.938 <sup>b</sup>	.564	.993	41.667	4	4	.002
Average Measures	.968	.721	.997	41.667	4	4	.002

Two-way random effects model where both people effects and measures effects are random.

- a. Type A intraclass correlation coefficients using an absolute agreement definition.
- b. The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Single Leg Stance Flat Surface = **0.968**

Standard Error of Measurement <sup>100</sup>= **0.344**

n=5, largest standard deviation= **1.923**

## Tandem Stance Flat Surface Error Score

### Reliability Statistics

Cronbach's Alpha	N of Items
.615	2

### Intraclass Correlation Coefficient

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.500 <sup>b</sup>	-.838	.937	2.600	4	4	.189
Average Measures	.667	-10.315	.968	2.600	4	4	.189

Two-way random effects model where both people effects and measures effects are random.

a. Type A intraclass correlation coefficients using an absolute agreement definition.

b. The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Tandem Leg Stance Flat Surface = **0.667**

Standard Error of Measurement <sup>100</sup>= **0.482**

n=5, largest standard deviation= **0.836**

## Double Leg Stance Foam Surface Error Score

### Reliability Statistics

Cronbach's Alpha	N of Items
.996	2

### Intraclass Correlation Coefficient

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.968 <sup>b</sup>	.564	.993	41.667	4	4	.002
Average Measures	.999	.721	.997	41.667	4	4	.002

Two-way random effects model where both people effects and measures effects are random.

a. Type A intraclass correlation coefficients using an absolute agreement definition.

b. The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Double Leg Stance Foam Surface = **0.99**

Standard Error of Measurement <sup>100</sup>= **0.00**

n=5, largest standard deviation= **0.00**

### Single Leg Stance Foam Surface Error Score

Cronbach's Alpha	N of Items
.993	2

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.985 <sup>b</sup>	.897	.998	136.000	4	4	.000
Average Measures	.993	.946	.999	136.000	4	4	.000

Two-way random effects model where both people effects and measures effects are random.

- a. Type A intraclass correlation coefficients using an absolute agreement definition.
- b. The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Single Leg Stance Foam Surface = **0.993**  
 Standard Error of Measurement <sup>100</sup>= **0.221**  
 n=5, largest standard deviation= **2.64**

### Tandem Stance Foam Surface Error Score

Cronbach's Alpha	N of Items
.951	2

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.924 <sup>b</sup>	.411	.992	20.333	4	4	.006
Average Measures	.960	.583	.996	20.333	4	4	.006

Two-way random effects model where both people effects and measures effects are random.

- a. Type A intraclass correlation coefficients using an absolute agreement definition.
- b. The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Tandem Stance Foam Surface = **0.960**  
 Standard Error of Measurement <sup>100</sup>= **0.565**  
 n=5, largest standard deviation= **2.82**

## BESS Total Error Score

### Reliability Statistics

Cronbach's Alpha	N of Items
.991	2

### Intraclass Correlation Coefficient

	Intraclass Correlation <sup>a</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.981 <sup>b</sup>	.866	.998	112.846	4	4	.000
Average Measures	.990	.928	.999	112.846	4	4	.000

Two-way random effects model where both people effects and measures effects are random.

- Type A intraclass correlation coefficients using an absolute agreement definition.
- The estimator is the same, whether the interaction effect is present or not.

ICC(2,k) BESS Total Error Score = **0.990**  
 Standard Error of Measurement <sup>100</sup>= **0.634**  
 n=5, largest standard deviation= **6.34**



APPENDIX F  
POWER ANALYSIS

## POWER ANALYSIS

### **BESS**

Docherty CL, Valovich McLeod, T.C., Shultz, S.J. Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. *Clin J Sports Med.* 2006;16:203-208.

Overall Mean Error Score:  $(15.7-10.7) / ((6.0+3.2) / 2) = 1.08$

Power = .80

Alpha = .05

Approximate subjects per group: ~17

Linens, SW, Ross, SE, Arnold, BL, Gayle, R, Pidcoe, P. Postural-stability tests that identify individuals with chronic ankle instability. *J Athl Train.* 2014;49(1):15-23.

Overall Mean Error Score:  $(13.6-11.1) / ((4.0+3.0) / 2) = 0.71$

Power= .80

Alpha= .05

Approximate subjects per group: ~33

AVERAGE: ~25 Subjects per group