COMPARISON OF KINESIO TAPING AND TRADITIONAL NON-ELASTIC PROPHYLACTIC ANKLE TAPING ON ANKLE RANGE OF MOTION AND MUSCULOTENDINOUS STIFFNESS IN DIVISION I TENNIS ATHLETES

By

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ANKLE TAPING ON ANKLE RANGE OF MOTION

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Abstract: **Context:** Kinesio tape (KT) is an elastic tape that can be utilized in any phase of injury as an intervention for increasing lymphatic drainage, facilitating or inhibiting muscle activity, providing ligament and tendon support and functional correction. While the KT brand claims to provide patients a variety of therapeutic benefits, there is limited research to support these claims. **Objective:** The purpose of this study was to compare the effect of KT for functional correction by assisting dorsiflexion (DF) and eversion (EV) and inhibiting plantar flexion (PF) and inversion (IV). **Design:** Randomized crossover study design. **Setting:** Clinical setting. **Patients/Participants:** 19 Division I Tennis Athletes, 10 males and 9 females. **Interventions:** Participants were randomly assigned to start with no tape (NT), KT or traditional, non-elastic tape (WT) and randomly assigned to start with PF/DF or IV/EV for a one-time test on the Biodex 3 isokinetic dynamometer. **Main Outcome Measure(s):** Each participant's range of motion (ROM) and musculotendinous were measured using a Biodex 3 isokinestic dynamometer. Musculotendinous stiffness was calculated as the slope of the angle-torque curve generated by the Biodex 3. **Results:** No significant difference was found between NT and KT for ROM and MTS in any direction of ankle motion. A significant decrease in ROM was found between NT and WT for PF and EV, as well as MTS of the dorsiflexion muscle group. Significant differences were found between WT and KT for PF ROM and the DF muscle group. **Conclusion:** Results of this study do not support the claims of KT for functional correction to assist dorsiflexion and eversion and inhibit plantar flexion and inversion. These results do not justify the use of KT as an alternative to traditional, non-elastic prophylactic tape for preventing ankle injuries. Key words: Kinesio tape, musculotendinous stiffness, range of motion, ankle tape, taping, ankle sprains.

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CHAPTER I

INTRODUCTION

Originally invented in 1973, Kinesio tape (KT) has grown in popularity dramatically after the 2008 Summer Olympics, where it was donated for use by the world's elite athletes.[1] Developed by Japanese chiropractor Dr. Kenzo Kase, KT is an elastic tape that can be worn for multiple days after application, approximates to the skin and has the ability to stretch between 40 and 60% of its resting length just as the skin is able to stretch to these proportions.[2,3] The tape reportedly can be used in any phase of injury and can be used as an intervention for increasing lymphatic drainage, facilitating or inhibiting muscle activity, providing ligament and tendon support and functional correction.[1,2,3,4]

Prophylactic taping is a very common intervention utilized by sports medicine professionals to prevent the occurrence of ankle injuries.[5,6,7] While many types of athletic tape exist, a traditional closed-basket weave ankle tape procedure is completed using a thin layer of foam underwrap to protect the skin followed by a non-elastic cloth tape. The purpose of taping is to prevent or reduce the severity or incidence of injury by providing supplemental dynamic support and restriction of inversion and plantar flexion ROM, the most common mechanism of ankle injuries.[5,7] Although application of tape provides some athletes with a sense of confidence and stability, others may report that wearing tape during athletic activity makes them feel like their ankle is stiff and the tape is restricting their performance.[8] It has also been shown that after an extended period of activity, non-elastic tape loses its rigidity and decreases in effectiveness against excess ROM.[7,9-11] Restriction of inversion ROM was shown to decrease by 54%,[10] and for plantar flexion ROM an 8% decrease was shown.[7] With its skin –like properties and design for extended wear, KT may provide a more comfortable alternative to traditional non-elastic ankle taping for athletes. The proposed effects of KT on muscle activity and proprioception[2,3,12,13] may enhance the prophylactic effects of taping.

The purpose of this study was to examine the effects on ankle range of motion (ROM) and musculotendinous stiffness (MTS) of KT application targeted to restrict the most common mechanism of injury for lateral ankle sprains compared to a traditional, non-elastic closed basket weave ankle taping. MTS is a common method for measuring the passive properties of the muscle-tendon unit. A less stiff muscle would allow greater lengthening following an applied load, compromising the joint's dynamic stability, allowing for increased translation at the joint and increased risk of injury to tendon or ligament.[14] Determining the effectiveness of KT on restricting motion and increasing stiffness at the ankle could provide sports medicine professionals with evidence to justify the use of KT in practice. As well, objective measures supporting the proposed effects of KT could give reason to use KT as an alternative method of prophylactic taping, satisfying athletes' needs for stabilization of the ankle without being perceived as restricting or impeding athletic performance. It was hypothesized that KT applied to assist dorsiflexion (DF) and eversion (EV) and restrict plantar flexion (PF) and inversion (IV) will decrease PF and IV ROM and increase stiffness of the muscle groups responsible for DF and EV, providing stabilization comparable to that of traditional, non-elastic closed-basket weave prophylactic taping.

CHAPTER II

METHODS

Study Design

This study utilized a randomized, within-subjects, cross-over design. Passive ankle ROM and applied torque measures for plantar flexion (PF), dorsiflexion (DF), inversion (IV) and eversion (EV) were obtained under three conditions: control (NT), following KT application and following non-elastic, closed-basket weave taping (WT). Data was collected using a Biodex 3 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA) set in passive mode with the ankle attachment.

Participants

Nineteen (10 male, 9 female, age = 20.4±1.33 years, height = 178.4±11.73 cm, mass = 73.2±11.64 kg) division I college tennis athletes volunteered for participation. No participants had past medical history (PMH) of foot or ankle injury within the past three months as determined via self-report survey prior to data collection. All participants signed informed consent form approved by Institutional Review Board before participating in study.

Passive Range of Motion and Musculotendinous Stiffness Assessment

Participants were asked to sit in the dynamometer chair with their leg elevated by a support arm placed under the distal femur. The dynamometer was adjusted so that their hip was in 90 degrees of flexion and the knee in 30 degrees of flexion. The ankle attachment consists of a thick rubber heel cup attached to a foot-plate to secure the calcaneus and a strap extending over the distal metatarsals with a small pad between the strap and skin for comfort. The foot-plate was adjusted so that the ankle was in a neutral position of 0 degrees of plantar flexion and dorsiflexion and 0 degrees of inversion and eversion. Once the participant was positioned in the dynamometer, the examiner set the ROM limits on the dynamometer by manually moving the participant's ankle until they verbally acknowledged they felt they had reached their maximum ROM where the maximum tolerable torque threshold was increased to a pain free, point of discomfort as previously described.[15] Once these limits were set, the subject was informed that the machine will initiate all movement and they should remain relaxed during the entire testing protocol. The dynamometer was set to move at a speed of 5 degrees per second with a torque limit of 100 ft-lbs so that applied torque would not limit ROM. One set consisted of three repetitions through the full ROM of either PF/DF or IV/EV. At the completion of one set, the protocol was paused and tape was either applied or removed. This procedure was repeated for each taping condition on a bare right foot. Once all three sets were completed, the dynamometer was shifted and the same procedure was repeated for the motions not tested in the first three sets. Taping conditions and ankle motions were randomized for each participant and were applied by a single clinician. ROM and applied torque measures for each set were obtained from a print out generated by the Biodex 3 that provided a table of values and a plot of the angle-torque curve. MTS was calculated by plotting two points on the angle-torque curve and calculating the slope between these two points.

Taping Techniques

Kinesio tape

Participants were taped to assist DF and EV to limit re-injury of the lateral ankle using the functional correction technique described by the Kinesio taping method.[2] The participant's leg was cleaned with isopropyl alcohol prior to application. One strip of 2-inch tape (Kinesio Tex

Classic, Kinesio Holding Corporation, Albuquerque, NM) was used with edges rounded, and application began by placing an anchor with no tension on the medial aspect of the arch superior to the base of the 1st metatarsal. The participant's ankle was then placed in DF and EV and the strip of tape brought over the plantar surface of the foot with no tension applied. The strip was then stretched to 50% of available tension and an anchor of 3-4 inches placed on the mid to proximal 1/3 lateral aspect of the tibia, ending just distal to the fibular head, with no tension. The examiner then applied pressure at both anchors, instructed the patient to move into IV and PF, and brought both hands together to initiate adhesive. The tape was then rubbed vigorously to initiate adhesive prior to further patient movement.[2]

Closed-Basket Weave

The participant was instructed to have their ankle remain at a 90-degree angle throughout the taping procedure. A layer of foam underwrap (Cramer Products, Gardner, KS) was applied in a single layer extending from just distal to the base of the 5th metatarsal of the foot up to the base of the calf musculature. One and a half inch, white adhesive tape (Zonas Athletic Tape, Johnson & Johnson Consumer Companies, Inc., Skillman, NJ) was used to complete tape procedure. One anchor placed around the ankle approximately 6 inches (15cm) above the malleolus just below the belly of the calf musculature. A second anchor was placed around the foot directly over the styloid process of the fifth metatarsal. A stirrup strip was applied posterior to the medial malleolus beginning attached to the anchor, under the calcaneus pulling the ankle into EV, and up to attach to the lateral anchor strip. A horseshoe strip was applied inferior to the malleolus attaching to the distal anchor on both sides. This procedure was repeated two more times in an alternating series overlapping half of the preceding strip. Next, two heels locks were applied beginning high on the instep, bringing the tape along the ankle at a slight angle, hooking the heel, leading under the arch, then coming up on the opposite side, and finishing at the starting point. The same was repeated on the opposite side of the ankle. Seven circular strips were applied leading up the ankle to the proximal anchor, and two strips laterally to medially at the level of the distal anchor to complete the tape procedure.[16]

Statistical Analysis

Data was analyzed with SPSS 22 software (Armonk, NY). A separate one-way (across conditions [NT, WT, and KT]) repeated measures analysis of variance (ANOVA) was performed for each dependent variable (ROM and MTS) in each direction of ankle motion (PF, DF, IV, EV). An alpha level of 0.05 was used to determine statistical significance for all comparisons. Bonferroni pairwise comparisons were used for post-hoc assessments.

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CHAPTER III

RESULTS

Passive Range of Motion

Taping condition had no significant effect [$F_{2,36}$= 1.899, p=0.166] on IV ROM. Taping condition had no significant effect [$F_{2,36}$= 2.116, p=0.135] on DF ROM. For PF, a significant effect [$F_{2,36}$= 22.089, p<0.001] was found for taping condition. In pairwise comparison, it was found that WT resulted in significantly less ROM than NT and KT. For EV, a significant effect [$F_{2,36}$= 5.027, p=0.012] was found for taping condition. In pairwise comparison, it was found that WT resulted in significantly less ROM than NT, but no significant difference was found between WT and KT. Means and standard deviations for ROM are listed in Table 1.

Table 1. Passive Range of Motion (degrees) Means and Standard Deviations

	Condition		
ROM	NT	WT	KT
PF	50.53 ± 4.82^{W}	$44.26 \pm 6.21^{N,K}$	49.58 ± 6.08^{W}
DF	35.11 ± 9.54	32.89 ± 9.35	34.21 ± 7.93
IV	46.95 ± 9.73	44.26 ± 12.04	44.89 ± 12.00
EV	43.11 ± 10.02^{W}	39.32 ± 11.20^{N}	40.89 ± 11.42

^{N} = significantly different than No Tape condition, ^{W} = significantly different than With Tape, ^{K} = significantly different than kinesio-tape

Musculotendinous Stiffness

Taping condition had no significant effect [$F_{2,36}$= 1.060, p=0.357] on MTS of the EV muscle group. Taping condition had no significant effect [$F_{2,36}$= 0.566, p=0.573] on MTS of the PF muscle group. Taping condition had no significant effect [$F_{2,36}$= 2.023, p=0.147] on MTS of the IV muscle group. For the DF muscle group, a significant effect [$F_{2,36}$= 10.291, p<0.001] was found for taping condition. In pairwise comparison, it was found that WT resulted in significantly less MTS than NT and KT, and KT resulted in significantly more MTS than WT. Means and standard deviations for MTS are listed in Table 2.

Table 2. Musculotendinous Stiffness (ft-lbs/degree) Means and Standard Deviations.

	Condition		
Muscle group	NT	WT	KT
DF	$.84 \pm .34^{W}$	$.65 \pm .33^{N,K}$	$.77 \pm .36^{W}$
PF	.94 ± .55	.98 ± .49	.95 ± .56
EV	.45 ± .31	.42 ± .28	.49 ± .44
IV	32 ± .12	.30 ± .14	.34 ± .17

^{N} = significantly different than No Tape condition, ^{W} = significantly different than With Tape, ^{K} = significantly different than kinesio-tape

CHAPTER IV

DISCUSSION

Prophylactic ankle taping is a procedure commonly practiced by sports medicine professionals on healthy patients and injury-prone patients alike. The purpose of taping is to prevent or reduce the severity or incidence of injury by providing additional dynamic support and restricting the ROM common to ankle injuries.[5,7] With the rising popularity of the use of KT by professional, collegiate and recreational athletes, many sports medicine professionals are including it in their daily practice. The combination of the elastic properties of KT as well as its claimed ability to enhance functional stability through muscular and proprioceptive activation[2,3,17] may provide sports medicine professionals with an alternative taping method that meets both the mechanical and proprioceptive purposes of ankle taping as well as the subjective perception of comfort by the patient. KT might also provide a more economical alternative for practitioners with its ability to be worn for multiple days and use of very few strips of tape per taping protocol. While the KT brand claims to provide patients a variety of therapeutic benefits,[2,3] there is limited research to support these benefits. The protocol as prescribed by Kase et al[2] for lateral ankle sprains utilized in this study is intended for functional correction by assisting DF and EV, while inhibiting PF and IV.

The results of this study do not suggest that functional correction KT causes significant changes to ROM or MTS, failing to support its use for prophylactic purposes. Changes in ROM after KT application have been reported for facilitative application. KT was shown to result in an immediate increase in DF ROM when applied directly to the calf, as well as hip flexion ROM when applied to the hamstrings.[1] KT application also resulted in significant increases in shoulder external rotation ROM when applied to the pectoralis major muscle.[18] When examining ROM in this study, the only conditions that resulted in significant change were for PF and EV with WT, suggesting that WT may be a viable source of prophylactic support. Ho et al[6] also found significant restrictions in EV following the application of non-elastic tape, but no effect on PF. Non-elastic tape has also been shown to cause decreases in ROM during ambulation.[5,19] When compared to non-KT elastic tape applied in a closed-basket weave orientation, non-elastic tape showed comparable restrictions in ROM upon initial application, but greater loss of restriction after 30 minutes of intense exercise, especially in IV.[7] As well, subjects perceived elastic tape to be more comfortable and less restrictive.[7] Previous studies have also reported loss of restriction after exercise, compromising the integrity and prophylactic benefits of WT.[9-11] Our study was conducted utilizing passive ankle motion rather than active, functional ankle motion, which may have influenced our results compared to the results of previous studies.

When examined under dynamic functionality, KT application has been shown to have no inhibition on ankle function during dynamic balance and functional performance testing,[13,20] but also has resulted in decreases in athletic function.[6] When examining subjects with known chronic ankle sprains, Bicici et al[20] found that KT had no negative effects on performance and was associated with increased performance during a single-leg hurdle test. Ho et al[6] also utilized subjects with known ankle instability and reported decreased function in vertical jump testing after application of KT. When comparing the KT procedures utilized in these two studies, Ho et al[6] applied KT in an orientation not consistent with Kase's method, nor was Kase cited. Bicici et al[20] not only cited Kase's manual, but utilized less tape as well as less tension on the tape during application compared to Ho et al[6]. These factors may have influenced the discrepancy between functionality in vertical jump test. Fayson et al[13] who utilized subjects with no known history of ankle injury, also applied KT in an orientation and tension as cited in Kase's manual and produced significant increases in stiffness against anterior translation of the ankle joint after 24 hours of wear, however no significant outcomes were found from dynamic tests. Though Bicici et al[20] and Fayson et al[13] produced significant results to support the use of KT by following Kase's method, this study as well as Miralles et al[17] cited Kase's method and did not yield significant results. KT was shown to have no significant effects on joint position sense at the ankle following both initial application as well as 48 hours post-application, and data showed joint position sense actually worsened after application of KT.[17] However, non-elastic tape has also failed to produce significant evidence of enhanced proprioception at the ankle.[12]

MTS describes the viscoelastic properties of the muscle-tendon unit (MTU) and is defined as the ratio of change in force in a muscle to its change in length.[14,21] More specifically, MTS is the relationship between passive resistive torque and joint displacement.[22] When examining MTS, our results yielded significant changes only in the DF muscle group. For WT, MTS was significantly decreased compared to NT, indicating greater lengthening of the muscle and decreased resistance to PF. For KT, MTS of the DF muscle group increased compared to WT, however with no significant differences existing between KT and NT, there is limited support of our hypothesis or the claimed purpose of the KT to assist DF.[2] Currently, no research exists examining the effects of KT on MTS of the ankle, but it was shown that 24 hours after application KT resulted in significant increases in stiffness against anterior translation of the ankle joint.[13]

The effects of stretching on MTS have been investigated, although the various modes and durations of stretching implemented leaves no clear definition as to what stretching intervention results in the most change. With evidence to support the relationship between passive stretching and changes in MTS,[15,23-25] the number of stretches produced at the ankle over the duration of data collection might have altered the results of this study. Hoge et al[26] reported increases in ankle ROM following passive stretching but no changes in MTS, suggesting ROM might not be linked to MTS. Rees et al[27] also reported results to suggest the lack of relationship between ROM and MTS after finding that proprioceptive neuromuscular facilitation (PNF) stretching increased both ROM and MTS in the ankles of active women.

Limitations and Future Research

As with any research study, limitations did exist. A small sample size may have limited the significance of the results. Gender differences might be a factor influencing magnitude of MTS. Gender differences were not examined in the study, but they have been directly compared at the ankle joint in previous studies.[14,15,23,25] Another limitation to the study is the accuracy of IV and EV ROM measurements on the Biodex 3. Although the Biodex 3 has been found reliable to measure isokinetic inversion- and eversion –strength[28], the motion created by the Biodex 3 does not accurately mimic the motion of the ankle while weight bearing. Additionally, it was difficult to eliminate accessory rotation of the hip and knee joints, which might have contributed to greater ROM during the testing procedure. Since the muscle groups surrounding the hip and knee joints act in conjunction with the ankle joint when weight bearing for dynamic support of the entire kinetic chain, limited conclusions can be drawn from our study about the functional effectiveness of KT during active ROM since only passive ROM was examined. With only single planar motion being assessed, it is difficult to determine how taping may effect the occurrence of ankle injury since ankle injuries typically occur as the result of a multi-planar mechanism of injury. Accuracy of the MTS measurements may have also been a limiting factor to this study as they were collected from the Biodex 3 angle-torque curve print out rather than utilizing continuous signaling of MTS throughout the full ROM. Data was collected using the Biodex 3 machine located in the university athletics facility for convenience purposes, and signaling capabilities were not available for use with this machine. The effects of KT might also have been limited in this study because measures were only taken immediately after application of KT and not after extended wear. One of the proposed benefits of KT is its ability to remain adhered to the skin for multiple days[2,3], and it has been previously reported that significant changes occurred after extended wear of KT.[1,13,18] As well, all subjects had no PMH of right ankle injury. Because KT for functional correction is intended to be used as a therapeutic intervention, perhaps more significant changes would have been observed if subjects with PMH of ankle injuries were examined.

Future research is needed to draw more definitive conclusions on the effectiveness of KT on the musculoskeletal system. For functional correction at the ankle, comparisons need to be made between NT, WT and KT for active ROM as well as dynamic, functional movement of the ankle. Effects of extended wear of KT on the ankle should also be examined to determine if significant changes in ROM or MTS would occur after extended wear of KT to provide greater prophylactic support. Effects of extended wear should also be tested and compared to those of WT to assess the amount of restriction lost following activity. Future research might also focus on a test population of subjects with PMH of ankle injuries rather than a healthy population.

CHAPTER V

CONCLUSION

While KT provides sports medicine professionals with an additional taping option to provide to their patients, limited evidence exists to support it's claimed affects. This study failed to produce significant differences between conditions of no tape and Kinesio tape on ankle ROM and MTS, providing no evidence to support the use of KT for functional correction at the ankle. Without significant effect on ROM or MTS, KT cannot be deemed as a comparable alternative to traditional non-elastic prophylactic taping. Future research is needed to further investigate the influences of KT on the musculoskeletal system and it's ability to assist and inhibit muscle action.

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APPENDICES

A. Review of Literature

Kinesio Tape

The Kinesio Taping Method was first conceptualized in 1973 by Japanese chiropractor, Dr. Kenzo Kase. His purpose behind creating the taping method was to provide his patients with some type of pain relief in between clinic visits without prescribing medication. Kase believed that by lifting the skin, movement of the interstitial fluids would be increased with the goal of decreasing the residual fluid pressure resulting from edema. It was theorized that by decreasing the interstitial fluid pressure is improved muscle function associated with pain and edema. This theory is how Kinesio Tape (KT) was named, since the definition of kinesiology is muscle function or the function of movement.[2,3] KT was thought to mimic what the practitioner could do with their hands so that after application it as if the patient is being assisted through movement without the practitioner physically being there. For this reason, KT is intended to be worn by the patient for 3-5 days between clinic visits.[2,3]

KT was designed to mimic the characteristics of the superficial layer of skin. The tape itself is 100% cotton, with an adhesive that is 100% heat activated acrylic. These qualities make KT suitable for patients with sensitive skin and is safe for use on patients with latex allergies. The adhesive is printed on the tape in a pattern that resembles fingerprints, which exaggerates the concept that the tape is mimicking the human touch. KT has the ability to stretch between 40 and 60% of its resting length just as the skin is able to stretch to similar proportions. KT was designed to stretch longitudinally, and the degree of stretch approximates the elastic qualities of human skin. The thickness of KT was also strategically designed to mimic the epidermis so there is no stimuli of excessive weight on the skin and no restriction of movement that might be caused by other types of prophylactic taping techniques.[2]

Clinical Applications

Kase et al[2] claim that KT can be used in any phase of injury whether it be acute, sub-acute or chronic, and can be used in combination with other types of manual therapies and therapeutic treatment techniques. Since its original conceptualization in 1973, the Kinesio Taping Method has evolved to include a multifaceted approach to therapeutic treatment, spanning outside of just the interstitial lymphatic circulation theory. In fact, Kase et al have developed 6 Corrective Application Techniques, including mechanical, fascia, space, ligament/tendon, functional and lymphatic. Specific application procedures and treatment goals are associated with each application technique.[2]

Mechanical correction techniques claim the ability to provide positional stimuli through the skin as determined by the amount of stretch applied to tape. The goal of a mechanical correction technique is to put the tissue in the desired position and provide stimulus so the body will adjust position to minimize the tension created by the tape, or provide a "blocking" action of joint or tissue movement. [2]

Fascia correction utilizes the recoil effect of KT to break down the limitations of fascia movement through a combination of movement of the skin and the elastic properties of KT. When applying KT for fascial correction, gentle oscillations are applied to KT as a sort of micro-massage to break down fascial fibers so that they will realign in a more organized position.[2]

Space correction techniques are essentially the original concept of KT. By utilizing the recoil effect of KT, the interstitial space is increased so that pain, inflammation, swelling and edema in the space directly below the application of KT can be reduced. Kase et al[2] also state that these techniques influence stimulation of chemoreceptors, mechanoreceptors and nocioceptors, which also contribute to pain relief. [2]

Ligament and tendon correction techniques aim to increase stimuli over the effected tissue. Increased stimulation of the mechanoreceptors in ligaments creates a proprioceptive stimulus, allowing the brain to perceive normal tissue tensions. Tendon correction is aimed to increase stimulation of the golgi tendon organs to stimulate the central nervous system to perceive normal tissue tensions. [2]

Functional correction techniques are utilized as a sensory stimulus to either assist or limit a motion. The KT is applied such that the tension is removed during active movement. It is believed the tension created by increased stimuli during active movement will stimulate the mechanoreceptors, thereby influencing motion. [2]

Circulatory and lymphatic correction techniques are applied so that a directional pull of KT redirects exudate to areas of lower congestion. These techniques are similar to space correction techniques, but differ in that their application is aimed to guide lymphatic drainage away from the affected area in a specific direction, such as pulling swelling of an ankle sprain from distal to proximal.[2]

For the purpose of this review, effects of functional correction techniques will be discussed. As outlined by Kase et al[2], KT can either facilitate or inhibit a muscle based on the direction of application of the tape. To facilitate a muscle, the KT must be applied from proximal to distal, following along the muscle from origin to insertion. Once applied, the recoil effect of KT creates a line of pull toward the origin of the muscle, mimicking the direction the muscle fibers move during active contraction. This technique is utilized when attempting to treat weak or atrophied muscles. To inhibit a muscle, the KT is applied from distal to proximal, or insertion to origin. Again, the recoil effect creates a line of pull, this time in the direction of the muscular insertion, acting to lengthen the muscle and thus inhibit it. This technique is used when treating a muscle with acute or chronic stiffness or contracture.[2]

Although the application, theory and proposed effects for each KT technique exist, objective measures are necessary to prove whether there is actually a physiological effect caused by application of KT, or if KT provides more of a psychological, placebo effect.

Upper Extremity Application

Studies utilizing the upper extremity include application of KT to wrist flexor muscles of the forearm, pectoralis major, scapular rotators of the shoulder (upper/middle/lower trapezius and serratus anterior muscles), and biceps brachii.[18,29-32] Variables measured in these studies included maximal grip strength and force sense, passive ROM, electromyographic (EMG) muscle activity and isokinetic peak torque. [18,29-32]

Chang et al[29] found that an inhibitory KT technique may enhance absolute or related force sense in grip strength but maximal grip strength was unchanged by application of KT to wrist flexor muscles of the forearm in healthy collegiate athletes (n=21). Gusella et al[18] compared facilitative and inhibitory KT techniques on the pectoralis major muscle ROM in 24 healthy individuals and found that the facilitative technique, significantly enhanced muscle tone. Although this was a randomized, blinded study, findings of this study related to muscular activity are limited since no measures of electric activity were assessed.[18] EMG activity of the scapular rotator muscles of the shoulder was measured in separate studies by Cools et al[30] and Hsu et al[31]. Cools et al[30] found no significant differences in EMG activity between the control and intervention groups of twenty healthy individuals tested. Hsu et al[31] reported a significant increase in lower trapezius muscle activity as well as an increase in scapular posterior tilt in baseball players with shoulder impingement syndrome. Since Hsu et al[31] recruited subjects who had a musculoskeletal pathology, this may explain the result achieved by the intervention when comparing to a separate study that utilized healthy individuals with no underlying pathology or mechanical correction to be made.[30,31] Fratocchi et al[32] investigated the effect of KT applied over the biceps brachii of healthy subjects on isokinetic elbow peak torque. A significant effect on concentric elbow peak torque with the application of KT was found when compared to no tape application. Although there was an increase of eccentric peak torque with the application of KT compared to the application of a placebo tape, these differences were not statistically significant.[32]

Lower Extremity Application

In studies conducted utilizing the lower extremity, four of the five studies[4,33-35] reviewed examined the application of KT to the thigh musculature (quadriceps femoris and/or hamstring groups), while one study[1] examined posterior lower extremity musculature (hamstring and gastrocnemius).

Utilizing young elite soccer players, de Hoyo et al[33] examined the immediate effects of KT on strength, jump ability, speed and muscle contractile properties. KT was applied to the rectus femoris muscle in a facilitative orientation as described in Kase's KT manual.[2] Increases were observed for power output tests, countermovement-jump test and speed tests, however none of these increases were of statistical significance.[33] Fu et al[34] examined immediate effects of KT as well as delayed effects on muscle strength of the quadriceps and hamstring muscles when KT was applied to the anterior thigh of healthy individuals. KT was applied to facilitate rectus femoris. Using an isokinetic dynamometer, measures of peak torque and total work at various velocities were examined without KT, immediately after application of KT, and 12 hours following KT application. No significant differences were found between conditions tested.[34] Wong et al[4] conducted a similar study utilizing an isokinetic dynamometer, however KT was applied directly over the vastus medialis muscle rather than rectus femoris. Maximal concentric knee extension and flexion at three velocities were measured as well as peak torque, total work done and time to peak torque of knee extension and flexion. Results of this study revealed no differences between peak torque generation and total work performed after the application of KT, but there was a significant difference in time to peak extension torque.[4] In a randomized control trial (n=60), Lins et al[35] examined immediate effects of KT on EMG activity of the quadriceps femoris group, postural balance and lower limb function. KT was applied over rectus femoris, vastus medialis and vastus lateralis muscles per suggested taping technique.[2] No significant differences were noted for EMG activity. To measure lower limb function and balance, single and triple-hop tests as well as a one-foot static balance test were utilized and revealed no significant differences between conditions.[35] Lumbroso et al[1] examined the effect of KT on both the hamstring and gastrocnemius muscles. KT was applied to the hamstring in a facilitative orientation and to the gastrocnemius in an inhibitory orientation. Measures of passive range of motion for hip flexion, knee extension and ankle dorsiflexion were assessed, as well as peak force for the quadriceps, hamstring and gastrocnemius muscle groups. Measures were taken at baseline without tape, 15 minutes following the application of KT, and a final measure taken 48 hours after application of KT. Immediately, there was an increase in peak force in the gastrocnemius group, as well as an increase in hip flexion and ankle dorsiflexion range of motion. After two days, there were significant increases in hamstring peak force, gastrocnemius peak force, as well as knee extension range of motion.[1]

Ankle Anatomy

The ankle, or talocrural joint, is classified as a stable hinge joint with bony articulations between the dome of the talus and the distal ends of the tibia and fibula. This bony arrangement is known as the ankle mortise, with the medial and lateral malleoli of the tibia and fibula preventing displacement of the talus in the coronal plane.[16] Movements that occur at the talocrural joint are plantar flexion and dorsiflexion. The shape of the talus bone provides additional anatomical stabilization of the joint, with the anterior portion being wider. As a result, the most stable position of the ankle is in dorsiflexion where the wider anterior talus comes in contact with the malleoli causing a gripping effect. Inferior to the talocrural joint is the subtalar joint where the talus articulates with the calcaneus. Movements occurring at this joint include inversion, eversion, pronation and supination.[16]

Stabilization of the joint is provided by both the musculature surrounding the joint as well as the ligaments[16,36] Muscular stabilization is provided anteriorly by tibialis anterior, extensor hallicus longus and extensor digitorum longus muscles, which function to dorsiflex the ankle and extend the toes. Laterally, peroneus longus and brevis serve to evert the ankle and peroneus tertius assists in ankle dorsiflexion. Posteriorly, the gastrocnemius and soleus muscles lie superficially and plantarflex the ankle, while the tibialis posterior, flexor digitorum longus and flexor hallicus longus muscles lie deep and invert the ankle.[16]

Key ligaments of the ankle are the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), posterior talofibular ligament (PTF), which stabilize the lateral aspect of the ankle. Specifically, ATF restrains anterior displacement of the talus, CF prevents inversion of the calcaneus and PTF prevents posterior displacement of the talus. Medially, the deltoid ligament stabilizes the ankle. The deltoid ligament is actually a triangular shaped ligament complex composed of superficial and deep fibers attaching the talus to the tibia superiorly, and inferiorly to the calcaneus and the navicular bone of the foot. The primary function of the deltoid ligament as a whole is prevention of eversion, however the individual portions of the deltoid ligament assist in preventing abduction, pronation and anterior displacement of the ankle.[16]

Pathology

Lateral ankle injuries (LAI) are the most common injury to the ankle,[13,16,20,36] accounting for approximately 85% of ankle injuries.[13,20] Sports reported to have the most LAI are soccer, volleyball and basketball due to high demand on athletes to move laterally, pivot and jump.[37] Structures most frequently affected are the ATFL, CFL and PTFL, with the ATFL being the weakest and most commonly injured ligament of the three, and PTFL least commonly injured.[16,36] Most LAI occur from a mechanism placing the ankle in inversion and plantar flexion, where the talus is placed in its most unstable orientation relative to the malleoli.[13,16,36] This position puts the most stress on the ATFL, but more severe injuries affect CFL due to its shared origin with the ATFL.[16,36] Once injured, overall structural stabilization of the joint is compromised and if not properly managed, can result in chronic lateral ankle instability.[12,16,36,37] Aside from injury to the ligaments, pathology of the peroneal tendons can also occur with more severe LAI.[12,27,36] It is thought that injury to the ankle results in impaired proprioception at the ankle, impairing the ability of the mechanoreceptors to respond to stimuli associated with joint position, as well as loading and movement.[12,17,36] For this reason, treatment for ankle injuries should not only focus on reduction of pain and swelling, but functional rehabilitation to strengthen the surrounding muscular stabilizers and increase proprioception.[12,17,36] Prophylactic support in the form of taping or bracing can be used as an additional preventative measure to reduce the risk of re-injury during rehabilitation as well as once the patient returns to activity.[12,16,36]

Prophylactic Ankle Taping

Prophylactic taping is a procedure commonly practiced by sports medicine professionals on healthy patients and injury-prone patients alike. The purpose of taping is to prevent or reduce the severity or incidence of injury by providing additional dynamic support and restricting the ranges of motion common to ankle injuries.[5,7,16] Proper ankle taping for LAI decreases inversion and plantar flexion, and has been shown to reduce peak dorsiflexion and average eversion moments in side stepping.[6] In addition to the mechanical support provided by taping, stimulation of the cutaneous mechanoreceptors by direct contact of the tape to skin is said to increase proprioceptive function.[12,13] There exists some psychological reassurance to the patient as well, providing them with a feeling of confidence and perceived stability.[7,8,38] Traditionally, a closed-basket weave tape job is applied using non-elastic porous tape extending from the mid foot to the base of the calf musculature. When completed, this tape job consists of approximately 15-20 individual strips of tape strategically placed to intertwine and stabilize the ankle by limiting range of motion in plantar flexion and inversion.[5,12,16] While this procedure remains the most commonly used taping procedure in the sports medicine world, subjective feedback from patients includes complaints of the tape being uncomfortable and restrictive, thus impeding athletic performance.[7,8] There is limited evidence to prove the effectiveness of ankle taping as mechanical support and raises the question of if the support provided by the tape is more detrimental than beneficial to dynamic function. In a review conducted by Simon and Donahue,[38] three studies examining effects of ankle taping on dynamic balance testing showed no significant difference in performance during balance tests, although subjects did report an increased psychological perception of confidence and stability. Non-elastic tape has also been shown to cause decreases in ROM during ambulation.[5] When compared to elastic tape applied in a closed-basket weave orientation, non-elastic tape showed increased loss of restriction after 30 minutes of intense exercise, especially in inversion. Additionally, subjects perceived elastic tape to be more comfortable and less restrictive.[7]

With the combination of the elastic properties of KT as well as its reported ability to enhance functional stability through muscular and proprioceptive activation,[2,17] KT may provide sports medicine professionals with an alternative taping method that meets both the mechanical and proprioceptive purposes of ankle taping as well as the subjective perception of comfort by the patient. KT might also provide a more economical alternative for practitioners with its ability for extended wear for multiple days and use of very few strips of tape per taping protocol.

KT was shown to have no significant effects on joint position sense at the ankle following both initial application as well as 48 hours post-application, and data showed joint position sense actually worsened after application of KT.[17] However, non-elastic tape has also failed to produce significant evidence of enhanced proprioception at the ankle.[12] When examined under dynamic functionality, KT application has been shown to have no inhibition on ankle function[13,20] but also has resulted in decreases in athletic function in jumping.[6] When examining subjects with known chronic ankle sprains, Bicici et al[20] examined effects on functional performance of KT, placebo taping, no tape and traditional non-elastic tape utilizing 6 functional performance tests. KT had no negative effects on performance in any of the six tests and was associated with increased performance during a single-leg hurdle test. Non-elastic tape was also associated with increased performance for the single-leg hurdle test, but resulted in decreased performance in a standing heel rise test and a vertical jump test.[20] Ho et al[6] also utilized subjects with known ankle instability and reported decreased function in vertical jump testing after application of KT. When comparing the KT procedures utilized in these two studies, Ho et al[6] applied KT in an orientation that was not consistent with Kase's method nor was Kase cited. Compared to Ho et al[6], Bicici et al[20] utilized the prescribed method[2] and utilized less tape and less tension on the tape during application. These factors may have influenced the discrepancy between functionality in vertical jump test. Fayson et al[13] who utilized subjects with no known history of ankle injury, also reported applying KT in an orientation and tension prescribed in Kase's manual.[2] Results of this study produced significant increases in stiffness against anterior translation of the ankle joint after 24 hours of wear, however no significant outcomes were found from dynamic tests. Though Bicici et al[20] and Fayson et al[13] produced significant results to support the use of KT by following the prescribed application method[2], Miralles et al[17] also cited Kase's manual[2], but did not yield significant results for improvements in joint position sense.

Musculotendinous Stiffness

Musculotendinous stiffness (MTS) describes the viscoelastic properties of the muscle-tendon unit (MTU) and is defined as the ratio of change in force in a muscle to its change in length.[14,21] More specifically, MTS is the relationship between passive resistive torque and joint displacement.[22] MTS is a common method for measuring the passive properties of the MTU, and is calculated using passive angle-torque or angle-force curves during a passive stretch. The slope of the tangent to the passive angle-torque curve at a specific joint angle represents MTS at that joint angle, and this method of measurement can be utilized to measure stiffness throughout an entire ROM.[22,26] With a higher magnitude of MTS, a given force will induce less lengthening of the muscle compared to a less stiff MTU.[14] While it is believed that reducing MTS and increasing ROM may reduce the risk of muscular injury[22] decreases in MTS may alter the viscoelastic and neuromuscular properties of the MTU.[14,26] A less stiff muscle would allow greater lengthening following an applied load, compromising the joint's dynamic stability, allowing for increased translation at the joint and increased risk of injury to tendon or ligament.[14] With athletes' heavy reliance on the lower extremity in sport activity, it is important for clinicians to understand the role that MTS plays in relation to athletic performance and how alterations in MTS can influence risk of injury.

MTS of the ankle joint provided by the plantar flexor and dorsiflexor muscle groups is just one structural contributor to overall ankle stability. Changes in MTS could therefore influence susceptibility to injury at the ankle joint. The effects of stretching on MTS have been investigated, although the various modes and durations of stretching implemented leaves no clear definition as to what stretching intervention results in the most change. Passive stretching was reported to cause decreases in MTS at the ankle joint[15,23,24] however stretching protocols varied greatly among studies. Ryan et al[15] found that the minimum number of passive stretches necessary to induce change in MTS was two 30-second constant torque passive stretches, while McNair et al[24] found that one 60-second continuous passive hold resulted in significant decreases in MTS. Morse et al[25] also yielded significant changes in ROM and MTS with a series of 60-second continuous passive holds. These protocols may be more practically relevant to clinicians compared to the passive stretch protocol used by Herda et al[23], where a passive stretch was held for 135-seconds, released for 5-seconds, and then repeated for a duration lasting approximately 20 minutes. Hoge et al[26] reported increases in ankle ROM following passive stretching but no changes in MTS, suggesting ROM might not be linked to MTS. Rees et al[27] also reported results to suggest the lack of relationship between ROM and MTS after finding that proprioceptive neuromuscular facilitation (PNF) stretching increased both ROM and MTS in the ankles of active women. The observed increase in MTS directly correlates to an increase in the viscoelastic properties of the muscle, and Rees et al[27] suggest PNF stretching might be most beneficial to enhance mechanical efficiency and overall athletic performance while maintaining dynamic stability of the joint. Dynamic stretching yielded increases in ROM but decreases in MTS of the hamstring muscles in men.[22]

Gender differences might also be a factor influencing magnitude of MTS and have been directly compared at the ankle joint. Blackburn et al[14] found that MTS was greater in males than in females and suggested these differences might be the result of differences in muscle architecture between males and females. Hoge et al[26] found no changes in MTS between sexes following passive stretching, but noted increased ROM in females only. Females tested in this study were noted to have all been tested during menses. Effects of female hormones on MTS have been investigated at the knee flexors and decreases in MTS relative to hormones were only noted during the ovulatory phase (week 3) of the menstrual cycle. Ryan et al[15] and McNair et al[24] conducted testing on both males and females but reported no differences.

B. IRB Approval

Oklahoma State University Institutional Review Board

Date:	Friday, March 04, 2016
IRB Application No	ED1611
Proposal Title:	Comparison of kinesio taping and traditional non-elastic prophylactic ankle taping on ankle range of motion and musculotendinous stiffness in division 1 tennis athletes
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved **Protocol Expires: 3/3/2017**

Principal Investigator(s):

Angie Pectol
Stillwater, OK 74078

Jason DeFreitas
198 CRC
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

PARTICIPANT INFORMATION
OKLAHOMA STATE UNIVERSITY

Title: *Comparison of Kinesio Taping and Traditional Non-elastic Prophylactic Ankle Taping on Ankle Range of Motion and Musculotendinous Stiffness in Division I Tennis Athletes*

Investigator: Angie Pectol, ATC, LAT, CSCS
Graduate Assistant Athletic Trainer
Oklahoma State University

Purpose: The purpose of the research study is to compare the effects of Kinesiology taping versus traditional prophylactic ankle taping on musculotendinous stiffness and ankle range of motion. Results from this study can be used to justify the use of alternative taping techniques for prevention of injuries.

What to Expect: This research study is administered in face-to-face meeting. Participation in this research will involve completion of one questionnaire, administered through Qualtrics questionnarie service online. After consent form is signed and returned to PI, an email will be sent to you with access information to Qualtrics. Questionnaire will ask demographic questions (age, sport participation, years of participation, etc.) as well as questions regarding history of lower extremity injury. Information given in this questionnaire will not be attached to your name, and shall remain anonymous. You will be assigned a number attached to your online questionnaire that will need to be remembered for physical data collection. You may skip any questions that you do not wish to answer. You will be expected to complete the questionnaire once. It should take you about 5-10 minutes to complete.
After completion of survey, you will schedule an appointment with PI to report to the athletic training room in Gallagher-Iba Arena for physical data collection. A brief familiarization period will take place before data collection to ensure you are comfortable with the use of the Biodex 3 dynamometer. Once familiar, control (no tape) condition will be tested first to establish baseline measures of range of motion and musculotendinous stiffness. Test conditions (Kinesio tape, traditional tape) will be tested at random on the right ankle. Testing procedure consists of application of taping technique, followed by range of motion testing utilizing Biodex 3 dynamometer. You will be positioned in dynamometer as described in Biodex 3 application/operations manual with the foot placed in a plate with a rubber heel cup and straps securing the foot in place. The dynamometer will move the foot through range of motion until a maximum stretch has been reached. You will notify the PI when this stretch has been reached and the PI will return the foot to the starting position. After all testing conditions have been applied and measured, this will conclude testing and participant will be released with no further follow up appointment.

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered in daily life.

Benefits: There are no direct benefits to you. However, you may gain an appreciation and understanding of how research is conducted.

Compensation: You will receive no compensation for participating in this study.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time.

Confidentiality: All data collected will be kept on password locked computer and destroyed after 3 months of data collection. Only PI will have access to information from data collection. All consent forms will be kept in locked file cabinet, where PI only has access to. Participants will be given a number in their survey that they complete that will connect them to their data collection so therefore no personal information will be able to trace back to them.

Contacts: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Angie Pectol, ATC, LAT, CSCS
170G Athletics Center, Gallagher-Iba Arena
Stillwater, OK 74075.

Email: angie.pectol@okstate.edu
Phone: 321-615-6762

Jason M. DeFreitas, PhD, CSCS*D
Assistant Professor, Exercise Physiology
Oklahoma State University
188 Colvin Center
Stillwater, OK 74078
(405) 744-9935
jason.defreitas@okstate.edu

If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

If you choose to participate: Returning your completed survey in the envelope provided indicates your willingness to participate in this research study.

Signature of Participant ______________________ Date ______________________

Printed Name ______________________

Okla. State Univ.
IRB
Approved 3-4-16
Expires 3-3-17
IRB # ED-16-11

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jason.defreitas@okstate.edu

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I, ________________________, give Angela Pectol permission to utilize the Oklahoma State

__________________________ team as subjects for this study.

______________________________ ______________________________

Signature of Coach Date

Okla. State Univ.
IRB
Approved 3-4-16
Expires 3-3-17
IRB # ED-16-11

VITA

Angela Marie Pectol

Candidate for the Degree of

Master of Science

Thesis: COMPARISON OF KINESIO TAPING AND TRADITIONAL NON-ELASTIC PROPHYLACTIC ANKLE TAPING ON ANKLE RANGE OF MOTION AND MUSCULOTENDINOUS STIFFNESS IN DIVISION I TENNIS ATHLETES

Major Field: Health and Human Performance – Applied Exercise Science

Biographical:

Education:

Master of Science in Health and Human Performance May 2016
Oklahoma State University – Stillwater, Oklahoma

Bachelor of Science in Athletic Training May 2014
University of Central Florida – Orlando, Florida

Experience:

Graduate Assistant Athletic Trainer Aug 2014 – May 2016
Oklahoma State University Athletics – Stillwater, Oklahoma

Professional Memberships:

State of Oklahoma, Board of Medical Licensure and Supervision
Licensed Athletic Trainer No. 837
National Strength and Conditioning Association
Certified Strength & Conditioning Specialist No. 7247901334
Board of Certification for the Athletic Trainer
Certification No. 2000016518
National Athletic Trainers' Association
Member No. 62478