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Original Article

Effect of non-elastic closed-basket weave ankle taping on muscle activity of tibialis anterior, peroneus longus, medial, and lateral gastrocnemius during jump landing on a hard, flat surface in healthy individuals: a pilot study

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Abstract

Background: Inversion ankle sprains are among the most common traumatic injuries for both men and women caused by jumping and landing activities. The ankle is protected by the static and dynamic stabilizers to reduce the incidences of injuries. Furthermore, using a non-elastic closed-basket weave taping technique is one of the common interventions to prevent it. Knowledge about the muscle activity reaction of the dynamic stabilizers upon application of tape is limited with varying results. **Objectives:** To determine the effect of non-elastic closed-basket weave ankle taping on the muscle activity of tibialis anterior, peroneus longus, medial, and lateral gastrocnemius on healthy individuals during jump landing on a hard, flat surface. **Methods:** This study is a quasi-experimental study using a pre- and post-test design. Peak amplitude muscle activity was assessed and analyzed using surface electromyography (sEMG) after landing from a jump. The pre-test was done by jump landing without tape, after which post-test data was immediately collected after applying the non-elastic closed-basket weave taping. Jump landing was done for three trials for both pre- and post-tests. A paired t-test was used to determine significant differences in pre-post taping**.** **Results:** Fifteen healthy participants were included in the study (9 females, 6 males) with a mean age of 21 $\pm$ 1.03 years old and BMI of 22.74 $\pm$ 1.63 kg/m^2. No significant difference was observed on peak amplitude muscle activity of the tibialis anterior (p= 0.06), medial gastrocnemius (p= 0.32), and lateral gastrocnemius (p= 0.66) after application of tape. However, a significant difference was observed in the peroneus longus after the application of tape (p= 0.05) during jump landing. **Conclusion:** Non-elastic closed-basket weave taping decreased the peak amplitude muscle activity of the peroneus longus during jump landing. This research suggests that tape may influence the peroneus longus, and it may or may not be detrimental in reducing the risk of ankle sprains.

Keywords: *non-elastic taping, electromyography, jump landing, ankle taping*

INTRODUCTION

Inversion ankle sprains are one of the most common traumatic injuries in the lower extremity for both men and women. This injury affects adults and children, athletes and non-athletes, and occurs during activities such as walking, stair negotiations, and sports-related activities like twisting, jumping, or landing.[1] Studies revealed that the highest risk population for sustaining an ankle sprain are females and children,[2] and between the ages 14-37 years old,[3] with the highest risk activity occurring during indoor and outdoor sports such as basketball, volleyball, tennis, and wrestling.[2] Despite it being a common injury, there is little knowledge regarding the prevalence of ankle sprains in the general population. The few studies investigating the epidemiology of ankle sprains[4] and the exact mechanism of injury common to the general population have not been scrutinized thoroughly.[5]

The most common mechanism of injury in inversion ankle sprains is due to excessive inversion and plantarflexion, which are seen in running, jumping, or sudden changes in directions since these motions stress the lateral ligaments further, causing tears.[1] Previous case studies have shown that jumping and drop landing are often the mechanisms involved in the acquisition of ankle sprains during cutting maneuvers and jump landing tasks in field hockey, high jumps, tennis, and basketball games.[6] When an individual starts to jump, the ankle moves from a dorsiflexed to a plantarflexed position, then upon landing, it moves from plantarflexion to dorsiflexion. This motion decreases the stability of the ankle ligaments just when it is most needed. The ankle is protected by its static and dynamic stabilizers. Static stabilizers are bone articulations and ligaments that support the ankle. In contrast, dynamic stabilizers are the muscles firing around the joint for stability.[5] Eccentric control is noted to lessen the forces acting between the ground and the ankle joint, which is the dynamic stabilizer role. Synchronization of the muscles is a factor that any imbalances may result to decrease in the distribution of forces surrounding the joint which can cause excessive stress that may result in injury.[7]

Jumping has different phases, namely: 1) take off – the period of propelling the body off the ground; 2) flight phase – the period where the body establishes contact with the ground; 3) landing phase – the period where the body re-establishes contact with the ground. In the first phase, the ankle is put into dorsiflexion as the knee bends before propulsion. Furthermore, as the body is in the air, the ankle goes into plantarflexion when the knee extends. Gravity and the follow through of the calf and foot muscles put the foot into plantarflexion when it loses contact. This position carries over into the landing phase, wherein ankle sprain injury usually occurs. The foot contacts the ground while the ankle is in plantarflexion and inversion or its open-packed position. This position causes the ligaments of the ankle to be lax and is forced to absorb the high impact created by landing. This mechanism can cause an excessive stretch or tear to the lateral ligaments and is considered as an ankle sprain.[8,9]

Landing from a jump involves eccentric-concentric contraction of lower extremity muscles working to absorb the impact through the activation of the muscles surrounding the ankle, knee, and hip. The leg muscles help stabilize the ankle in one fixed position during the landing phase, through which different injuries can be prevented. Among these muscles are the peroneus longus, which acts as a primary defense mechanism of an injured ankle,[10] the gastrocnemius,[8,9] and the tibialis anterior, which allows dorsiflexion to handle landing stability.[11] A study by Ebben[10] showed a significant effect of the gastrocnemius muscle to stabilize the ankle in vertical jumps greater than 50 cm, aside from the involvement of the hip and knee muscles during jumping and landing activities. In a study done by Walsh,[8] wherein they observed the muscle activity immediately after contact in jump landing. The gastrocnemius is seen to be contracting first for ankle stabilization, followed by the contraction of the biceps femoris and rectus femoris. Any alterations in the muscle activation may yield errors in the positioning of the ankle during dynamic activities.

Most studies have observed the ankle biomechanics and kinetics during landing from a drop jump,[12,13] and showed the use of the non-elastic closed-basket weave taping technique for the prevention strategies of an inversion ankle sprain. Taping can increase kinesthetic awareness and limit the range of motion at the ankle joint, reducing inversion motion.[14,15] However, knowledge about the leg muscles' muscle activity upon application of tape is limited and has varying results. Several studies have noted that after tape application, there was increased activation of the peroneus longus;[11,16] however, several studies have shown that the use of tape had a decrease in the muscle activity on the tibialis anterior, medial head of gastrocnemius, and peroneus longus.[14,17] Another study showed that the tape does not affect the peroneus longus muscle activity and that it can be beneficial, allowing the evertor to develop torque.[18] Due to the varying results and the limited leg muscle activity observation in most current studies, the researchers opted to include the lower leg stabilizers and determine the effect of the tape during jump landing.

To address this, we conducted a quasi-experimental study using peak amplitude muscle activity measured with surface electromyography (sEMG). Thus, this study's objective is to determine the effect of non-elastic closed-basket weave ankle taping specifically on the tibialis anterior, peroneus longus, medial, and lateral gastrocnemius muscle activities during jump landing on a hard, flat surface.

METHODOLOGY

Ethical Approval. This study complied with the Principles of the World Medical Association Declaration of Helsinki and the Good Clinical Practice Guidelines of the Philippines Health Research Ethics Board. Approval was sought from the Ethical Review Committee of the College of Rehabilitation Sciences of the University of Santo Tomas. Participants gave their written informed consent before the study.

Study Design. This research utilized a quasi-experimental study using a pre- and post-test design.

Sample Size. This is a pilot study and cannot feasibly use a larger sample size and calculation for a higher alpha. The sample size was based on the study by Abian-Vicen.[19] Seventeen participants were recruited during the data gathering; however, the data of the 2 participants had problems in their sEMG results, wherein the data were not recorded on specific muscles. Thus, only fifteen (15) participants' data were analyzed. There were no dropouts, injuries, nor adverse reactions to tape occurred, and there were no complaints nor reports of discomfort and pain from the participants during the duration of this research.

Recruitment of Participants. Convenience sampling was used to recruit participants by sending out posters/fliers by a person and sharing posts through social media. Participants were screened using the following inclusion criteria: 1) 14-37 years old; 2) BMI range of 18.5 to 24.99 kg/m^2; 3) individuals who engage at least a total of 150 minutes of moderate to vigorous aerobic physical activity per week, in bouts of 10 minutes or more for at least three times a week (non-consecutive); 4) normal balance by Berg Balance test; 5) Foot ankle disability index (FADI) score of 100% representing no dysfunction; 6) able to give verbal and written consent; g) able to follow instructions. And the exclusion criteria were the following: 1) flat-footed as assessed by the Navicular drop test; 2) with history of ankle sprain or any other ankle injury; 3) with current musculoskeletal, neurological, or cardiovascular conditions; 4) allergic to non-elastic tape (Mueller™); 5) athletes who participate in the competitive field.

Setting. This study was conducted inside the Physical Therapy Skills Laboratory of the College of Rehabilitation Sciences of the University of Santo Tomas.

Outcome Measures. A surface electromyography (sEMG) is a reliable way to describe and determine the quality and muscle activation patterns during movement. Muscle activity was recorded with a wireless electromyography processor unit (Delsys Trigno, Boston, USA) using surface electrodes. It is an electrodiagnostic tool to measure electrical muscle activity during rest and movement or contraction. It was used to measure the peak amplitude muscle activity of the leg muscles during landing from a vertical jump. The sEMG has many time domains representing myoelectric patterns such as mean absolute value, zero crossings, waveform lengths, and a Time-Frequency domain, which shows transient myoelectric signal pattern classification. The surface electrodes were placed on specific muscles of the lower leg with a 2 cm electrode distance from each other. The muscles observed were the tibialis anterior (TA), peroneus longus (PL), medial gastrocnemius (MG), and lateral gastrocnemius (LG) during jump landing. Results of the sEMG were gathered and analyzed using the SciLab analyzer. Assessors for participant screening were different from the assessors for the data gathering. Two assessors underwent reliability testing on the electrode placement, and the interclass correlation coefficient agreement value of 0.7-0.8 was accepted. Researchers with high reliability were the ones who placed the surface electrodes on the muscles of the dominant leg of the participants.

Data Gathering Procedure. Participants who met the sampling criteria were oriented of the procedure and were notified that researchers would record a video during the jump landing. The face of the participant was concealed to ensure anonymity. Video recording was done for documentation and verification during the landing phase of the jump, where toes touch the ground to the sEMG muscle activation. Participants were required to wear cycling shorts for the leg muscles to be properly exposed, and any shirt and rubber-soled footwear to their comfort. On the day of data gathering, as a warm-up, each subject was taught the fencer stretching for 15 seconds and repeat it three times on each leg. The participants were asked to kick a ball to determine their dominant leg. Electrode placement sites on the participants' dominant leg were cleaned and shaved by the EMG standard procedures. Surface electrodes were placed on the specific locations of the muscles of the dominant leg: 1/3 from the muscle belly of the tibialis anterior, center of the muscle belly of the peroneus longus (parallel to the muscle fibers, the distal end of the muscle belly of the medial gastrocnemius, and 2/3 proximal end from the muscle belly of the lateral gastrocnemius.[20] The Maximal Voluntary Isometric Contraction (MVIC) was done on each muscle to note that the placement of the sEMG electrode is in line with the tested muscle. Data were analyzed and recorded using EMGWorks by Delsys for all trials of jump landing. Data were sampled at 1000Hz and full-wave rectified and smoothed using a 500-ms moving window to get the peak amplitude. All data were exported using MS Office Excel for calculations.

Participants did a trial of jump landing twice and were instructed to jump as high as they can with both feet and landing on their toes with their knees bent. With a metronome as a prompter, each participant was instructed to jump on the third sound. The jump landing was done for three trials [Figure 1]. After the first 3 trials of jump landing without the non-elastic tape, the closed-basket weave taping technique was applied on the ankle of the same leg. A licensed sports physical therapist, who has undergone seminars with taping and has been using tape on individuals for at least two years applied the tape. The duration of the tape application served as the allotted 5 minutes rest period for the participant. The participant was then asked to repeat the jump landing activity [Figure 2].

Figure 1. Phases of vertical jump landing without tape on dominant leg. Succeeding images display the landing phase in a frame-by-frame representation.

Figure 2. Phases of vertical jump landing with closed basket weave ankle tape on dominant leg. Succeeding images display the landing phase in a frame-by-frame representation.

Data Analysis. Baseline demographics were analyzed using the Shapiro-Wilk test set at $p<0.05$. The collected data and results were interpreted and analyzed by the researchers using SPSS. Muscle activity peak amplitude was gathered from the time of landing from a jump using a 500-ms window after contact were analyzed. Data were analyzed using a Paired t-test, and a 95% confidence interval for the true mean difference was computed.

RESULTS

The overall mean of the different demographic profiles is seen in Table 1 for the different participants (n=15) of the study. Fifteen participants (Females = 9, Males = 6) were included in the study with their dominant foot, mostly on the right leg (87%). The age and BMI are homogenous at baseline for all the participants. With a mean age of 21 ± 1.03 years old ($p= 0.46$) and BMI of 22.74 ± 1.63 kg/m^2 ($p= 0.29$). Inter-reliability testing using intraclass correlation results on the muscles of TA (0.94), PL (0.978), MG (1.00), and LG (0.98), showed high reliability for surface electrode placement.

Table 1. Demographics of participants. Significant level for Shapiro-Wilk Test of Normality is set at $p<0.05$.

Characteristics (n=15)	Percentage Distribution (%)	
Sex		
• Male	40	
• Female	60	
Leg Dominance		
• Right	87	
• Left	13	
	Mean ± SD	**Shapiro-Wilk**
Age (yrs.)	21.07 ± 1.03	0.46
BMI (kg/m^2)	22.74 ± 1.63	0.29

The average peak amplitude of the TA, PL, MG, and LG muscles of each of the participant's dominant leg during jump landing with and without tape are shown in Table 2. As presented, there was a decrease in TA and PL muscle activities during jump landing when the tape was applied on the ankle, in contrast to an increase in muscle activity for the MG and LG. Results also showed that of all the muscles observed, the medial gastrocnemius showed more drastic muscle activity with tape compared to the other muscles.

Results showed that there is no significant difference pre- and post- tape on the peak amplitude muscle activity of the tibialis anterior (p= 0.06), medial gastrocnemius (p= 0.32), and lateral gastrocnemius (p= 0.67) muscles during jump landing. However, the peroneus longus (p= 0.05) showed a significant difference when it comes to peak amplitude muscle activation from without tape to the application of tape during jump landing (Table 2).

Table 2. Statistical representation of the results of muscle activity peak amplitude (Paired t-test <0.05).

Paired Samples Statistics				95 % Confidence Interval of the Differences		Sig
Peak Amplitude (microvolts)	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Lower**	**Upper**	
TA without tape	1088.67	1389.36	358.73	-11.58	562.20	0.59
TA with tape	813.35	1302.91	336.41			
PL without tape	405.82	123.14	31.79	1.649	120.43	0.05*
PL with tape	344.78	153.34	39.59			
MG without tape	1107.22	727.36	187.80	-1324.38	465.78	0.32
MG with tape	1536.52	1484.16	383.21			
LG without tape	1110.27	1160.65	299.68	-1209.50	797.78	0.67
LG with tape	1316.13	1615.20	417.04			

Note: *significant difference p<0.05
TA = tibialis anterior; PL = peroneus longus; MG = medial gastrocnemius; LG = lateral gastrocnemius

DISCUSSION

This study has shown the different effects of muscle activity peak amplitude also demonstrated in the literature. The tibialis anterior and peroneus longus had a decrease in muscle activity during jump landing when the tape was applied on the ankle. However, only the peroneus longus displayed a significant difference in pre- and post- taping. The findings are consistent with the existing literature, wherein non-elastic taping has been found to increase joint stiffness, thereby causing a decrease in muscle activity.[14] The muscle stiffness is due to the perception of the nervous system for increased support in the mechanical setting at the ankle joint. The adaptation of muscle activation is responsible for the decreased demand for dynamic stabilization and improved stability in planned and unplanned tasks.[21] In the closed-basket weave taping or prophylactic ankle taping using a non-elastic tape, the ankle is taped in a slightly everted position for stability and promotes restriction. The tape can be perceived by the body of increased support that may decrease the demand on the muscles around the area especially towards eversion.[17,22]

In an injured ankle, the peroneus longus acts as the primary defense mechanism during movement. The reduced activation is consistent with the findings by Delahunt, which identified integrated EMG muscle activity during a single leg drop jump,[9,23] and by Dodd[17], along with the TA and MG following application of tape during landing from a netball pass, wherein the foot was taped in an everted position. Furthermore, it was shown that there is a higher muscle activity for both tibialis anterior and peroneus longus without the application of tape during drop landing.[17] The increase in muscle activity is also shown in a study by McLoda,[24] and that pre-activation of the muscle is essential following dynamic activities.[25] It is a neuromuscular response to increase joint stability and maintain balance to avoid inversion and excessive pronation or eversion after contact to the ground.[26,27] Allowing dorsiflexion on the ankle increases stability since eversion and dorsiflexion are the closed- packed position of the ankle joint. However, research has shown varying results. There were increases in peroneus longus activity in people with ankle sprains following the application of tape when the foot is stressed or forced into inversion.[16] The tape provides support to the ankle by cutaneous cues and aggressive pulling, which could lead to increases in muscle activity because of the sensory input. For individuals with chronic ankle instability, the tape enhances the muscle response on the area by maintaining high muscular activity during sudden inversion or different dynamic movements.[16,28] The tape had a facilitatory effect on the PL with immediate weight-bearing, therefore enhancing the inversion position sense, resulting in a need to counteract the force after landing.[11] The researchers suggest obtaining the pre-landing muscle activity to detect any anticipatory muscle activity strategies that would determine the muscle activity following a jump landing and the latency of muscle activity following ground contact.

The medial and lateral gastrocnemius, together with the tibialis anterior, did not have any significant differences in peak muscle activity upon landing. However, it was shown that the MG and LG had a higher level of muscle activity than the other muscles, with or without tape. As stated, an un-taped ankle has strong muscle contractions on both MG and LG, as they are the stabilizers of the ankle upon vertical jumping and landing.[9] The body uses the activity of these muscles as a strategy to enforce joint stability and protect the knee as well as the ankle from potential injuries and external forces acting on it.[29] Consequently, they are more important than the TAs, because of their ability to absorb eccentric forces.[30,31]

The lateral gastrocnemius would have its greatest peak during the early activity in drop landing for its role in stabilizing the ankle joint to prepare itself in landing from a jump.[31,32] However, in the study, there was a minimal difference between MG and LG in the average peak amplitude. Research has shown that an externally rotated tibia prompted significantly greater MG activation during heel raises and an internally rotated position would yield greater LG activation.[33] The MG has a shock-absorbing function as it rapidly stretches and stores elastic energy which is released to the fascicles and dissipated through active muscle lengthening.[34] The increased activity of the gastrocnemius muscles can also be associated with the spinal stretch reflex-induced activity or a stretch on the muscle spindle when the ankle moves from plantarflexion to dorsiflexion upon contact, such as in hopping and jump landing. This, in turn, would produce an increase in muscle activity causing muscle stiffness and increased joint stability.[35,36] During this study, the participants were instructed to land on their toes with knees bent after jumping with no particular instruction or preference on foot placement. This may have influenced MG and LG involvement, and the instructions may increase the cortical drive for greater anticipatory control contributing to increased activity in the posterior leg muscles.[37]

Studies have shown that the taped ankle diminished muscle activity and the rate of inversion on the ankle.[17,18,38] This is also demonstrated by wearing an ankle brace, restricting dorsiflexion and plantarflexion[39,40] as compared when there is no tape applied after ground contact during drop landing for LG.[32]

Due to the restriction brought about by the tape at the ankle joint, the eccentric action of the gastrocnemius is limited, therefore less energy is absorbed to control the movement,[38] and there is a decreased need to provide mechanical stability.[41] However, in the study, the tape caused an increase in gastrocnemius muscle activity. One possible explanation is an increasing demand for muscle activity during landing. There was greater activation of 1b afferents, increasing the muscle activity in a horizontal jump task.[35] As stated, the gastrocnemius muscles act as a shock absorber and increase muscle stability. The tape enhanced gastrocnemius activity rather than diminishing it, thereby causing more stability on the ankle joint upon landing. It may have caused an increase in the cutaneous cues, thus creating an increase in muscle activity. The position of the ankle when taped is also in slight eversion and dorsiflexion, causing a slight stretch on the gastrocnemius muscle spindles. As the foot contacts the ground, plantarflexion is limited, and there is a reflex-induced stretch activity from the gastrocnemius to protect and increase the joint stiffness upon landing.[36,37] The instructions given to the study participants during landing may have affected the peak amplitude muscle activity. Also, the impact of the forces and the range of motion at the knee and ankle joints may have influenced the amount of muscle activity during landing. The gastrocnemius reduces the ground reaction force during landing,[41] and with taping, it increases the force that the lower limb receives, especially if there are repeated and accumulated jumps.[19] The increase in muscle stiffness and increase in muscle activity may lead to an increased risk for injury, as this may also increase the ground reaction force from landing. The evidence for the gastrocnemius activity is conflicting and warrants further investigation since it did not achieve any significant difference at pre- and post-taping and is therefore inconclusive. The effects of taping on the muscles in terms of benefit or potential disadvantage for muscle activity are inconclusive in this study as there were varying results with limited outcomes.

Limitations. The outcomes in the study are limited by the small sample size and the number of trials for jumping. Jump height performance or jumping performance and ground reaction force should be added as outcomes to determine the impact of ankle taping in every individual. Furthermore, studies have shown varying activation patterns of the lower extremity when the drop height exceeds certain limits,[18] and that a standardization of the jump height should be necessary to avoid deviation of results. Lastly, the randomization of the application of tape could be used to address the possible order effect from the application of tape.

Implications. The results have shown that the application of non-elastic tape would affect not only the musculoskeletal system providing restriction on the ankle motion but also the nervous system, providing a perception of increased support resulting in muscular adaptation. Taping has been an effective way of stabilizing the ankle and reducing the risk of injuries,[15] however, its effects in the muscle activity may warrant further investigation, especially in its short- or long-term use.

CONCLUSIONS

The non-elastic closed-basket weave taping exhibited a significant effect on the peroneus longus peak amplitude muscle activity, having a decreased activation after application. However, the other muscles showed no statistically significant difference after the tape was applied at the ankle. This study suggests that tape may influence the peroneus longus by decreasing its muscle activation during jump landing, which may or may not reduce the risk of ankle injury in a healthy individual.

Further research may be done to determine the effect of the non-elastic closed-basket weave on healthy individuals against those with recurrent ankle sprains. Moreover, this study can be used as a reference for future studies involving non-elastic closed-basket weave taping and ankle stability involving dynamic ankle stabilizers. Furthermore, this may also serve as a basis for whether ankle taping effect may have short or long- term benefits or drawbacks by inhibiting the optimal contraction of the muscles surrounding the ankle during jump landing. Lastly, it is suggested that training programs in clinics and sports teams use the non-elastic closed-basket weave taping as an adjunct intervention but should focus more on strengthening and conditioning the dynamic stabilizers to increase the stability and reduce the risk of ankle injuries.

Individual Author's Contributions

F.C.; Designed and performed experiments, supervised the research, analyzed data, and co-wrote the paper. E.C., P.A., D.A., B.B., R.C., I.G., J.I., A.M., M.P.; Performed experiments, encoded data and co-wrote the paper.

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Conflicts of Interest

The authors declare no conflict of interest.

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