

Effects of Tape and Exercise on Dynamic Ankle Inversion

Mark D. Ricard, PhD; Stephen M. Sherwood, MS, ATC, CSCS;
Shane S. Schulthies, PhD, PT, ATC; Kenneth L. Knight, PhD, ATC

Brigham Young University, Provo, UT

Objective: To compare the effects of tape, with and without prewrap, on dynamic ankle inversion before and after exercise.

Design and Setting: Doubly multivariate analyses of variance were used to compare the taping and exercise conditions. Subjects were randomly assigned to a fixed treatment order as determined by a balanced latin square. The independent variables were tape application (no tape, tape with prewrap, tape to skin) and exercise (before and after). The dependent variables were average inversion velocity, total inversion, maximum inversion velocity, and time to maximum inversion.

Subjects: Thirty college-age male and female students (17 males, 13 females; mean age = 24.9 ± 4.3 years, range, 19 to 39 years) were tested. Subjects were excluded from the study if they exhibited a painful gait or painful range of motion or had a past history of ankle surgery or an ankle sprain within the past 4 weeks.

Measurements: We collected data using electronic goniometers while subjects balanced on the right leg on an inversion platform tilted about the medial-lateral axis to produce 15° of plantar flexion. Sudden ankle inversion was induced by pulling the inversion platform support, allowing the platform support base to rotate 37° . Ten satisfactory trials were recorded on the inversion platform before and after a prescribed exercise bout. We calculated total inversion, time to maximum inversion,

average inversion velocity, and maximum inversion velocity after sudden inversion.

Results: We found no significant differences between taping to the skin and taping over prewrap for any of the variables measured. There were significant differences between both taping conditions and no-tape postexercise for average inversion velocity, maximum inversion, maximum inversion velocity, and time to maximum inversion. The total inversion mean for no-tape postexercise was $38.8^\circ \pm 6.3^\circ$, whereas the means for tape and skin and for tape and prewrap were $28.3^\circ \pm 4.6^\circ$ and $29.1^\circ \pm 4.7^\circ$, respectively. After exercise, inversion increased by $1.0^\circ \pm 2.8^\circ$ for the no-tape condition, whereas the tape-to-skin and tape-over-prewrap inversion increased by $2.1^\circ \pm 3.2^\circ$ and $1.7^\circ \pm 2.2^\circ$, respectively.

Conclusions: There was no difference in the amount of inversion restriction when taping with prewrap was compared with taping to the skin. Tape and tape with prewrap significantly reduced the average inversion velocity, maximum inversion, maximum inversion velocity, and the time to maximum inversion. Both taping conditions offered residual restriction after exercise.

Key Words: ankle taping, prewrap, inversion, ankle sprain, inversion platform

Most ankle inversion injuries occur during landing with the foot plantar flexed and internally rotated.¹ Taping or bracing the injured ankle to decrease range of motion and thereby prevent further injury is standard practice among sports medicine clinicians.² Researchers have reported that tape provides adequate restriction of range of motion,³⁻⁹ even though it loosens with exercise.^{4,7,9,10}

Several factors have been suggested to affect the restrictive quality of a tape application: perspiration, skin mobility, prewrap, spray adherent, and taping configuration.¹¹⁻¹³ Opinions conflict concerning the relative effectiveness of taping over prewrap.¹¹⁻¹³ It has been reported that taping over prewrap results in greater,¹¹ the same,¹³ and less¹² inversion restriction than taping directly to the skin. Perhaps the inconsistent results were due to the methods used to study the question. Two of the studies involved nonweight-bearing tests,^{11,13} as did several others dealing with ankle

inversion^{2,4,14}; another study involved partial weightbearing.¹² But ankle sprains occur from dynamic, unexpected weightbearing inversion. Therefore, the purpose of our study was to test the effect of taping over prewrap on restricting dynamic, weightbearing inversion.

METHODS

Design

We used doubly multivariate analyses of variance to compare the taping and exercise conditions. The independent variables were tape application (no tape, tape with prewrap, tape to skin) and exercise (before and after). The dependent variables were total inversion, time to maximum inversion, average inversion velocity, and maximum inversion velocity.

Subjects

Thirty subjects (17 males, 13 females; height = 176.2 ± 7.8 cm, weight = 76.5 ± 12.9 kg, age = 24.9 ± 4.3 years, range, 19 to 39 years) with no acute symptoms of lower leg, ankle, or

Address correspondence to Mark Ricard, PhD, Physical Education Department, PO Box 22116, Human Performance Research Center, Brigham Young University, Provo, UT 84602. E-mail address: Mark_Ricard@BYU.EDU

foot injury volunteered to participate in this study. All subjects wore their own low-top athletic shoes for every trial. Subjects were excluded from the study if they exhibited a painful gait or painful range of motion or had a past history of ankle surgery or an ankle sprain within the past 4 weeks. We obtained institutional approval from the Institutional Review Board at Brigham Young University, and subjects gave written informed consent.

Instruments

We used an inversion platform with a foot-support base that rotates 37° after a trap door is pulled with a string to induce dynamic ankle inversion (Figures 1-3). To help simulate the mechanism of sprain,⁶ the back of the inversion platform was raised 15° so that ankle inversion could be measured with 15° of plantar flexion (Figure 1). The design and function of the platform is similar to that used in several other studies.^{7,11,12,14-18}

We chose to use an electronic goniometer to measure ankle inversion rather than video marker tracking because of the increased sampling rate available for the goniometer at 1000 Hz, compared with the typical video sampling rate of 60 to 120 Hz, which is not fast enough to capture the dynamic nature of ankle inversion. An electronic goniometer (Penny & Giles, Santa Monica, CA) was placed on the heel of the subject's shoe with adhesive tape, and its position was outlined with a marker for future reference. This goniometer measured the inversion-eversion of the subject's ankle as a function of time. Due to the fragile nature of the instrumentation and the potential that the exercise bout would alter the position of the goniometer, the instrument was removed for exercise and then replaced using the marker guidelines. Another electronic goniometer was placed on the platform from the base support to the trap door to measure the rate, distance, and time of the trap door fall (Figures 1-3).

Surface electromyography (EMG) was used to record the level of activity of the peroneus longus and the tibialis anterior to monitor preactivation and muscle guarding. A quiet signal (ie, no muscle activity) was obtained before the trap door was activated. EMG and goniometer signals were sampled at 1000

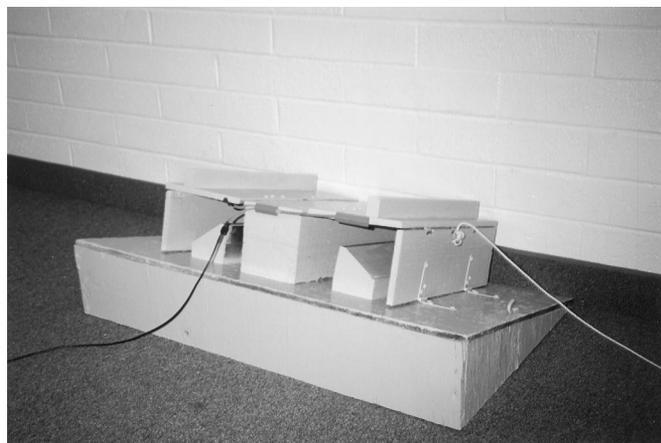


Figure 1. Inversion platform instrumented with an electronic goniometer to measure the rotation of the platform foot-support base. When the trap door is pulled out with the string, the platform foot-support base rotates 37°, causing a sudden ankle inversion. The back of the inversion platform was raised to allow the subject to be tested at 15° of plantar flexion.

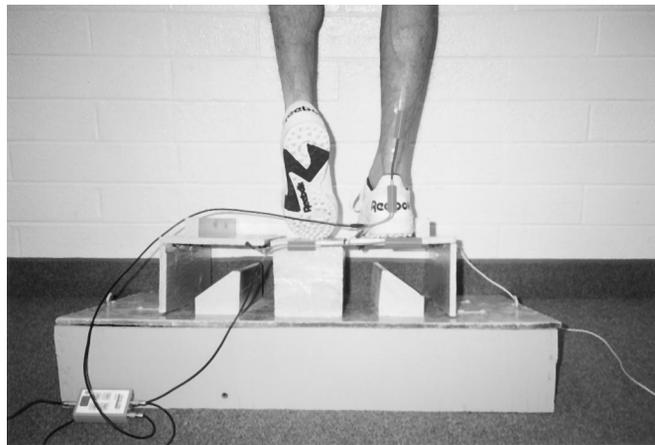


Figure 2. Inversion platform with the subject's weight on the right foot and using the great toe of the left foot to maintain balance. A goniometer was placed on the rear of the shoe and lower leg to measure ankle inversion. A second goniometer was placed on the inversion platform to measure the 37° rotation of the platform foot-support base after the trap door was pulled with the string shown. The back of the inversion platform was raised to allow the subject to be tested at 15° of plantar flexion.

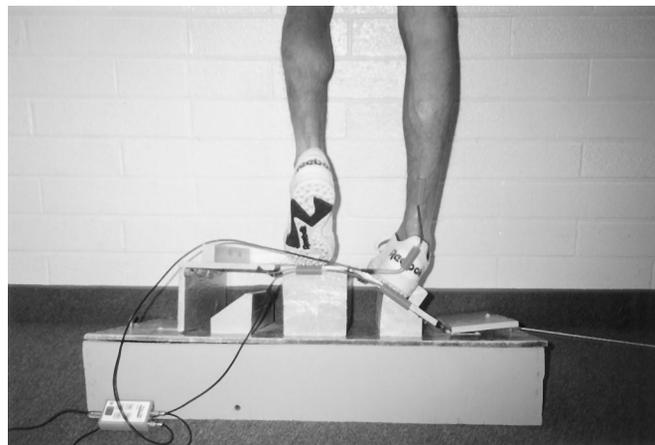


Figure 3. Inversion platform and subject after the trap door is released. The platform foot-support base rotates 37°, causing a sudden ankle inversion.

Hz using a Micron P-133 computer (Nampa, ID) interfaced to a Noraxon EMG amplifier (Scottsdale, AZ) by a Keithley-Metrabyte 1802 HC, 64-channel, 12-bit analog-to-digital converter (Taunton, MA). The EMG signals were recorded with Medicotest pregelled, M-00-S, circular, 30-mm-diameter, Ag/AgCl surface electrodes (Rolling Meadows, IL) placed over the muscle belly parallel to the muscle fibers, in pairs 3 cm apart from center to center. The electrode sites were prepared by shaving the hair, lightly abrading the skin with sandpaper, and cleansing the area with rubbing alcohol to lower input impedance below 3000 Ω. The EMG signals were differentially amplified with a gain of 1000 and a bandwidth of 16 to 500 Hz at -3dB using a Noraxon Telemetry telemetry system. The Noraxon amplifiers have an input noise below 1 μV RMS and an effective common mode rejection ratio of 135 dB.

Procedures

Subjects read and signed an institutionally approved subject consent form. Each subject's height, weight, age, and previous

injury history were recorded. Testing was conducted before and after exercise under 3 conditions: no tape (control), tape directly to the skin (tape-skin), and prewrap with tape (tape-prewrap). The treatment order was randomly assigned and determined by a balanced latin square. The testing of each condition occurred on separate days within a 3-week time frame.

Upon entering the research facility, the subjects were instructed to shave the right leg from the midcalf down to the toes. We recorded weight, age, and height. The EMG electrode sites were lightly abraded with sandpaper and cleansed with sterile alcohol prep pads (Professional Disposables, Orangeburg, NY). For the tibialis anterior, the EMG electrodes were located 7 cm below the level of the fibular head, and for the peroneus longus, 8 cm below the level of the fibular head. A ground electrode was placed directly over the fibular head.

We marked the positions of the electrodes to prevent misplacement if they became dislodged during the exercise bout and for accurate placement on subsequent days. The subjects were instructed not to remove either the goniometer or electrode placement marks until they completed the study. The subjects then had the right ankle taped according to the method specified by the assigned treatment order.

Taping Method

The same athletic trainer applied each tape application to all subjects. The choice of ankle taping method was based upon personal preference. The tape application included 3.8-cm (1.5 in) zinc oxide tape (Jaybird & Mais Athletic Products, Lawrence, MA), heel and lace antifriction pads (Mueller Sports Medicine, Inc, Prairie du Sac, WI), which contained a small amount of skin lubricant (Cramer Products, Inc, Gardner, KS), and tape adherent spray (Mueller Sports Medicine).

Tape adherent was evenly sprayed over the area to be taped and allowed to dry for a few seconds. The lubricated heel and lace pads were then placed over the Achilles and pretibial tendons. Tape was then applied in a basketweave pattern, followed by heel locks and figure eights. Anchors were placed around the leg at the base of the calf (musculotendinous junction of the gastrocnemius) and the base of the foot, slightly posterior to the base of the fifth metatarsal, and 4 inversion stirrups were applied from medial to lateral, with each stirrup followed by a circular anchor (3 to 6 total) working down the leg. Three heel locks and 2 figure eights were then applied. Reanchoring was the last step, starting from the top of the tape job down to approximately the malleolar level and around the foot.

The prewrap was applied in the following manner: starting in the midfoot range, the prewrap was applied in a circumferential manner, moving up the ankle and leg, overlapping half the width of the previous strip.

Pilot Study

In our study, we measured the angle between the rear of the shoe and the lower leg as an estimate of the amount of ankle inversion using an electronic goniometer sampling at 1000 Hz. To establish the validity of using a goniometer attached to the rear of the shoe to estimate ankle inversion, we conducted a pilot study using 2 goniometers: 1 was placed directly over the calcaneus and the other over the rear of the shoe. One subject was tested during 5 trials of sudden inversion. We then

calculated the total inversion, average rate of inversion, and correlation between the calcaneal inversion and shoe inversion. The mean correlation between calcaneal and shoe inversion for the 5 trials was 0.997. Total calcaneal inversion was $38.3^\circ \pm 0.11^\circ$, and total inversion calculated from the shoe goniometer was $38.1^\circ \pm 0.08^\circ$. The average rate of inversion of the calcaneus was $110.8^\circ/s \pm 0.44^\circ/s$, and the average rate of inversion of the shoe was $109.2^\circ/s \pm 0.81^\circ/s$.

Clarke et al¹⁹ and Nigg²⁰ have also established that measuring the rear of the shoe is a valid measure of ankle inversion. They used specially designed shoes with a clear plastic heel, placing markers on the calcaneus and the rear of the shoe and then digitizing the shoe and calcaneal movement relative to the rear of the lower leg. This methodology enabled them to quantify the effects of foot movement within the shoe, as well as the relationship between calcaneal movement and shoe movement. Frederick²¹ agreed with Clarke et al¹⁹ and Nigg²⁰ that placing markers on the rear of the shoe is a valid indicator of the amount of inversion and eversion about the subtalar joint.

Testing

Once the tape was applied, subjects were pretested, stretched the lower legs, exercised, and then were posttested. To minimize the effects of movement of the foot within the shoe during inversion testing, subjects were instructed to tightly lace their shoes before each set of platform inversion tests. For both pretesting and posttesting, the goniometer was attached to the back of the heel of the subject's shoe and to the base of the gastrocnemius in line with the Achilles tendon. Each time the goniometer was attached to the subject, it was zeroed with the subject's right ankle in a neutral inversion-eversion position. Zeroing the ankle inversion goniometer before inversion platform testing eliminates any errors due to removing the goniometer and replacing it before and after exercise. The platform goniometer was also zeroed at the beginning of each set of trials. The EMG electrodes were attached to the telemetry system at this time.

Subjects stood on the inversion platform facing away from the testers to avoid anticipation of the platform drop. They were instructed to stand with most of their weight on the right foot, using the left great toe for balance (Figures 2 and 3). The subject was instructed to relax the ankle and roll into the subsequent inversion. At random intervals, the platform door was dropped. Each trial was visually inspected and saved for analysis if there was no evidence of muscular preactivation and no delay between dropping of the platform and inversion of the foot. Most subjects required 10 to 13 trials to complete 10 acceptable trials.

Subjects stretched the quadriceps, hamstring, and gastrocnemius muscles of both legs. Each muscle was stretched 3 times for 30 seconds. The exercise bout included a 10-minute treadmill run at 9.66 kph (6 mph), running figure eights (9.1 m, 3 sets, 5 repetitions), shuttle runs (9.1 m, 3 sets, 3 repetitions), and bilateral toe raises (3 sets, 20 repetitions). Each subject's time was recorded for the figure eights and shuttle runs to ensure a consistent effort throughout the testing. Two subjects could not complete the treadmill run; they were instructed to decrease the speed of the treadmill to a comfortable pace to finish the allotted 10 minutes.

Once the exercise bout was completed, the goniometer was reattached, and the subjects were posttested on the inversion

platform using the pretest procedures until 10 satisfactory trials were collected.

Data Analysis

The EMG signals were visually inspected on the computer screen to verify that the subjects did not activate the peroneus longus or tibialis anterior before or during the inversion platform drop, and no further processing of the EMG signals was done. The ankle inversion and the inversion platform goniometers were sampled at 1000 Hz, resulting in a time between samples of 0.001 seconds. Total inversion was defined as the difference between initial joint angle (before dropping the inversion platform) and the maximum inversion point reached after platform drop (Figure 4). The time to maximum inversion was defined as the difference in time from the initiation of platform drop to the time at which the ankle was maximally inverted. The average inversion velocity was the total inversion divided by the time to maximum inversion. The maximum inversion velocity was defined as the greatest velocity obtained between platform drop and the maximum inversion point (Figure 4). The average of the 10 trials for each variable was used for statistical analysis.

Since it was possible that the tape could have loosened during the 10 trials of sudden inversion, we used single-factor repeated-measures analyses of variance (ANOVAs) to test for significant differences between the trials for each dependent variable. We found no significant differences between the trials for any of the dependent variables, justifying our use of the 10-trial averages for each variable.

Doubly multivariate analyses of variance¹⁹ were employed to compare the taping and exercise conditions on the 10-trial averages for the 4 dependent variables: total inversion, time to maximum inversion, average inversion velocity, and maximum inversion velocity. Post hoc tests of significant multivariate statistics were performed with univariate ANOVAs and Tukey test procedures.²² For all comparisons, α was set at 0.05.

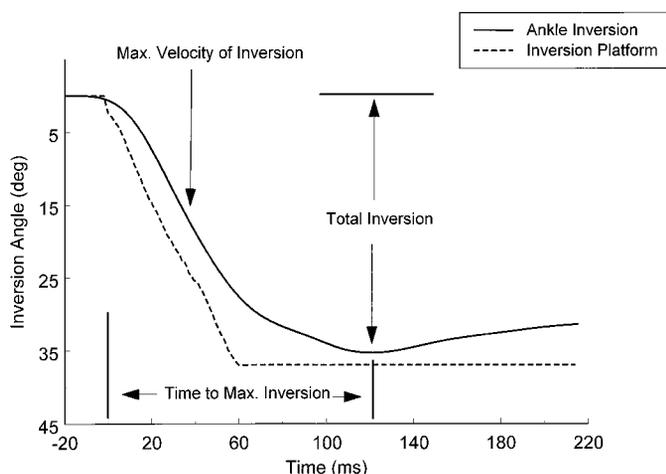


Figure 4. Typical trial of sudden ankle inversion. Total inversion was defined as the difference between the initial ankle inversion angle and the final ankle inversion angle after platform drop. The time to maximum inversion was defined as the difference in time from the initiation of platform drop to the time at which the ankle was maximally inverted. The average inversion velocity was the total inversion divided by the time to maximum inversion. The maximum inversion velocity was defined as the greatest velocity obtained between platform drop and the maximum inversion point.

RESULTS

There was no difference between taping over the skin and taping over prewrap for any of the 4 variables; however, both taping conditions were significantly different from the no-tape condition for all 4 variables (Table 1). The multivariate statistical results and power are shown in Table 2. Total inversion was approximately 10° less during the 2 tape conditions than during the no-tape condition ($F_{2,58} = 198.3$, $P = .000$) (Table 3). Total inversion increased 1° to 2° during exercise in the 3 conditions ($F_{1,29} = 28.11$, $P < .001$).

Time to maximum inversion was greater for the tape conditions than the no-tape condition both before and after exercise, despite the lesser distance ($F_{2,58} = 7.64$, $P = .001$, Tukey < 0.05). Time to maximum inversion was 7.1 milliseconds and 8.6 milliseconds less after exercise in the 2 tape conditions (Tukey < 0.05). The 1.5-millisecond reduction after exercise in the no-tape condition was not significant.

Average inversion velocity was 38% and 40% less during the tape conditions than the no-tape condition before exercise and 29% and 31% after exercise ($F_{2,58} = 89.42$, $P < .001$). Despite a significant difference between pre-exercise and post-exercise, tape to skin and tape over prewrap still significantly reduced the average inversion velocity over the control. Average inversion velocity was 36%/s greater after exercise in the 2 tape conditions ($F_{2,58} = 7.51$, $P = .001$, Tukey < 0.05). The 4.5°/s increase after exercise in the no-tape condition was not significant.

Maximum inversion velocity was 35% and 38% less during the tape conditions than the no-tape condition before exercise and 30% and 31% after exercise ($F_{2,58} = 292.14$, $P < .001$). Maximum inversion velocity was 40°/s to 76°/s greater after exercise in the 3 conditions ($F_{1,29} = 40.1$, $P < .001$).

DISCUSSION

Applying tape over prewrap is as effective as applying tape directly to the skin in reducing the amount and rate of dynamic ankle inversion. Our results agree with Manfroy et al¹³ but contradict the conclusions of Delacerda¹¹ and Keetch.¹²

Despite arriving at the same conclusions, Manfroy et al¹³ used methods that were considerably different from ours. They tested maximal ankle resistance to inversion under unipedal weightbearing conditions and measured their results in terms of N·m, not actual degrees of inversion; the degree of inversion was set at 15°. They reported no difference in the support provided by tape over prewrap or tape to the skin.

Delacerda¹¹ concluded that using prewrap, whether gauze or foam, was superior to taping to the skin in restricting inversion after exercise. He reported that inversion range of motion increased 7.67° after exercise for the foam prewrap and 7.88° for tape to skin. We found a considerably smaller increase in ankle inversion range of motion after exercise. Our tape-to-skin condition increased range of motion by 2.1° and tape over prewrap by 1.7° after exercise. We believe that the discrepancy between our results and Delacerda's¹¹ may be due to the static nature of his method of inversion and his limited sample size of 3 subjects.

Our methods were similar to those used by Keetch,¹² despite conflicting results. She reported a 3.5° loss for the tape-spray-prewrap condition and a 1.5° loss for the tape-spray condition. The control group exhibited a maximum inversion of only 15.6°, whereas our control group demonstrated approximately

Table 1. Experimental Variables by Tape and Exercise Conditions (Mean ± SD)

	No Tape*	Tape-Skin	Tape-Prewrap
Total inversion (°)			
Before exercise	37.8† ± 4.6	26.2† ± 4.7	27.4† ± 5.0
After exercise	38.8† ± 6.3	28.3† ± 4.6	29.1† ± 4.7
Difference	1.0 ± 2.8	2.1 ± 3.2	1.7 ± 2.2
Time to maximum inversion (ms)			
Before exercise	110.9 ± 24.4	124.4† ± 18.4	126.0† ± 17.4
After exercise	112.4 ± 26.2	117.3† ± 19.3	117.4† ± 63.5
Difference	1.5 ± 11.4	7.1 ± 13.2	8.6 ± 13.6
Average inversion velocity (°/s)			
Before exercise	364.2 ± 86.4	218.3† ± 49.3	226.9† ± 63.5
After exercise	368.7 ± 87.1	253.8† ± 44.7	262.7† ± 61.0
Difference	4.5 ± 38.2	35.5 ± 34.8	35.8 ± 46.3
Maximum inversion velocity (°/s)			
Before exercise	700.6† ± 105.1	435.4† ± 95.0	455.4† ± 110.2
After exercise	740.1† ± 108.6	511.0† ± 87.0	517.4† ± 100.6
Difference	39.5 ± 59.8	75.6 ± 79.4	62.0 ± 83.8

* No tape was always significantly different from tape-skin and tape-prewrap.

† Before exercise was significantly different from after exercise.

Table 2. Multivariate Statistics and Power

Within-Subjects Effects	Multivariate F (df)	Significance	Power
Tape conditions	38.1 (8, 110)	.000	1.000
Exercise conditions	12.5 (4, 26)	.000	1.000
Tape by exercise	2.9 (8, 110)	.006	.937

Table 3. Univariate ANOVA Follow-up Statistics and Power

Within-Subjects Effects	Univariate F (df)	Significance	Power
Total inversion			
Tape conditions	198.3 (2, 58)	.000	1.000
Exercise	28.2 (1, 29)	.000	.999
Tape by exercise	1.2 (2, 58)	.317	.247
Average inversion velocity			
Tape	89.4 (2, 58)	.000	1.000
Exercise	25.8 (1, 29)	.000	.998
Tape by exercise	7.5 (2, 58)	.001	.932
Maximum inversion velocity			
Tape	292.1 (2, 58)	.000	1.000
Exercise	40.1 (1, 29)	.000	1.000
Tape by exercise	2.2 (2, 58)	.121	.430
Time to maximum inversion			
Tape	5.4 (2, 58)	.007	.827
Exercise	7.8 (1, 29)	.009	.773
Tape by exercise	7.6 (2, 58)	.001	.936

38° of inversion. The differences between our results and Keetch's¹² may be explained by her use of a limited range of inversion, 15.6°, slower sampling rate of 60 Hz, and the possible firing of the subjects' evertor muscles to restrict movement.

Similar to previous studies,^{3,6,9,14} we found that inversion range of motion of a taped ankle does increase after exercise. Despite this increased range of motion after exercise, we found that ankle taping restricted the range of motion during sudden inversion by approximately 10°. In our study, total inversion in the no-tape condition was 38°, whereas the total inversion was 27° and 28° in the tape-skin and tape-prewrap conditions, respectively. Both taping conditions offered a residual inversion restriction of almost 10° after exercise. Furthermore, the time to maximum inversion increased by 4%, and the average

inversion velocity was decreased by 30%. This may not seem like much until we consider the mechanical delay of the evertor muscles. It takes the peroneal muscles approximately 115 milliseconds to impose a force substantial enough to cause an inversion response.^{16,23} Many ankle sprains occur before the ankle muscles can react to protect the joint. Konradsen et al¹⁶ suggested that, during a sudden inversion force, the evertor muscles cannot prevent the ankle from inverting. The reduction of inversion velocity and increase in time to maximum inversion in taped ankles may allow time for the body's natural reflex mechanism to activate and possibly prevent inversion or decrease the severity of the injurious movement.

We suggest that tape is effective in restricting inversion, despite the increased range of motion after exercise. However, several factors determine the relative potential of a load to cause an ankle sprain: the magnitude of force, the rate of application, the point of application, the direction of force application, the critical state of the tissues (bone, tendon, ligament, and muscle), and the preactivation of the muscles.¹⁵ A typical landing associated with a basketball rebound produces a peak vertical force of 3 to 6 times body weight in a time of 10 to 80 milliseconds, with most ankle injuries occurring between 30 and 50 milliseconds after ground contact.¹⁵ This rate of force exceeds the evertor muscles' ability to prevent inversion.^{16,24} The ideal method for testing devices designed to prevent ankle sprains would include forces of 4 to 7 times body weight, peaking in 12 milliseconds and producing an angular impulse of the subtalar joint of 4 to 6 N·m·s during the first 100 milliseconds.¹⁵

Our relatively small increased range of motion after exercise (1.7° and 2°) is much less than that reported in the literature (Table 4).^{2,4,7,12,24,25} The reported loosening of tape after exercise is less when the method of testing employs dynamic weightbearing inversion.^{7,12,24} Of the studies listed in Table 4, 3 used a weightbearing form of testing.^{2,4,14} Although Martin and Harter²⁴ used an 8.5° laterally tilted treadmill running test to evaluate inversion angles and concluded that tape is unable to restrict inversion under dynamic loads, their testing did not approach the anatomical limits for an ankle sprain to occur. Keetch¹² and Pederson et al⁷ used a weightbearing test; however, their sampling rate was relatively slow at 60 Hz (compared with our sampling rate of 1000 Hz), and their

Table 4. Loss of Inversion Restriction Reported by Other Authors

Author(s)	% Loss	Pre-exercise (°)	Postexercise (°)	Difference (°)	Method of Measurement
Fumich et al ⁴ (1981)	28	15.00	20.80	5.8	Active/NWB* PF/INV†
Greene and Hillman ² (1990)	44	42.2 ± 3.98	75.54 ± 8.45	33.3	Passive/NWB INV‡
Keetch ¹² (1992)	15	8.40 ± .40	9.94 ± .40	1.5	Inversion Platform INV
Martin and Harter ²⁴ (1993)	65	9.9 ± 3.3	16.3 ± 3.1	6.4	Active/NWB
	22	12.0 ± 4.2	15.4 ± 6.5	3.4	Treadmill/WB§ INV
Paris et al ²⁵ (1995)	23	28.7 ± 6.9	35.2 ± 8.0	6.5	Passive/NWB INV
Pederson et al ⁷ (1997)	20	21.5 ± 5.2	27.0 ± 5.4	5.5	Inversion Platform INV

* NWB, Nonweightbearing.

† PF/INV, Plantar flexion and inversion.

‡ INV, Inversion.

§ WB, Weightbearing.

inversion platform protocol did not include testing the subjects in a plantar-flexed position.

To adequately test the effectiveness of a force bypass such as tape or a brace in preventing injury, the methods must use dynamic inversion with a weightbearing, plantar-flexed position while monitoring the activation of the evertor muscles. Weightbearing dynamic inversion is essential because most ankle sprains result from ankle inversion caused by landing on an object on the medial side of the shoe, and it is the motion of the body that forces the ankle into inversion. To protect the ankle from injury, a force bypass such as tape must withstand the magnitude and rate of torque application caused by the body's center of mass about the ankle joint. In addition to recording the amount of inversion, it is also necessary to record the time to maximum inversion and the inversion velocity to clinically evaluate the effectiveness of taping or bracing in protecting the ankle. The ideal ankle-sprain paradigm should involve an unexpected inversion in which the ankle inverts 35° in under 60 milliseconds.

An important result was the increased range of motion of the ankle in the no-tape condition. After exercise, there was a 1.0° difference from pre-exercise, possibly due to the increased extensibility of the connective tissue from a warming effect of increased blood flow. Libera²⁶ reported 36% increased range of motion during his control condition. Pederson et al⁷ reported 0.6° increased range of motion during their control condition. In our study, since the no-tape condition increased range of motion by 1.0° and our taping conditions increased it by about 2.0°, it could be suggested that 50% of the tape-increased range of motion was a result of anatomical loosening of the ankle.

CONCLUSIONS

There was no significant difference in total inversion, average inversion velocity, maximum inversion velocity, or time to maximum inversion between taping to the skin and taping over prewrap before and after exercise. The tape loosened significantly during exercise; however, we feel these differences in the amount and rate of inversion are not meaningful and that ankle taping provides residual inversion restriction. Tape decreases the inversion velocity and increases the

time to achieve maximum inversion, possibly allowing the neuromuscular system additional time to respond.

We recommend that testing of ankle prophylactic devices be done using a dynamic, unexpected inversion that includes plantar flexion and precludes the activation of the evertor muscles.

We found no evidence to support or refute the use of prewrap when taping an ankle. Whether or not to use prewrap may be a personal choice of the athletic trainer or athlete or based on the budget concerns of the purchasing institution or the condition of the athlete's skin after several consecutive days of taping. About 50% of the reported loosening of tape after exercise may be due to the increased extensibility of the ankle connective tissue.

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