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# Testing postural control with kinesiology tape and a compression ankle sleeve in dancers

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**TESTING POSTURAL CONTROL WITH KINESIOLOGY TAPE AND A COMPRESSION ANKLE SLEEVE IN DANCERS**

by

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## Dedications

I would like to dedicate this thesis to my parents. Thank you Mom and Dad for your continuous support, guidance, and love.

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## Abstract

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The purpose of this study is to assess if kinesiology tape (KT) and compression sleeves can influence balance and postural control by assessing center of pressure (CoP). This study will also compare the effectiveness of increasing postural control between KT and a compression sleeve. Fifteen female subjects between the ages of 18 and 22 years old volunteered to participate in this study. One subject's data was discarded due to KT disruption. The fourteen remaining subjects were randomly assigned to either the KT, compression sleeve, or control group. Each subject performed a semi-dynamic balance test (modified Airplane Test) on a portable force plate at three instances, including pretest, right after application of KT or compression sleeve, and 48 hours after application. Those in the KT group had the tape on their ankle for the second and third trial, and those in the compression sleeve group had the sleeve on their ankle. Subjects in the control group were barefoot for each trial. Results indicated that no significant change in CoP occurred among the groups and testing instances. This indicates that KT nor a compression sleeve had an effect on postural control. There was no significant difference between the KT group, compression sleeve group, and control.

**Table of Contents**

**Table of Contents (Continued)**

**Table of Contents (Continued)**

**List of Figures**

Figure Page

**List of Tables**

# Chapter 1

## Literature Review

Dance requires optimal athleticism consisting of power, strength, and flexibility, along with artistic ability. There are many styles of dance such as ballet, modern, jazz, tap, and hip hop which all require precise proprioception and great postural control.[1] In a study, Leanderson et al.[1] assessed postural sway in a group of professional dancers and found that the male dancers had a smaller area of postural sway in comparison to the group of non-dancers. This indicates that dancers in comparison to the non-dance population have greater postural control.

Dancers have an increased sense of proprioception and better postural control than other athletes, however, this does not prevent them from becoming injured. Indeed, Kadel et al.[2] found that foot and ankle injuries account for approximately 34-62% of all injuries in dancers with lateral ankle sprains as the most common acute lower extremity injury amongst college aged ballet students.[1-3] In addition, the Achilles tendon and flexor hallicus longus tendons are the most common chronic conditions occurring in dancers.[2] This data suggests that injury of the lower extremity in dancers is a common part of their work. Strong proprioception and postural control are imperative to the success of this population.[4]

Many dancers do not have the adequate medical support when they are a part of a performing arts company. To this end, Weiss et al.[5] surveyed 184 professional modern dancers and showed that 46% of individuals did not have any medical insurance. Additionally, out of the 54% of individuals who had medical insurance, only 16% of the surveyed dancers had worker's compensation at their place of employment. Given the scarcity of coverage in dancers, injury prevention should be a focal point with regard to maintaining their psychological and economic well-being in the competitive dancing population.[5]

Steinberg et al.[6] explains that a deficit in proprioception at the ankle can lead to decrements in postural performance. These changes are related to reduced or delayed muscle control and power, and decreased sensation of inversion at the ankle.[6] Taping and bracing are techniques used to improve proprioception and postural control in dancers. However, few studies have shown improvement in proprioception and postural control with these methods during functional activities.[4,7-11] Consequently, dancers have used kinesiology tape (KT) to enhance proprioception and postural control during their performances.[4,7-11]

The use of KT, when applied to the ankle joint and lower leg, has been shown in some studies to aid in postural control in college-aged modern dancers.[4] Tekin et al.[4] assessed the effects of KT's effect on semi-dynamic activities (i.e. Airplane Test) and dynamic activities, such as monopodalic, straight, and transverse passé, to assess balance in healthy modern dancers. It was found that KT reduced errors for both types of balance tests, thus indicating improved proprioception.[4] In another study, Jackson et al.[7] applied KT to the ankle joint and lower leg for 48 hours on individuals with Chronic Ankle Instability (CAI). Balance performance improved following 48 hour KT application suggesting that the length of time the tape was applied may have an effect on postural control performance.[7] Since there is no standard protocol for KT application or length of time to wear it, the literature on KT reports inconsistent results[9,11]. However, when studies use an extended period of time for KT use, the results seem to show improved postural control.[4,7-10]

In the little research that has been done on compression sleeves, there are contradicting results of its effect on balance.[12,13] To the best of the author's knowledge, no study has been conducted on the effects of compression sleeves on postural ankle control in dancers. In a related study, Herrington et al.[12] studied angle tracking of the leg in recreationally active subjects while wearing a neoprene sleeve in comparison to the opposite leg not wearing a neoprene sleeve.[12] These authors found improvements in proprioception by correct angle reproduction by subjects and perceived angle testing for each test when the neoprene sleeve was used. This data suggests a compressive sleeve may help improve proprioception and kinesthesia.

Ewalt et al.[13] discusses taping and bandaging considerations for dancers, including KT, white athletic tape, and ACE wraps. It was concluded that the clinician should have a specific goal in mind when taping or wrapping a dancer with an ACE wrap because of their elastic quality.[13] Additionally, Ewalt et al.[13] suggested that compression of an injury can increase proprioceptive feedback, as well as reduce hemorrhaging, inflammation, and scarring. Therefore, the compression wrap was suggested for improving proprioceptive feedback and supporting the ankle without reducing range of motion.[13] More research needs to be done on compression sleeves and its effect on postural control because if they are found to improve proprioception and postural control, it can be an easy and financially accessible tool for the prevention and protection of the ankle in dancers.[13,14]

The sport of dance encompasses a need for athletic performance as well as aesthetic design. The use of KT and compression sleeves can accomplish these goals since both are sleek in design and can camouflage itself on the skin. Further, their use may be able to improve postural control, thereby, enhancing performance. Addressing the knowledge gap of compression sleeves regarding dance performance can improve upon current paradigms that govern the wellness, injury prevention, and performance potential of competitive dancers.

**Physiology of Proprioception**

The common definition of proprioception as described by Grigg[15] and Lephart et al.[16] is the joint's ability to sense itself in space. It is a variation of the body's ability to sense touch and position relative to internal (e.g. neural input, stretch reflex) and external (e.g. perturbations, visual stimuli) factors, of which many factors play a role in proprioception.[16] Lephart et al.[16] describes how movement occurs as the firing of afferent neurons in response to a stimulus which causes action potentials to ascend the spinal cord and reach the cerebral cortex. At the cerebral cortex, the response is integrated and efferent motor signals descend the spinal cord and initiate the process of movement so the limb can adjust to the stimulus.[16]

Another way movement occurs is from the external and internal stimulation of a proprioception system, such as the ocular and vestibular systems, muscle spindles, golgi tendon organs, and other mechanoreceptors to be discussed.[17] An important part of proprioception are mechanoreceptors, that are found in the skin, muscles, tendons, joints, and ligaments.[15] Shaffer et al.[17] states these mechanoreceptors convert external information to internal information which is done by electrical relay of neural impulses to the CNS.[16-18]

**The vestibular and ocular system.** Proprioception not only encompasses the somatosensory system, but it also depends on the ocular and vestibular systems to create a cohesive unit.[17,19] The vestibular and ocular system are two different systems in the body, but they work together in the somatosensory system which makes them easier to discuss as one. The body is able to receive and process information through the ocular and vestibular systems which then cause reflexes in alpha motor neurons to achieve control.[17]

Lephart et al.[16] considers the vestibular system as an important system that supplies proprioceptive information to the central nervous system (CNS).[16] The vestibular system relies on the semicircular canals, cochlea, and membranous labyrinth to interpret information which then feeds into the CNS.[16,20] The ocular system gives the body visual cues, such as reference points, to maintain balance and postural control.[16] Vision is considered the most dominant feedback mechanism for the CNS, but it does not work as quickly as other proprioceptor systems in generating a reflex.[20]

The vestibular and ocular systems are processed by the spinal cord, cerebellum nuclei, cerebellum, basal ganglia, and motor cortex.[16] Combined, these systems control the balance and postural control aspects of proprioception. All information the vestibular system receives is sent to the extraocular muscles and spinal cord. Hain et al.[20] explains that this channel of nerve impulses creates three reflexes, the vestibular-ocular reflex (VOR), the vestibulocollic reflex (VCR), and the vestibulospinal reflex (VSR).[20] The VOR creates clear eye sight while the head is moving which is important when considering how information interpreted from the eyes determines how the body will move. The VCR is a response of the neck musculature when motion is indicated by the inner ear organs. The VSR adjusts the angles and movements of the extremities and trunk while the body is moving to continuously maintain balance and control.[20]

**Somatosensory system.** The somatosensory system incorporates muscle spindles, golgi tendon organs (GTOs), and mechanoreceptors in ligaments, joints, and the skin to determine touch, pressure, and movement.[21] The somatosensory system uses periphery information to create feedforward and feedback loops which determine movement to maintain balance.[21] Feedforward loops uses previous experiences to help determine future movement, whereas, feedback loops are continuously adjusting due to ongoing muscle changes.[21]

***Feedforward and feedback loops.*** The feedforward loop is enhanced preparatory muscle activation when performing tasks that have been previously done.[22] The feedforward mechanism originates from the CNS and distributes its information to the peripheral nervous system (PNS) which will create motion.[22] When an individual does repetitive, functional motion, it triggers the feedforward mechanism, possibly through mental imagery and body position, and develops the body's efficiency to complete that task.[22] During quiet stance, it has been stated that feedforward loops are sufficient to stabilize posture at the ankle.[23] The feedback loop is still active to some extent during quiet stance, but only important information about maintaining stability will trigger a response.[23] When an environment is unstable, muscle activation increases to create more stability at a joint.[23] The feedforward loop plays the more prominent role in an unstable situation when compared to the feedback loop.[23]

The feedback loop informs the CNS of movement that is occurring.[22] The feedback mechanism transmits information from the PNS to the CNS and descends back to the PNS to alter muscle activation and trigger the stretch reflex.[22] In recent literature, it has been shown that the stretch reflex at the ankle when balancing in quiet stance is reduced when the surface stability is reduced.[23] However, in the same study it showed that when there are perturbations of the trunk and extremities, stretch reflex at the ankle increased.[23]

***Skin mechanoreceptors.*** Studies on skin mechanoreceptors, specifically of the finger tips, have been conducted to assess a light touch's effect on postural sway. According to Kouzaki et al.[24], during quiet stance light touch from the fingertips on a stable surface decreased mean velocity of center of pressure and reduced horizontal ground reaction force by 20% in comparison to no sensation of touch.[24] This indicates that light touch sensed from the skin mechanoreceptors of the fingertips aided the somatosensory system and reduced postural sway.

Other research, such as Saini et al.[25], have assessed skin mechanoreceptors in other parts of the body.[25] Saini et al.[25] addressed whether light touch sensation by a hepatic robot on the upper back of an individual balancing in a bipedal position would have decreased postural sway.[25] Decreased displacement of center of pressure was found when the light touch was applied to the upper back which resulted in decreased postural sway.[25] The stimulation of skin mechanoreceptors are more important in effecting proprioception than previously thought by Grigg[14].

***Articular mechanoreceptors.*** Joint and ligament mechanoreceptors are both considered articular mechanoreceptors.[15] These mechanoreceptors both respond to the same type of stimuli, which is rotation of a joint, and lie close to the joint. They will be discussed separately, but have similar roles in proprioception which is why they are grouped together.[15]

*Joint mechanoreceptors.* Every joint has two main mechanoreceptor types which are Ruffini Corpuscles and Pacinian Corpuscles.[15] Ruffini Corpuscles are Group II afferent sensory fibers which lie in the portion of the capsule that is stretched when a joint is extended, therefore, mainly respond to stress at extreme ranges of motion opposite of where it lies.[15,26] Ruffini Corpuscles are considered limit detectors in the joint.[15]

Pacinian Corpuscles are also Group II afferent neurons that are stimulated by compression and loading of the joint.[15] Pacinian Corpuscles are compression detectors and can also sense joint rotation.[15] Both Ruffini Corpuscles and Pacinian Corpuscles are large-diameter neurons, but according to Lephart et al.[26], Ruffini corpuscles are slow adapting whereas Pacinian Corpuscles are fast adapting.[15,26] Pacinian Corpuscles are more so involved in balance because they can quickly adapt to random perturbations of the body and aid in returning the body to a stabilized state.

Group III and IV afferent neurons are thin-diameter, unmyelinated neurons that conduct signals slowly and are found in joint articular tissue.[15] These neurons are unable to detect direction of movement, but can detect movement sense.[15] Group III and IV afferent neurons are triggered by deformation and tissue loading.[15]

*Ligament mechanoreceptors.* Ligament mechanoreceptors are stimulated by joint stretch, which is very similar to Ruffini Corpuscles.[15] Articular mechanoreceptors are not sensitive to specific types of movements.[15] They also provide a mechanical restraint that helps to protect the joint from injury.[15,26] When ligaments are stretched over capacity and become damaged, proprioception at the joint has been shown to decrease.[1,15]

***Muscle and tendon mechanoreceptors***. Muscle and tendons are major contributors to proprioception due to muscle spindles and GTOs. Muscles are stimulated when a joint moves causing the agonist muscle to contract and the antagonist muscle to relax.[15] Muscles can detect the movement because of muscle spindles and GTOs. Muscle spindles cannot work alone, they must coincide with not only GTOs, but with articular receptors as well to produce a stronger sense of proprioception. Muscle and joint mechanoreceptors work together to create a stable joint. Joint receptors are activated at the end range of motion and when muscle mechanoreceptors have smaller length changes or lose their ability to signal angular displacement.[15] The body is more stable when the joint and muscle mechanoreceptors work together because of the higher sense of proprioception.

Kristemaker et al.[18] states muscle spindles detect the length and rate of changes in the contractile element of muscle when a muscle stretches.[15,18] The muscle spindle detects length changes in the muscle fibers and initiates the stretch reflex. The stretch reflex occurs when the muscle spindle propagates the muscle to contract to resist the lengthening in the muscle.[16,18] Mechanoreceptors in muscles differ from the skin because they can detect the joint's position in space during mid-range of motion.[15] The contraction of muscles around a joint increases the joint's ability to perceive proprioception and decrease risk of injury due to alpha-gamma coactivation.[15]

**Postural control.** Postural control, defined by Palmieri et al.[19], is the body controlling its position in space to create overall balance. The three main systems that effect postural control are the somatosensory system, vestibular system, and ocular system.[27,28] Postural control is measured by center of pressure (CoP) which is the center of the distribution of weight from all surfaces of the body in contact with the ground.[19,27,30] The two main goals in the postural control system are to maintain balance and to correct imbalance which is when the CoP reaches the limits of the center of gravity (COG).[19] Imbalance is corrected by adjusting the orientation and segments of the body to modify CoP, the center of distribution of the total force applied on a surface, in reference to COG, the vertical position of the center of mass from the ground.[19]

Issues arise with postural control when damage occurs to the somatosensory system and CNS. Increase in time for the body to regain balance is noted after injury or compromise to the somatosensory system.[30] Previous research shows that people with ankle injuries, such as sprains or chronic pathologies, have poor single-leg balance comparison to the uninvolved limb and healthier individuals.[28,31] Poor balance can be attributed to a compromise of the joint stability because muscular stabilization, muscular synchronization, ligaments surround the joint are damaged and alter the somatosensory system, and also damage to the skin mechaoreceptors.[11,15,16]

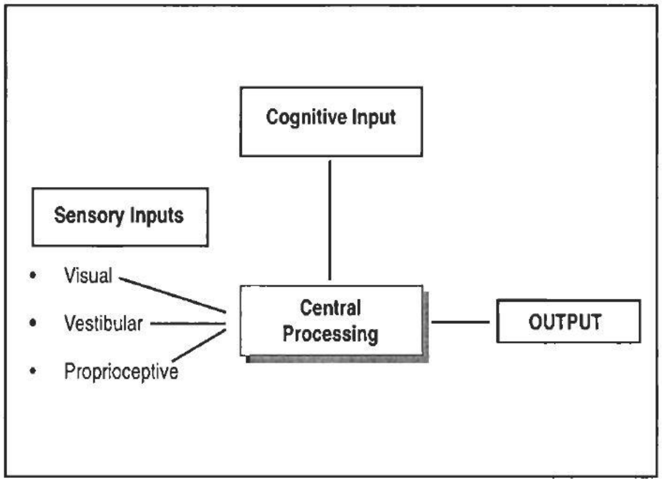


*Figure 1.* Model of the Postural Control System[14]

**Proprioceptive Performance in Healthy and Injured Individuals**

**Healthy proprioceptive behavior**. Han et al.[32] explains that proprioceptive performance can be predicted by a person's proprioceptive ability along with the quality of sensory information gathered from the mechanoreceptors, vestibular system, and ocular system. Athletes that have high proprioceptive abilities are able to perform better because they can interpret feedback related to external stimuli from the ocular system, vestibular, and somatosensory systems. As a result, athletes can adjust to and develop efferent responses during proprioceptive challenges seen during functional activities. Not only does proprioceptive-sensory input have an effect on performance, but experience does as well.

The feedforward loop prepares the body to protect itself due to past experience, along with proprioceptive input, and the feedback loop responds to its environment to maintain a safe state.[22,32] The culmination of past experience and a healthy neuromuscular system creates optimal proprioceptive performance in individuals.

**Proprioception in dancers**. Dancers are thought to have higher levels of proprioceptive ability due to the nature of their sport.[1,4] Many times they are required to balance, not only in static positions, but also during semi-dynamic and dynamic movements as well. A study by Leanderson et al.[1] compared healthy professional ballet dancers' postural sway to non-athletes.[1] This study reported that male ballet dancers had a significantly smaller area of postural sway in comparison to their non-athletic counterparts.[1] These results suggest that dancers have more advanced proprioceptive performance in comparison to non-dancers. It is also important to note that all of the dancer's left feet performed better than their right.[1] This can be correlated to the feedforward loop because dancers mostly balance and turn on their left foot in comparison to their right foot.[1,30]

**Damaged proprioceptive behavior**. When damage occurs to mechanoreceptors, the afferent feedback is either not sent correctly or is delayed to the spinal cord causing proprioceptive deficits.[24] Trauma will reduce sensitivity to proprioception, which in turn, may cause greater injury.[24] Leanderson et al.[1] studied dancers that were injured in between pretest and posttest sessions and found that injured dancers had a larger area of displacement during balance compared to their pre-injury state. The decreased performance was attributed to the lateral ankle sprains they all experienced. It was suggested by Leanderson et al.[1] that the ligaments became overstretched and could resist movement like they had before. This study only addressed that the ligaments were injured, but it is also important to understand that joint capsule and muscle mechanoreceptors may have also experienced trauma which would additionally lead to proprioceptive deficits.

**Center of Pressure**

Duarte et al.[30] states that balance conditions rely on forces and torques that are applied to the body.[30] Postural control is affected by not only external torques of ground reaction forces (GRF) and gravity, but also internal torques such as muscle activation and inhibition from standing and physiological disturbances.[30] The most common way to assess postural control is CoP.[29]

**Root mean square amplitude and root mean square velocity to measure CoP**. CoP can be further calculated into Root Mean Square (RMS) amplitude.[28] RMS shows the variability of data.[19] Typically, a lower value for RMS will indicate greater ability to maintain a stable condition.[19] RMS amplitude has been shown to be sensitive to postural control changes in stroke victims, especially in the anterior-posterior view.[19]

RMS velocity determines how fast the CoP displacements are occurring during a postural task.[28] RMS velocity has also been used to assess postural control changes in stroke victims and has shown great sensitivity.[19] There is moderate correlation that RMS and RMS velocity measure the same aspects of the postural control system during an eyes-open condition in the frontal plane, whereas, when eyes are closed the correlation decreases in the frontal plane.[19] This is an important factor when considering whether eyes should be open or closed or what planes one is assessing. It is important in this study to assess changes in postural control which is why RMS amplitude and RMS velocity should both be used as measurements of COP.

**Total displacement of CoP**. Total displacement (TD), also known as total excursion, is the total amount of sway that occurs over a testing period.[19] Palmieri et al.[19] used an example of a squiggly line that represents the TD and if one was to pull the squiggly line straight, one would see the total amount of displacement. Palmieri et al.[19] states that the literature does not support TD due to the lack of evidence, but does support the use of CoP velocity.

**Validated Tests to Assess Postural Control**

The Star Excursion Balance Test (SEBT), balance in a passé, grandé plié in first, second and fifth positions, Romberg's Test, and the Topple Test have been used to assess postural control in prior research.[4,10,33,34] The SEBT and Romberg's Test are both valid and clinically useful tests, however, their lack of specificity to dancers make the use of these tests inappropriate in comparison to other testing options.[4] Postural control can be tested using a static or dynamic test, but the nature of movement in dance is dynamic. Testing should reflect typical movement in dance which is why static balancing in a passé is not the best test that can be used to assess postural control in dancers.

Grandé pliés are dynamic, but they have not been validated as to whether they can accurately measure postural control.[33] The Topple Test has been used in prior research as an assessment of postural control in which the person perform a single pirouette.[34] The Airplane Test is a more appropriate choice in comparison to the Topple Test because the force plate in use is raised. A person may fear falling and feel uncomfortable if they are to turn on a raised platform which would lead to failed attempts. Failed attempts and fear from the subject will increase touch downs, errors, and skewed data which is best to avoid.[19] The Airplane Test has been validated, is dance specific, and a safer movement on the force platform to be used.

**Airplane test.** The Airplane Test was developed as a functional screening tool for injury prevention programs in dancers.[35] It has since been used to assess a dancer's readiness for beginning pointe dancing in ballet.[33,34] The Airplane Test is a semi-dynamic test which asks the subject to stand on one leg with their arms abducted 90°. They are then asked to lower their upper body while lifting their non-weight bearing leg into an arabesque position and stopping at 90° of hip flexion of the dominant/weight-bearing leg. While in this position they must plié five times while horizontally adducting the arms to touch the finger tips as close to the ground, if not, actually touching the ground.[33,34] The subject fails the test if their knee falls into valgus, their hip internally or externally rotates and is not square to the ground, if the non-support leg lowers itself, arms do not horizontally abduct, and they cannot complete 4 pliés.[33,34] It has not been stated whether the subject should have their eyes closed or open, however, all subjects are oriented to their surroundings prior to testing.

Testing a subject in a single-legged stance adds challenge to the movement which would better assess those with advanced proprioception.[19] Since the person is in a single-legged stance, it reduces the base of support and creates greater demand from all systems involved in balance and postural control. The clinician can increase the challenge of the test by asking the subject to close their eyes or asking them to look at a designated point of reference.[19] It certainly is more of a challenge to the somatosensory system when the eyes are closed, however, this may cause more touchdowns or falling which would negatively impact data. Likewise, dance performance is not completed with a person's eyes closed. The procedure of establishing a point of reference or orienting them to the space they will be tested has shown to decrease touch downs and fear of falling.[19]

**Force plates.** The two main types of force plates include those that only record the vertical component of GRF and those that record the medial-lateral, anterior-posterior, and vertical components of GRFs.[29] Force plates can also be used for two different kinds of testing, static or dynamic.[19] Static testing is typically done through quiet stance with two feet on the ground.[19] Dynamic testing is used to look at the response of a subject when perturbations or displacements occur.[19] To assess postural control it is necessary to assess anterior-posterior and medial-lateral aspects of GRF. Research has indicated that force plates are the best way to assess COP because they can attain quantitative data from the calculations of anterior-posterior and medial-lateral displacement.[12,28]

## External Factors That May Influence Postural Control

Lower extremity injuries are the most common injury type in the dance population which can lead to time out of class and work or some choose to continue dancing which may progress their problem.[3,4] Many dancers must be additionally responsible for their own injury prevention and treatment strategies since many do not have easy access to a health care professional.[4] KT and compression sleeves have both been used by dancers in the past and continue to be used presently.[4,13] In the literature, KT has produced inconclusive results as it pertains to postural control and no research has been done on a compression sleeve on a dancer.[4,7-10,36]

**Kinesiology tape.** There are many different versions of KT such as Kinesio Tape, Kinesiology RockTape, and Thera-band Kinesiology tape. Kinesiology tape is an adhesive fabric that is designed for longitudinal stretch. It has been reported that it has the ability to stretch 140% from its resting state, thereby, allowing the tape to stretch with the joint and not restrict motion.[8,9] Jackson et al.[7] and Simon et al.[8] have stated it has the ability to stay adherent to a person's skin three to five days in comparison to other tape (ie., linen tape) options which only lasts a few minutes to a couple of hours.[13]

***Effects of kinesiology tape on postural control.*** Various research has addressed aspects that could impact the effects of KT. Time of application is varied in the research and has resulted in contradicting reports.[7-11] Type of testing may also impact the results found and its significance to a clinical setting. Finally, KT has also been used on healthy and injured individuals. Those who are injured have reduced function to their somatosensory systems, which causes delays in the stimuli response, feed-forward and feedback mechanisms, and kinesthesia, thereby influencing how the KT will affect postural control.

*Time of application.* Several investigators concluded that long term KT application (24, 48, 72 hours) resulted in increased ankle proprioceptive ability.[7,8,10] Nakajima et al.[10] used a healthy population, however, Jackson et al.[7] and Simon et al.[8] used participants with CAI and functional ankle instability (FAI). The importance of using both a healthy and unhealthy subjects is that KT benefited both groups when worn between 24 and 72 hours.

Other studies that examined acute application of KT in a healthy, non-dancing population did not report improved proprioceptive performance. Long et al.[11] and Halseth et al.[9] applied KT to the ankle joint and lower leg and tested their subjects by making them recreate a joint position, thereby, testing proprioception. After the pretest, they removed the KT and completed a posttest.[9,11] Long et al.[11] and Halseth et al.[9] did not look at long term effect of KT nor the effect of wearing KT over an extended period of time.[9,11] Both studies found no change in proprioceptive ability and concluded that KT did not improve proprioception.[9,11] Since research has provided conflicting evidence on the acute use of KT, it should be questioned if people are using it as intended, as it was designed for wear over a period of time.

*Static versus dynamic testing*. A study looked at healthy, young adult modern dancers and the acute effects of KT applied to the ankle joint and used the Airplane Test to assess postural control while doing complex movements.[4] Results showed that KT, when applied to the supporting leg's ankle and lower leg, can significantly decrease Airplane Test errors, indicating enhanced proprioception. It is important to test the dance population with semi-dynamic or dynamic tests because dancers will almost never be in quiet stance.

*KT in healthy and unhealthy populations.* Previous research uses different types of populations to assess the effectiveness of KT. KT can produce significant improvements in proprioception and postural control in not only a healthy population, by an injured population as well.[6-8] As stated earlier, dancers generally have better postural control than the normal population, but research provides evidence that KT can even improve a dancer's postural control.[4] Acute and chronic injury rate are more common in the feet and ankles of dancers in comparison to other parts of the body, therefore, that is why research must be done to determine if KT has an effect on the ankle joint.[1-3]

***Physiological effects of kt on skin.*** KT was created to promote movement, increase muscle activation, and enhance proprioception by stimulating the skin.[6-10,13] Much research contradicts one another on whether KT effectively does any of the things it claims to do.[4,7-11,30] KT has not been validated in the use of ballet dancers, but has shown evidence in studies in dancers to control ankle pronation and static and dynamic balance through its effect on skin and muscle mechanoreceptors and providing continuous feedback pertaining to joint position.[6,7] Jackson et al.[7] states that applying tape from the origin of a muscle to its insertion will aid in muscle activation which would help balance.

Another theory may be that since muscle spindles react to stretch of a muscle and KT is laid over a muscle, when the KT stretches not only do the skin mechanoreceptors respond to the KT, but the muscle spindles recognize the stretch of that muscle and also contract to avoid further damage.[15] The feedback received from the skin mechanoreceptors being stretched may also activate a response up to the CNS.[15]

**Compression sleeves.** Compression sleeves are typically worn to support a body segments underlying tissue and has the ability to conform to joint contours for which it is worn.[36] Barss et al.[36] concluded that when a compression sleeve was worn at the elbow, the sleeve filtered out irrelevant mechanoreceptor data. It only allowed the necessary information to stimulate the nervous system when testing movement sense, thus improving kinesthesia.[36]

Compared to KT, very little research has been done specifically on compression sleeves for ankle postural control and balance. A study by Bennell et al.[14] assessed ankle compression sleeves and compared it to several other conditions. They found that elastic bandages had no significant effect on balance when performing a single-leg static balance test.[14] It was concluded that since the compression sleeve did not restrict ankle motion, it did not negatively impact or improve the stimuli in the CNS.[14]

Other research has been conducted on the knee which may be applicable to the neural process involving of compression sleeves and ankles. Herrington et al.[12] concluded that use of neoprene sleeves did improve proprioceptive performance at the knee.[12] However, Heit et al.[37], when looking at a commercial compressive ankle brace, did not report any improvements for proprioception.

It has been reported that the main mechanism that creates the potential for the sleeve to work is its compression.[12] Herrington et al.[12] stated that, theoretically, compression sleeves should stimulate the skin and muscle mechanoreceptors. The skin mechanoreceptors may be stimulated because they can sense touch, but muscle mechanoreceptors are only stimulated by muscle spindles and GTOs which require length change or tension.[15] Therefore, it seems more likely that compression would mainly stimulate skin receptors to enhance the perception of joint position and less likely to activate muscle spindles and GTOs.

***Why compression sleeves?*** More research needs to be done on the effects of compression sleeves on postural control. They are reusable and cost effective which is important to dancers that may not be able to afford KT because of its high cost and disposability due to its one-time use. Not only are they easily accessible, they are unobtrusive to the wearer and will not interrupt technique and movement of the dancers' ankle joint.[13]

**Conclusion and Suggestions for Future Research**

Many dancers struggle to afford medical insurance, or dance while injured due to no compensation for time off or the threat of losing their job. Research needs to be devoted towards the dance field so injuries can be prevented, or handled quickly to reduce or eliminate the time dancers miss from their work.

Improved proprioception and postural control have been shown to reduce the risk of ankle injuries. A valid, movement specific test that will assess semi-dynamic movement and postural control is the Airplane Test. Force plates have been shown to be the most accurate method to evaluate postural control. Combining both the Airplane Test and a force plate has been reported to be effective in evaluating proprioception and postural control in dancers.

KT and compression sleeves can possibly have a place in the dance world, but more research must be done to test them during a semi-dynamic balance task. Even though there has been a significant amount of research on KT, the results are contradicting. Since the research that shows significant improvements in proprioception applied the tape for longer than 48 hours, research should focus on the length of time. There is little research pertaining to compression sleeves and, therefore, time should be devoted to the efficacy and influence on balance because of their accessibility, little expense, and theoretical potential from a physiological standpoint. At this point in time, there is no literature on the comparison of KT and compression sleeves in the assessment of postural control in dancers.

**Problem Statement**

The purpose of this study is to assess postural control during the application of KT and compression sleeves around the ankle in collegiate dancers. This investigation will address the current knowledge gap in the literature on the topics of KT and compression sleeves, specifically, by the direct comparison of the two interventions.

**Specific Aims and Hypotheses**

**Specific Aim 1**: Assess the influence of KT on postural control during semi-dynamic movement.

**Hypothesis 1:** KT will increase the success rate during the Airplane Test when compared to the control group.

**Specific Aim 2**: Assess the influence of a compression sleeve on postural control during semi-dynamic movement.

**Hypothesis 2**: A compression sleeve will increase the success rate during the Airplane Test when compared to the control group.

**Specific Aim 3**: Determine whether KT or a compression sleeve is more effective in improving postural control.

**Hypothesis 3**: KT will increase the success rate during the Airplane Test when compared to the compression sleeve.

# Chapter 2

## Manuscript

### Abstract

The purpose of this study is to assess if kinesiology tape (KT) and compression sleeves can influence balance and postural control by assessing center of pressure (CoP). This study will also compare the effectiveness of increasing postural control between KT and a compression sleeve. Fifteen female subjects between the ages of 18 and 22 years old volunteered to participate in this study. One subject's data was discarded due to KT disruption. The fourteen remaining subjects were randomly assigned to either the KT, compression sleeve, or control group. Each subject performed a semi-dynamic balance test (modified Airplane Test) on a portable force plate at three instances, including pretest, right after application of KT or compression sleeve, and 48 hours after application. Those in the KT group had the tape on their ankle for the second and third trial, and those in the compression sleeve group had the sleeve on their ankle. Subjects in the control group were barefoot for each trial. Results indicated that no significant change in CoP occurred among the groups and testing instances. This indicates that KT nor a compression sleeve had an effect on postural control. There was no significant difference between the KT group, compression sleeve group, and control.

### Introduction

Many dancers struggle with injury or pain throughout their career with minimal resources to help them.[5] Professional dance companies may not offer a physician or other health care professional for the dancers to see when they are injured. Unfortunately, insurance coverage amongst many professional dancers can often be bare minimum.[5]

Most commonly, dancers are afflicted with injuries to the foot and ankle which can leave them with no choice other than to dance with an injury, or take time off and possibly threaten the future of their career.[2,5]

When an injury occurs to the ankle, it can decrease neuromuscular control, which affects balance and postural control, with both characteristics being imperative to functional movement in dance.[4] It is important to the health and wellness of a dancer that injury prevention is provided, as well as devices to aid the injury when it occurs.

Two suggested ways to improve postural control and balance are KT and compression sleeves.[4,7,8,14,36] Through skin and muscle mechanoreceptors, it is suggested that both KT and compression sleeves can contribute to the somatosensory system and influence balance and postural control.[7,12,37] It is the aim of the author to fill the gap in the literature by comparing the relationship between KT and a compression sleeve's effect on postural control.

Muscle spindles and golgi tendon organs (GTOs) stabilize a joint when stretch or tension occurs in the muscle, respectively.[15] Muscle spindles, GTOs, and skin mechanoreceptors are theorized to be stimulated when KT is applied or a compression sleeve is put on over the joint.[7,8,12] KT has been suggested to aid in activation of a muscle when it is applied from origin to insertion.[7]

KT also provides feedback when a joint moves and creates stretch in the tape.[7] The stretch of the tape stimulates both skin mechanoreceptors and muscle spindles which will cause the muscles to contract and bring the joint back to its normal state. Skin mechanoreceptors can be stimulated by a compression sleeve as well because of the compression of the skin in the sleeve.[12]

Even though KT has conflicting results in research, when tape is applied for more than 24 hours results have shown a significant effect on improving postural control and balance at the ankle.[4,7,8,10] Compression sleeves have much less research about their effect on postural control and balance in comparison to KT. It can be difficult to define what a compression sleeve is because researchers could consider elastic wrap, neoprene, or a cotton blend to all be compression sleeves. Little research has been done on the various types listed with results showing improvements, negative influence, or no influence on balance and proprioception.[12,14,36]

Both KT and compression sleeves should be further researched on their influence on balance and postural control in dancers because of their sleek designs, easy accessibility, the support offered to the ankle joint, and lack of range of motion restriction. It is important to note that accessibility allows dancers to purchase them without relying on insurance.

The purpose of this study is to assess if KT and compression sleeves applied to the ankle joint can improve balance and postural control and, ultimately, to identify if one has a greater influence in dancers. This research may present a way for dancers to prevent or support injury by using a financially minimal and easily found product that is both aesthetically pleasing in dance and functional for the dancer. To the author's knowledge, this is the first study to assess a compression sleeve's effect on postural control in a dancer and also compare a compression sleeve and KT.

**Methods**

**Subjects.** All participants were asked to sign the consent form which was approved by the Institutional Review Board at Rowan University prior to completing the study. Fifteen healthy female participants were recruited to participate in this study. Subject's characteristics can be found in Table 1. A power analysis was done on Gpower 3.1 using a repeated measures analysis of variance (ANOVA) within-between interactions. An alpha of 0.05, a power of 0.8, and an effect size of 0.5 produced a total sample size of 12 subjects to reduce a Type I error. The power of 0.8 was chosen because of the small sample size in the study.

Inclusion criteria included male and female students at Rowan University between the ages of 18 and 22 years old. All subjects had at least 2 years of dance experience either through teaching, taking classes, or extracurricular activities (dance team, plays, etc.). Exclusion criteria included those with any lower extremity injury that occurred in the past 6 months of their projected participation, any surgical history to the lower extremity, recent diagnosis of concussion, previous experience with KT or compression sleeves, and any neurological conditions that could affect balance.

Table 1

*Subject Characteristics*

| | KT (n=5) | CS (n=5) | Control (n=4) |
|---|---|---|---|
| *Age (yrs)* | 20±1.6 | 20.6±0.9 | 20.5±1.3 |
| *Body Weight (kg)* | 63.814±11.8 | 60.274±5.4 | 61.25±17.5 |
| *Height (cm)* | 62.6±1.1 | 63±3 | 62±4.1 |

**Experimental design.** The study used a randomized control pretest-posttest design. All subjects were randomly assigned to either KT, compression sleeve, or the control group through simple randomization by an online list randomizer (https://www.random.org/lists/). As a result of randomization, 6 subjects were assigned to the KT group, 5 subjects were assigned to the compression sleeve group, and 4 subjects were assigned to the control group. All subjects completed the study, however, 1 subject's data from the KT group could not be used because their KT did not remain adhered to their ankle for the prescribed time period. Therefore, only 5 completed data for the KT group.

## Instruments

**Airplane test.** The Airplane Test,[33-35] a semi-dynamic balance test, was planned to be used for this study, however, during pilot testing many subjects found it too difficult and uncomfortable from a safety perspective to complete the test on a platform while blindfolded. The test was altered so subjects began on their dominant leg, which was defined as whichever leg they would stand in a single-leg stance the longest on (Figure 2A,2C). They then moved into the airplane test start position (Figure 2B,2D) and then moved into a 90° standing leg hip flexion with head, torso, arms in 90° abduction, and non-dominant leg in line and maintain their balance to then return to their beginning test position. Subjects were instructed to get into the Airplane position and return to their beginning position in a time frame of 10 s.

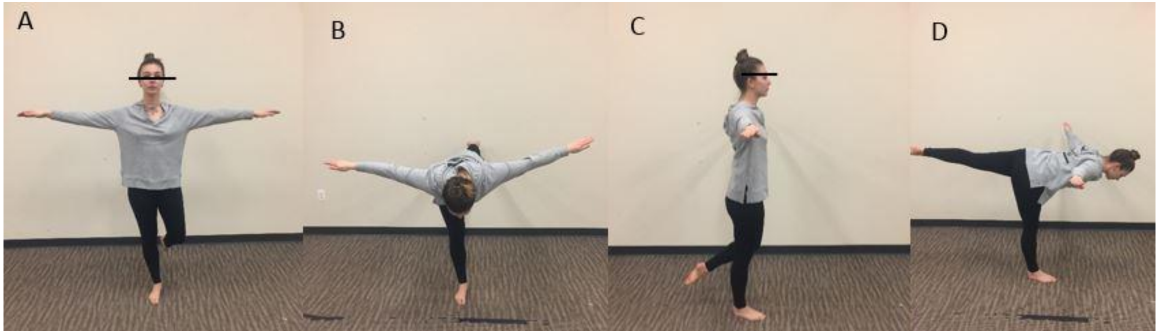


*Figure 2.* Beginning (Figure A- Anterior, Figure C- Lateral) and End (Figure B- Anterior, Figure D- Lateral) of Airplane Test

Subjects were scored by a pass or fail method described by Liederbach et al.[35] If they hiked their non-dominant leg's hip, fell out of position, their non-dominant leg was not in line with their spine and head, or they did not keep their torso parallel to the floor it was considered a failed attempt. The investigator decided what pass or fail was through recorded video of the test. The investigator was not blinded to the subjects' condition.

**Kinesiology tape.** The Kinesio Tex Gold (Kinesio, Albuquerque, NM) in beige was used in an attempt to blend the tape color into skin tones, which is consistent with dancer use. An alcohol wipe was used to remove any dirt or skin oils from the skin's application site prior to the KT being applied. Adhesive spray was then applied so the tape would have the best chance of staying adhered to the ankle for the required 48 hours. The KT technique used for the ankle was the Kenzo Kase lateral ankle method (Figure 3).[7]

*Figure 3.* Lateral and Anterior View of Kenzo Kase Lateral Ankle Tape Method

**Compression sleeve.** The compression sleeve used in this research was the C60-45 Champion Brand Figure 8 compression sleeve (Champion, Cincinatti, OH) in beige (Figure 4). This compression sleeve was chosen because it fits the ankle like a figure 8 used during a typical linen tape application on the ankle, however it does not completely encase the ankle or restrict plantarflexion. This compression sleeve was carefully chosen to determine the one most applicable to a dancer's need for unrestricted range of motion during performance (Figure 4).

*Figure 4.* Anterior and Lateral View of C60-45 Champion brand Figure 8 Compression Sleeve

**Force plate and software.** Postural control was assessed using a 35.43 x 23.62 inch portable force plate (AMTI, Inc. Newton, MA), that was housed within the Rowan University Applied Biomechanics Laboratory (Figure 5). Vertical, mediolateral, and anteroposterior GRFs were measured to obtain Fz, Fx, and Fy coordinates, respectively. Moments were also measured in the directions listed above to obtain Mz, Mx, and My. Data was collected using a sampling rate of 60 Hz. Standing weight was collected in Newtons on the force plate prior to testing so data would be relative to the individual's body weight. $CoP_x$ was calculated by $-My/Fz$ and $CoP_y$ was calculated by $Mx/Fz$. The software used to collect data was AccuPower software (AccuPower Solutions, Watertown, MA).

*Figure 5.* Force Plate

**Video camera.** Each trial was recorded using a Sony Hdr-cx240 (Sony, New York, NY). Videography was used because multiple joints needed to be assessed to determine if a subject passed or failed a trial. Pass or fail criteria was decided by reviewing the subject's completed test immediately after completion. The video camera was filmed facing the subject's anterior body on the coronal place.

**Procedures**

**Pilot testing.** Pilot testing was completed and provided insight on minor changes to be made in the testing procedures. Instead of just 1 trial for pretest and both posttests, 3 trials were determined for testing so an average could be calculated. Subjects were also originally blindfolded during pilot testing, however, they were unable to maintain the test and/or made comments that they felt like they would fall. It was decided to not use the blindfold during testing and to instead make a mark on the floor since giving a point of reference has shown to decrease touchdowns, which is consistent with dance performance.[19.]

**Testing.** All subjects completed a familiarization period in which subjects practiced four times with a minute in between each practice trial. All subjects were taught how to complete the test, the errors they should not make, and any corrections they should fix for the next practice trial. After the familiarization period, a 5 minute break was given to reduce any effects of fatigue.

All subjects completed 3 trials for the pretest, for the posttest immediately after the application of the KT or compression sleeve, and again after a 48 hour period. Subjects were given a minute break in between each trial. The pretest consisted of the subject completing a 10 second balance test on the force platform using the modified

Airplane Test position. This was followed by a 5 minute break where subjects quietly rested while either the KT or the compression sleeve was applied depending on which group they were assigned to. Following the application of the KT or compression sleeve, each subject completed a 10 second posttest on the force plate utilizing the same procedures as the pretest. A second posttest was given to all groups 48 hours after the application of the KT or compression sleeve using the same parameters previously described (Figure 6).

Subjects in the KT group kept the tape on for a 48 hour period, but those in the compression sleeve group did not keep the sleeve on for that period. This was decided because KT is made for long term wear, whereas, compression sleeves are not.[14,36,37] Subjects were provided verbal feedback pertaining to their time, so that they could complete each trial within a 10 second window.

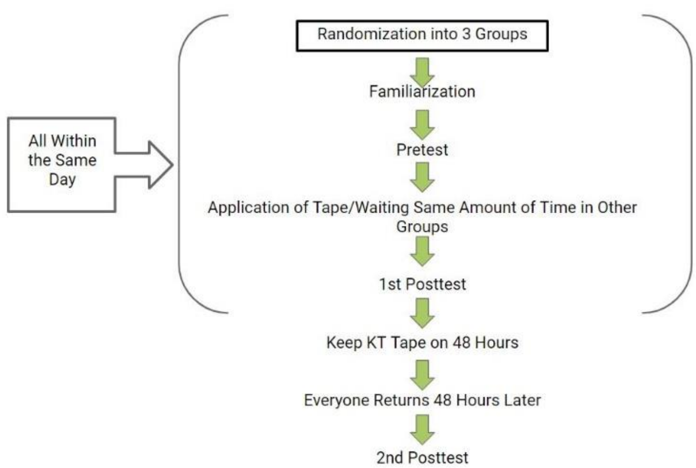


*Figure 6.* Flow Chart of Testing

**Force Plate Data Acquisition**

The software used to obtain data from the force plate was AccuPower software (AccuPower Solutions, Watertown, MA). The sampling rate of the software was 60 Hz and measured Fx, Fy, and Fz, as well as, Mx, My, and Mz, to quantify the center of pressure changes. Subjects were weighed on the force plate before they began the trial only at the beginning of each day. They were then instructed to get into their start position and to begin when they were ready. Immediately when subjects began to descend into the modified Airplane Test position, the software was started and data was collected. The software was set for 10 seconds to coincide with the length of the test. Anterior-posterior was X direction and medial-lateral was the Y direction.

Data was saved on the lab computer using each subject's own file number with a data encrypted USB. The videos of the subjects doing their testing were also saved on this USB.

**Data Analysis**

The variables assessed for the pretest and both posttests were average, RMS, amplitude, mean velocity, and TD of both CoPx and CoPy. Statistical analysis was calculated using the Statistical Package for the Social Sciences (IBM Corp., Armonk, NY). A within-between ANOVA was used to assess the comparison among the 3 testing periods and the 3 groups for CoP x and y average, RMS, amplitude, mean velocity, and TD. CoP x and y were individually calculated for RMS, amplitude, and mean velocity, but were calculated together for TD. Formulas are consistent with those used by Duarte et al.[30] and are referenced in Table 2.[30] An independent t-test assuming unequal variances was conducted to compare all groups. If significance was shown, a Fischer's Least Significant Difference (LSD) would be completed.

Table 2

*Formulas for Average, RMS, Amplitude, Mean Velocity, and TD*

| Variable | Formula |
|---|---|
| Average (CoPx; CoPy) | AVERAGEap=(sumCPap/cells); AVERAGEml=(sumCPml/cells) |
| RMS (CoPx; CoPy) | RMSap=sqrt(sum(CPap.^2)/length(CPap)); RMSml=sqrt(sum(CPml.^2)/length(CPml) |
| Amplitude (CoPx; CoPy) | AdCPap=max(CPap) - min(CPap); AdCPml=max(CPml) - min(CPml) |
| Mean Velocity (CoPx; CoPy) | MVap=sum(abs(diff(CPap)))*freq/length(CPap) MVml=sum(abs(diff(CPml)))*freq/length(CPml) |
| Total Displacement | DOT=sum(sqrt(CPap.^2+CPml.^2)) |

Note: RMS (Root-Mean-Square), DOT (Total Displacement), ap (anteroposterior), ml (mediolateral), MV (Mean Velocity), Ad (Amplitude), CP (Center of Pressure)

**Results**

This study assessed whether KT and compression sleeves had an impact on a dancer's balance and postural control, and compared the two methods. Balance and postural control was quantified by looking at CoP and calculating it through several variables. All groups were assessed using an independent t-test assuming unequal variances. No significant differences were found between groups.

**Average CoP $_X$ and CoP $_Y$.** The average CoP in both mediolateral and anteroposterior directions were assessed to establish whether a decrease in average CoP occurred. A decrease would indicate that the subject was stable and able to better control their balance. A two-way (3-time periods x three groups) within-between ANOVA revealed that there was no significant interaction between time periods and groups (F=0.254, p=0.904) for average CoPx. The main effects of time (F=1.452, p=0.256) and groups (F=2.327, p=0.144) were also not significant for average CoPx.

Statistical analysis also revealed that there was no significant interaction between time periods and groups (F=0.647, p=0.635) for average CoPy. The main effects of time (F=0.285, p=0.754) and groups

(F=1.648, p=0.237) were also no found to be significant for average CoPy.

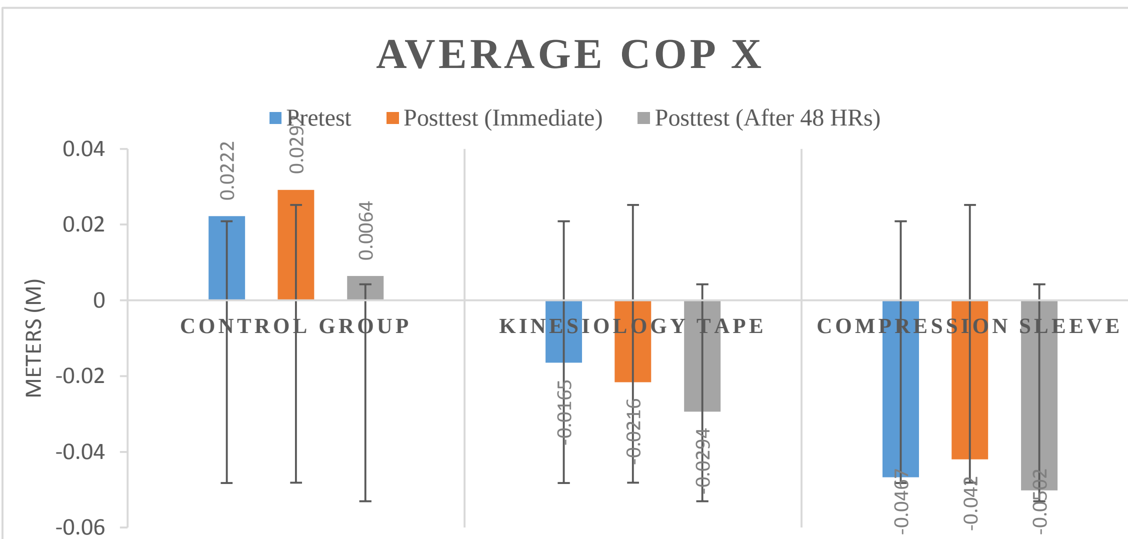


*Figure 7.* Average CoP X (Means with Standard Deviation)

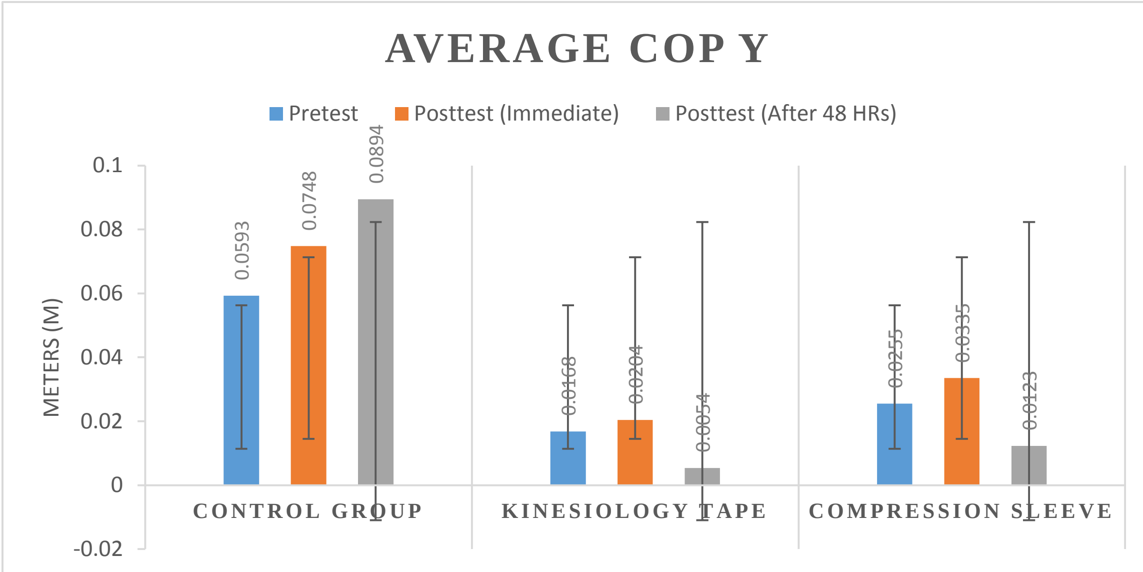


*Figure 8*. Average CoP Y (Means with Standard Deviation)

**RMS for CoP $_X$ and CoP $_Y$.** A two-way (3-time periods and three groups) within-between ANOVA found no significant interactions between time periods and groups (F=0.407, p=0.802) for RMS of CoPx. The main effects of time (F=1.732, p=0.200) and groups (F=0.300, p=0.747) were also not found to be significant.

It was also revealed that there was no significant interaction between time periods and groups (F=1.498, p=0.237) and there was no interaction for RMS of CoPy. There was no significant effect for the main effects of time (F=1.663, p=0.213) and groups (F=0.352, p=0.711).

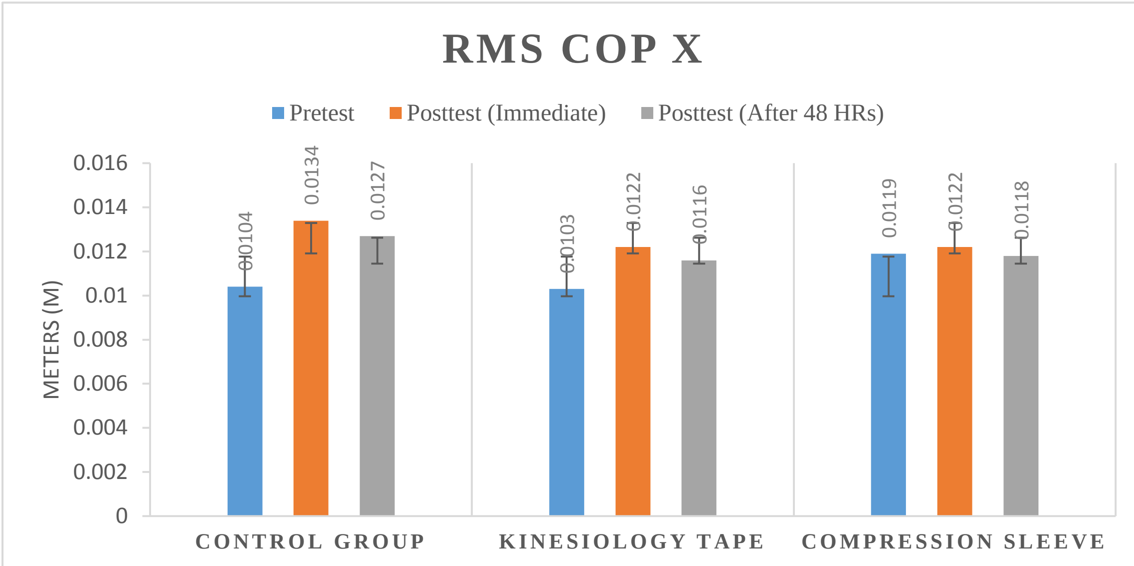


*Figure 9.* RMS CoP X (Mean with Standard Deviation)

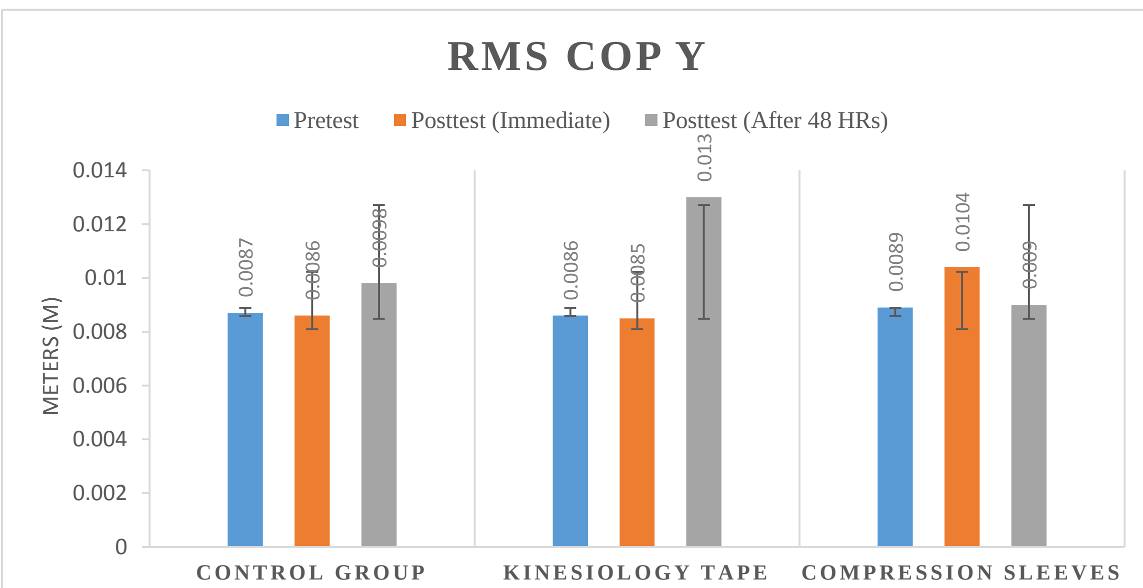


*Figure 10.* RMS CoP Y (Mean with Standard Deviation)

**Amplitude for CoP $_X$ and CoP$_Y$.** It was revealed through a two-way (3-time periods and three groups) within-between ANOVA that there was no significant interaction between time periods and groups (F=0.120, p=0.974) for amplitude of CoPx. The main effects of time (F=0.726, p=0.495) and groups (F=0.022, p=0.978) were not significant as well.

A two-way (3-time periods and three groups) within-between ANOVA revealed that there was no interaction between time periods and groups (F=0.452, p=0.770) and the main effects of time (F=0.176, p=0.840) and groups (F=0.352, p=0.711) were not significant.

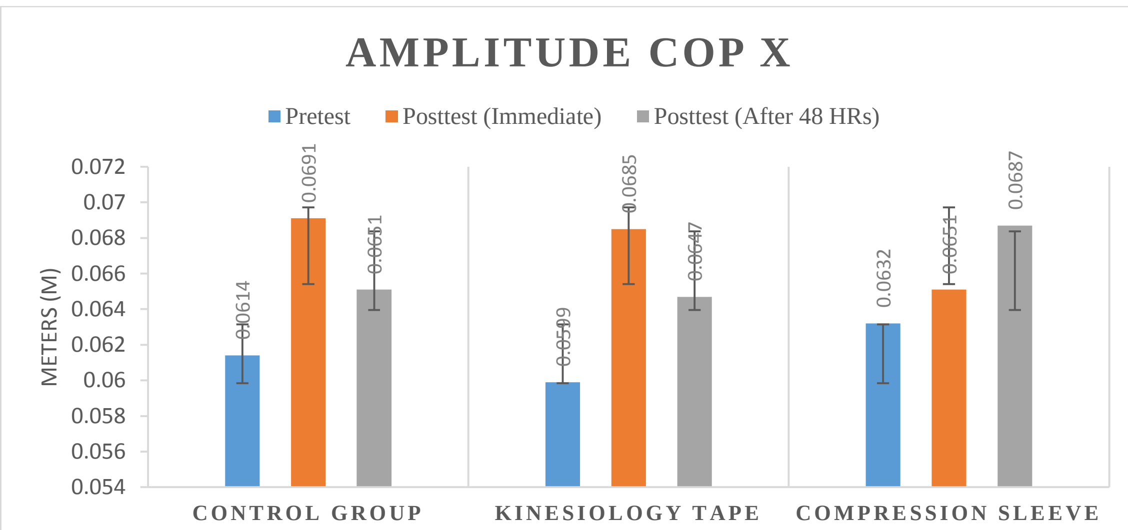

*Figure 11*. Amplitude CoP X (Mean with Standard Deviation)

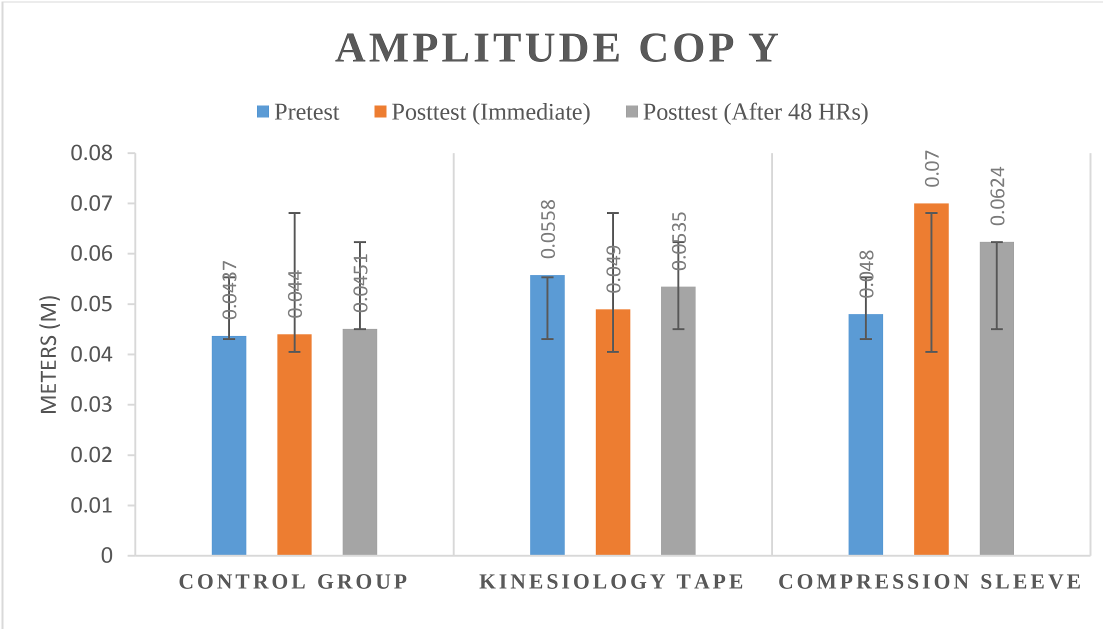


*Figure 12.* Amplitude CoP Y (Mean with Standard Deviation)

**Mean Velocity for CoP $_X$ and CoP $_Y$.** A two-way (3-time periods and three groups within-between ANOVA revealed that there was no significant interaction between time periods and groups (F=0.122, p=0.973) for mean velocity of CoPx. The main effects of time (F=0.725, p=0.495) and groups (F=0.022, p=0.978) were not significant.

A two-way (3-time periods and three groups) within-between ANOVA found there was no interaction between time periods and groups (F=0.523, p=0.720) and the main effects of time (F=0.184, p=0.834) and groups (F=0.294, p=0.199) were not significant for mean velocity of CoPy.

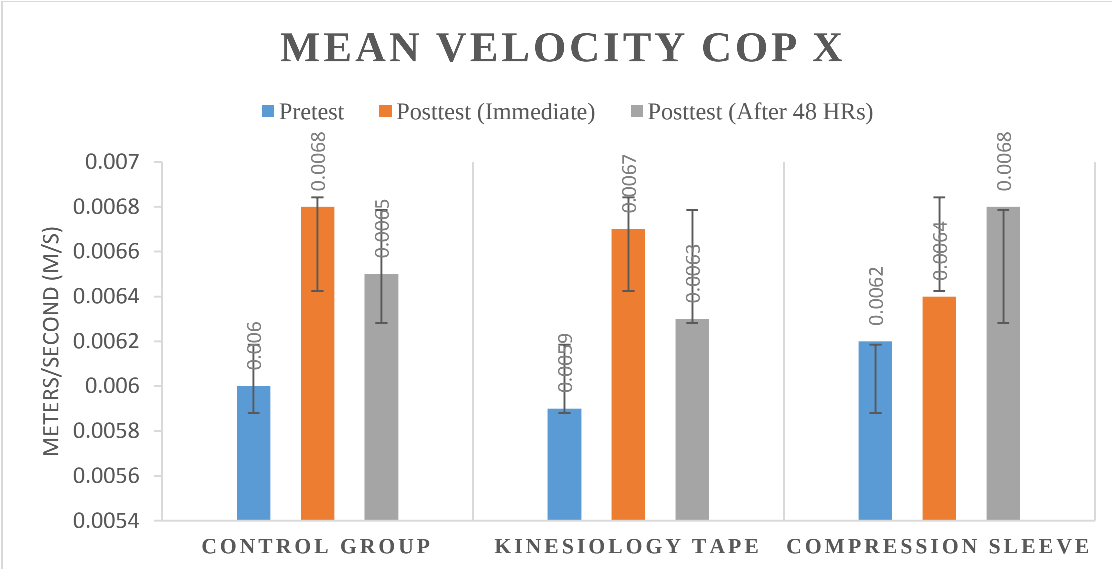


*Figure 13.* Mean Velocity CoP X (Mean with Standard Deviation)

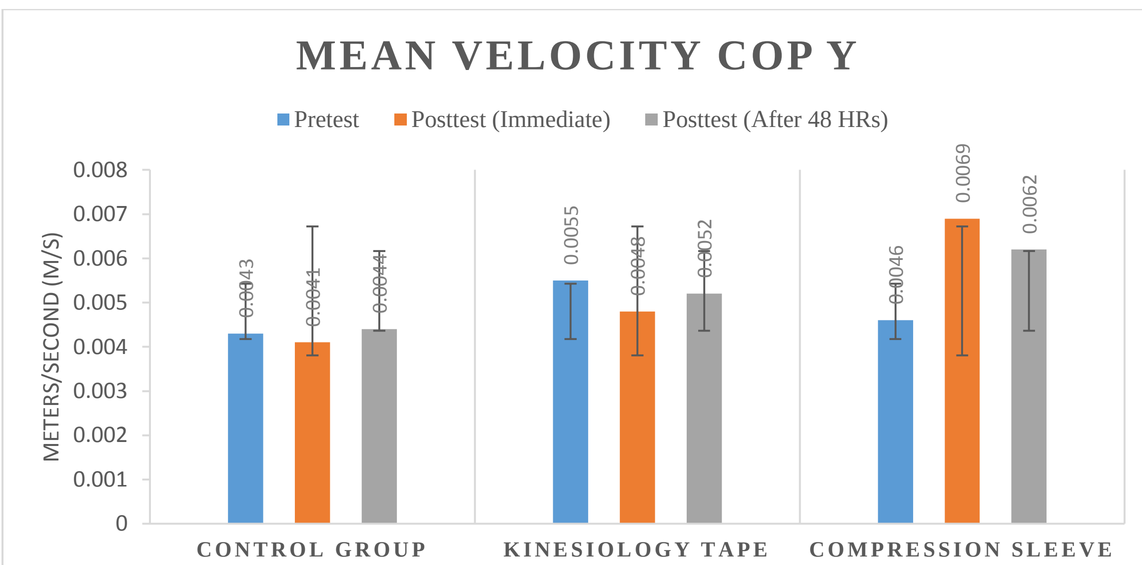


*Figure 14.* Mean Velocity CoP Y (Mean with Standard Deviation)

**Total displacement.** A two-way (3-time periods and three groups) within-between ANOVA revealed that there was nosignificant  interaction between time periods and groups (F=0.435, p=0.782) and the main effects of time (F=1.308, p=0.291) and groups (F=0.390, p=0.686) were also not significant.

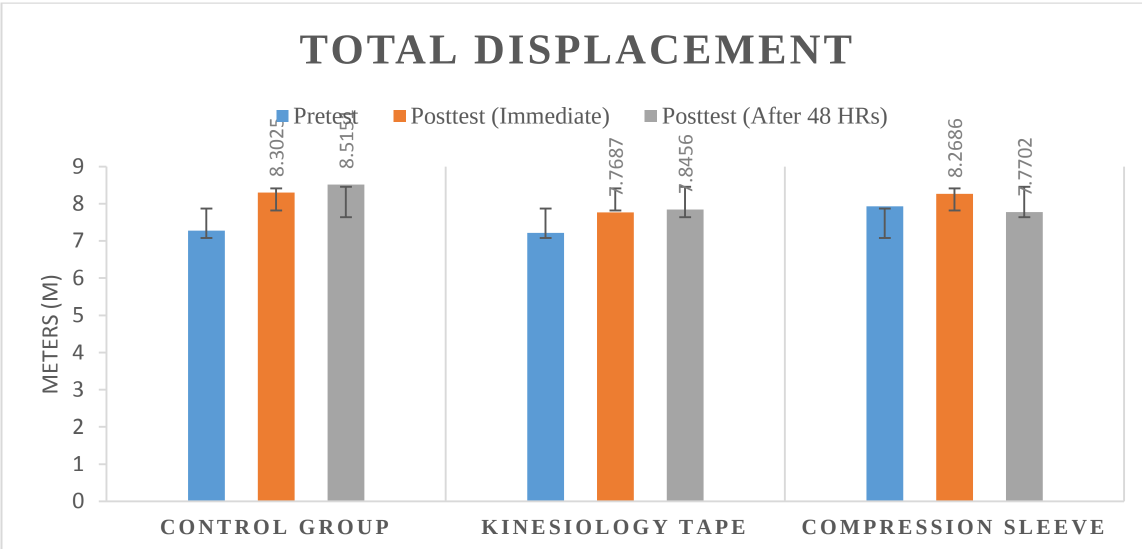


*Figure 15*. Total Displacement (Mean with Standard Deviation)

## Discussion

The findings of this study suggest that neither KT nor compression sleeves had an effect on postural control or balance. It also suggests that there is no difference between KT and compression sleeves on postural control and balance.

**Healthy versus injured subject population.** Jackson et al.[7] and Simon et al.[8] both used people with CAI and FAI and found improvement in balance and postural control in those that wore KT tape. Jackson et al.[7] explains that applying KT to a healthy individual may not be as effective because their muscle mechanoreceptors and skin mechanoreceptors are not injured, therefore, they may not rely on the extra feedback provided by the KT. This study presumed that the findings that Jackson et al.[7] and Simon et al.[8] found would be replicable. However, due to the subject pool in this study, who were all healthy individuals with no current injury, this may have affected the results. Jackson et al.[7] also suggested that applying KT from muscle origin to insertion increases muscle activation, thereby improving balance. KT was applied from insertion to origin in this study, which is opposite of what Jackson et al.[7] suggests, which may have effected muscle activation. This could have contributed to the lack of change in the KT group.

Halseth et al.[9] and Heit et al.[37] used healthy, non-dancer subjects and neither one found significant improvement of postural control or joint position sense when using the KT or compression sleeve, respectively. All subjects in this current study were healthy, and had no injury within the past 6 months of being tested. The current study's results are consistent with these findings and suggest that KT and compression sleeves may not improve balance or postural control in healthy populations.

**One balance test versus multiple balance tests for assessment.** Tekin et al.[4] used 3 separate balance tests: the Airplane Test, turn-out passé balance tests, and monopodalic balance tests- to assess postural control and balance. They found a significant change in semi-dynamic and dynamic balance for the KT group.[4] The Airplane Test had significant improvement of reduced errors within groups for Tekin et al.[4], and they used a small effect size. The current study used a moderate effect size for all of the calculations due to the small sample size. Since the effect size was moderate, it is more difficult to find a smaller significant change in a smaller population size, especially in just one test. The use of multiple tests could help catch small changes that may not be present in one type of balance (static, semi-dynamic, and dynamic). The use of only one type of balance test could contribute to the contradictory result of produced in the KT group during the Airplane Test.

**Sample size.** Tekin et al.[4] used a sample size of 33 subjects assigned to 3 groups and assessed postural control using the Airplane Test, turn-out passé balance tests, and monopodalic tests. Nakajima et al.[10] used 52 subjects assigned to 2 groups to assess postural control using the Star Excursion Balance Test. Jackson et al.[7] used a sample size of 30 subjects assigned to 2 groups to assess balance by using the Balance Error Scoring System Test.

Barss et al.[36] used 25 subjects with half in the control group and half in the compression sleeve group, and assessed reaching accuracy by sensory stimulation with the compression sleeve on the subject's elbow. Bennell et al.[14] used 24 subjects with each subject as their own control, and used a single-legged balance test to assess postural control at the ankle while wearing a compression sleeve.

Tekin et al.[4], Nakajima et al.[10], Jackson et al.[7], Barss et al.[36], and Bennell et al.[14] all found significant improvements for either postural control, balance, or joint position sense. The sample size of the current study was 14 subjects, which fit the power and alpha chosen, but the effect size was moderate. This made finding small changes difficult with a small sample size. The sample size could have worked if each subject was their own control, such as in Bennell et al.'s[14] study. They compared a control condition and multiple taped or braced conditions, and used each subject as their own control. The small sample size and use of the moderate effect size made finding a change difficult, therefore, this may explain why the current study's results are contrary to previous studies of KT and compression sleeves effect on balance and postural control.

**Subject inclusion too generalized.** Tekin et al.[4] used criteria that included dancers participating in modern or ballet styles a minimum of 3 days/week for 10 hours/week as well as having 2 prior years of modern dance experience. All subjects in their study were on the same technical level due to the stricter inclusion. Subjects in this current study only needed to have participated in dance for at least 2 years, however, they did not have to be currently dancing or have hour requirements of dance throughout the week. This suggests that subjects were not on the same technical level as one another, therefore, results could have been affected due to the possible skill level differences.[11]

## Chapter 3

## Conclusions, Future Work, and Limitations

### Conclusions

This study evaluated the effects of KT, as well as establish research on compression sleeves and postural control in dancers, and compare the two products. The results did not show that KT or compression sleeves had an influence on postural control acutely or after 48 hours of KT application.

CoP changes were insignificant for KT in this instance. The compression sleeve also did not produce a significant decrease in CoP during the Airplane Test. Objectively, there was no difference in results between the KT and compression sleeve during the Airplane Test.

KT and compression sleeves did not produce significant results in this study, but should be researched because of their unique qualities that fit into the dance world. This study does not suggest that KT nor compression sleeves decrease CoP changes in healthy dancers. In regards to KT, there are varying results on its effect on balance and postural control, therefore, studies should continue to assess its efficacy. There is not as much research on compression sleeves, and this study suggests they may not decrease CoP displacement. Prior research on compression sleeves are also contradictory to one another, and research should be continued on compression sleeves. More research must be done in this field to provide dancers with options to prevent and protect ankle and foot injuries. To the author's knowledge, there are no studies that compare KT and a compression sleeve's effect on CoP in dancers. Also, there are no known studies to the author's knowledge that assesses the change in CoP in a dancer while also wearing a compression sleeve.

**Future Work**

This study has established a foundation for future research to be conducted for the dance community. If a sample size cannot be increased, the subjects can be made to be their own controls and the testing setup would be altered to accommodate the compression sleeve and extended time of wearing the KT. Researchers should consider testing subjects with a chronic injury such as CAI or FAI to determine if KT or compression sleeves can help those with a deficit in balance and postural control. The use of multiple balance tests may also be helpful so various kinds of balance, such as static, semi-dynamic, and dynamic, can be assessed.

**Limitations**

Some limitations were discussed in the previous discussion section, such as the subject inclusion of the study being too generalized which caused a variety of technical levels amongst the dancers. Other limitations include the small sample size, the modification of the Airplane Test to exclude the pliés, and not using a blindfold to remove the ocular system from consideration. Another difficulty was getting the KT to reliably stay adhered for 48 hours on a subject after the subject left the Applied Biomechanics Lab. The KT for one subject came off around their ankle, which could have been due to not applying enough adhesive spray, from the subject excessively changing shoes, or from getting the tape wet in the shower.

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**Appendix A**

**Consent Form**

**TITLE OF STUDY:** Dancers' Postural Sway and Neuromuscular Control Tested while Barefoot, with Kinesiology Tape, and a Neoprene Ankle Sleeve
**Principal Investigator:** Robert Sterner

You are being asked to take part in a research study. This form is part of an informed consent process for a research study and it will provide key information that will help you decide whether you wish to volunteer for this research study.

Please carefully read the key information provided in questions 1-17 below. The purpose behind those questions is to provide clear information about the purpose of the study, study specific information about what will happen in the course of the study, what are the anticipated risks and benefits, and what alternatives are available to you if you do not wish to participate in this research study.

The study team will explain the study to you and they will answer any question you might have before volunteering to take part in this study. It is important that you take your time to make your decision. You may take this consent form with you to ask a family member or anyone else before agreeing to participate in the study.

If you have questions at any time during the research study, you should feel free to ask the study team and should expect to be given answers that you completely understand.

After all of your questions have been answered, if you still wish to take part in the study, you will be asked to sign this informed consent form.

You are not giving up any of your legal rights by volunteering for this research study or by signing this consent form.

After all of your questions have been answered, if you still wish to take part in the study, you will be asked to sign this informed consent form.

The Principal Investigator, Robert Sterner, or another member of the study team will also be asked to sign this informed consent.

**1. What is the purpose of the study?**

The purpose of this study is to look at dancers balance and body control during different conditions. I want to assess if having kinesiology tape on the ankle or an ankle brace alters balance compared to a bare foot condition. The purpose of this investigation is to assist dancers in being aware of their balance capabilities and the appropriate treatment (e.g., kinesiotherapy tape, bracing or bare feet) in order to enhance postural control and prevent lower extremity injuries. This study is also being done to fulfill my requirement of a thesis for a Masters in Athletic Training.

**2. Why have you been asked to take part in this study?**

I am asking that you be a part of this study because you are either a dance major or minor at Rowan University.

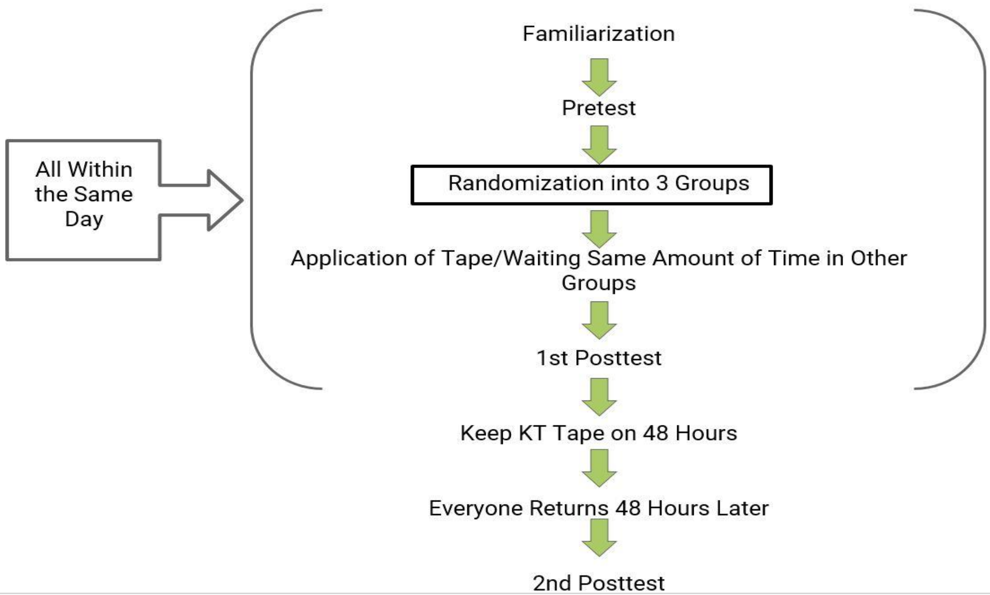
3. **What will you be asked to do if you take part in this research study?**

This study requires you to be tested on two separate days that are 48 hours apart. On the first day every person will learn how to do the balance test that I am asking them to do. The balance test is called the Airplane Test. The Airplane Test will be done on a force plate that looks at your balance capabilities.

After you learn the balance test, you will complete the first test barefooted using your dominant leg. After the first test, you will be randomly assigned into one of 3 groups: a bare foot group, a kinesiology tape group, and a neoprene sleeve group. You will be asked, immediately after being assigned to a group, to complete a second balance test utilizing that condition for which you were randomly assigned (e.g., barefoot, kinesiotherapy tape or neoprene ankle sleeve). Subjects in the kinesiology tape group will keep the tape on for 48 hours and not remove it for any reason (unless an allergic reaction occurs). After 48 hours, you will be asked, no matter which group you have been assigned, return for a second day of testing.

All testing will be done in James Hall in the Biomechanics Lab.

*Flow Chart of Protocol Pictured Below*




**4. Who may take part in this research study? And who may not?**

Inclusion: Male and female Rowan university major/minor dancers between the ages of 18-23 and with at least 2 years of experience dancing are being asked to volunteer for this study.
Exclusion: Dancers with any lower extremity injury within the past 6 months, any surgical procedure to the lower extremity, recent concussion diagnosis, symptoms of a head cold, and any neurological disorder that affects balance, any previous experience with kinesiology tape on the ankle, or any previous experience with a neoprene ankle sleeve will not be able to participate in this study.

5. **How long will the study take and where will the research study be conducted?**
   Testing will occur in two sessions with each session taking approximately 1 hour to complete. Participants will be asked to report to the Applied Biomechanics Laboratory for both sessions which will be separated by 48 hours. All study testing will be done in James Hall in the Biomechanics Lab.

6. **How many visits may take to complete the study?**
   Only two visits to the Applied Biomechanics Laboratory are needed.

7. **What are the risks and/or discomforts you might experience if you take part in this study?**
   There is minimal risk of injury in performing the static balance tests used in this study. Subjects who do not like to be blindfolded may choose to not take part in the study.

8. **Are there any benefits for you if you choose to take part in this research study?**
   The data gathered from your participation will add to the understanding of which prophylactic condition enhances balance in collegiate dancers, thereby potentially preventing lower extremity injuries.

9. **What are the alternatives if you do not wish to participate in the study?**
   You may choose to not be a part of this study, but there is no alternative treatments in this study.

10. **How many subjects will be enrolled in the study?**
    About 60 subjects will be needed for this study.

11. **How will you know if new information is learned that may affect whether you are willing to stay in this research study?**
    During the course of the study, you will be updated about any new information that may affect whether you are willing to continue taking part in the study. If new information is learned that may affect you, you will be contacted.

12. **Will there be any cost to you to take part in this study?**
    There is no cost for involvement in this study.

13. **Will you be paid to take part in this study?**
    Subjects will not be paid to take part in the study.

**14. Are you providing any identifiable private information as part of this research study?**

We are not collecting identifiable private information in this research study.

**15. How will information about you be kept private or confidential?**

All efforts will be made to keep your personal information in your research record confidential, but total confidentiality cannot be guaranteed. Your personal information may be given out, if required by law. Presentations and publications to the public and at scientific conferences and meetings will not use your name and other personal information. All paper data will be kept in a folder secured within a locked filing cabinet within the Applied Biomechanics Laboratory. All electronic data will only have numbers associated with the data, no names will be attached and stored on the Rowan university secured server. A file linking your personal information to data collected will be deleted at the conclusion of data collection.

**16. What will happen if you do not wish to take part in the study or if you later decide not to stay in the study?**

Participation in this study is voluntary. You may choose not to participate or you may change your mind at any time.

If you do not want to enter the study or decide to stop participating, your relationship with the study staff will not change, and you may do so without penalty and without loss of benefits to which you are otherwise entitled.

You may also withdraw your consent for the use of data already collected about you, but you must do this in writing to Sarah Unger at ungers0@students.rowan.edu or 420 Overbrook Avenue Glassboro, NJ

If you decide to withdraw from the study for any reason, you may be asked to participate in one meeting with the Principal Investigator.

**17. Who can you call if you have any questions?**

If you have any questions about taking part in this study or if you feel you may have suffered a research related injury, you can call the Principal Investigator:

Robert Sterner
Department of Health and Exercise Science
(856) 256-4500 ext. 53767

If you have any questions about your rights as a research subject, you can call:

Office of Research Compliance
(856) 256-4078– Glassboro/CMSRU

**18. What are your rights if you decide to take part in this research study?**

You have the right to ask questions about any part of the study at any time. You should not sign this form unless you have had a chance to ask questions and have been given answers to all of your questions.

**AGREEMENT TO PARTICIPATE**

I have read the entire information about the research study, research risks, benefits and the alternatives, or it has been read to me, and I believe that I understand what has been discussed.

All of my questions about this form or this study have been answered and I agree to volunteer to participate in the study.

Subject Name:______________________________________________

Subject Signature:______________________ Date:___________

**Signature of Investigator/Individual Obtaining Consent:**

To the best of my ability, I have explained and discussed the full contents of the study including all of the information contained in this consent form. All questions of the research subject and those of his/her parent or legal guardian have been accurately answered.

Investigator/Person Obtaining Consent:_________________________________

Signature: ______________________________ Date________________

You have already agreed to participate in a research study conducted by Sarah Unger. We are asking for your permission to allow us to include optional procedure, such as videotape, as part of that research study. You do not have to agree to be recorded in order to participate in the main part of the study.

The recording(s) will be used for:

- analysis by the research team
- pictures used in the thesis and future publications

The recording(s) will include the person's entire body. As mentioned previously, you will be blindfolded during all testing, which will also obstruct the investigators and co-investigators from being able to identify you during the video.

The recording(s) will be stored on the secure Rowan University network. The recording will be done using a recording device within the Applied Biomechanics Laboratory. All files will be in reference to the subject number, not their name. All video data will be deleted upon publication of study results.

Your signature on this form grants the investigator named above permission to record you as described above during participation in the above-referenced study.  The investigator will not use the recording(s) for any other reason than that/those stated in the consent form without your written permission.

Name ______________________________________

Signature ______________________________________ Date __

## Appendix B

## Recruitment Flyer

# Dancer's Postural Control and NMC while barefoot, with KT Tape, and neoprene ankle sleeve

Volunteers are needed for important research in dance medicine!

Are you a Rowan University Dance Major or Minor with 2 or more years of dance experience?
If so, then you can be a part of this study!

The main purpose of this study is to determine if kinesiology tape or compression ankles sleeves have an effect on the balance and postural control in dancers.

This study will only require 2 days of your time, no more than a half hour each day. The study will be held in James Hall in the Applied Biomechanics Lab.

If you are interested or have any questions please contact:

Sarah Unger: ungers0@students.rowan.edu (856)-371-5638

Robert Sterner: sterner@rowan.edu

This study has been approved by Rowan University's IRB (Study #Pro2019000492)

## Appendix C

## Recruitment Email

To Whom It May Concern:

Hello, my name is Sarah Unger and I am a graduate student in the athletic training program at Rowan University. I am working towards completing my Master's degree and I am studying the effects of kinesiology tape, compression sleeves, and bare feet on balance and postural control. I am in need of dance majors and minors between the ages of 18-23 with two years or more of dance experience to volunteer their time and take part in this study. Subjects will only be required to meet in James Hall Applied Biomechanics Lab for no more than a half hour on two separate days.

Any person who has been injured within the past 6 months, surgery on the lower body, recent concussion diagnosis, symptoms of a head cold, any neurological disorder that affects balance, any previous experience with kinesiology tape on the ankle, or any previous experience with a compressive ankle sleeve will not be eligible to participate in this study.

If you are interested in volunteering your time or have questions, please contact:

Sarah Unger (Co-Investigator): ungers0@students.rowan.edu (856)-371-5638

Or

Robert Sterner (Principal Investigator): sterner@rowan.edu

This study has been approved by Rowan University's Institutional Review Board (#Pro2019000492).

If you have questions about your rights as a subject, please contact the Office of Research Compliance at (856) 256-4078.

Thank you,

Sarah Unger

Rowan University

Master's Student in Athletic Training