Residual Mechanical Effectiveness of External Ankle Tape Before and After Competitive Professional Soccer Performance

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Objective: To evaluate the presupposed preventive residual mechanical effectiveness of the widespread use of adhesive elastic ankle tape after a nonlaboratory, realistic soccer-specific outfield intervention reflecting a soccer halftime.

Design: A prospective nonrandomized test–retest design was used.

Setting: Laboratory.

Participants: Seventeen professional male outfield players (mean age, 25.5) without any signs of chronic ankle instability.

Intervention: Participants were investigated before and after a 45-minute soccer-specific field intervention.

Main Outcome Measures: The passive inversion range of motion (ROM) of the ankle was tested unloaded on a self-developed inversion device with and without a standardized ankle tape before and after the intervention. Additionally, electromyography signal was taken to assure the inactivity of the protective evertor muscles, and reliability tests for the inversion device (test–retest and trial to trial) were conducted in 12 healthy controls.

Results: Tape restricted the maximum passive inversion ROM of the uninjured ankle significantly to 50.3%. The protection declined nearly completely after 45 minutes of outfield soccer performance to a negligible nonsignificant ROM restriction of 9.7%. Pearson correlation coefficient for the reliability was 0.931 ($P \leq 0.001$) for the test–retest and 0.983 ($P \leq 0.001$) for the trial-to-trial test.

Conclusions: The initial significant protection of external ankle-tape support declines almost completely without relevant remaining residual mechanical effect after 45 minutes, reflecting a soccer halftime. The so far presupposed residual mechanical effectiveness of tape to prevent injury is increasingly irrelevant during soccer performance and consequently antidromic to the increasing injury risk toward the end of a soccer halftime.

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The authors report no conflicts of interest.

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INTRODUCTION

Apart from muscle sprains, ankle distortions—especially of the inversion type with lesions of the anterolateral capsule ligament structures—are the most frequent injuries in professional soccer sports accounting for about 20% of all traumas.[1–6] In the majority of cases, excessive inversion of the foot causes the ankle sprain, whereat a simultaneous plantar flexion increases the injury risk.[7–9] Some injuries are forced by extrinsic factors such as landing on another player's foot.[10,11] However, the distortion may also occur as a consequence of deficits in proprioceptive and postural control at the moment of landing or when suddenly changing direction, especially in preinjured or fatigued athletes.[5,12,13] During soccer matches, a disproportionately high number of injuries occur during the last third of each halftime.[5,14–16]

Independent of the cause of injury, due to electromechanical and extended neuromuscular latency,[17,18] the dynamic defense mechanism is delayed. Consequently, the evertor muscles alone may not respond quickly enough to prevent ankle inversions.[10,17,19,20] Thus, to prevent ankle injuries in professional soccer players, in addition to specific proprioceptive and postural control exercises,[5,21,22] external ankle support seems essential, especially in players with a history of ankle injury.[5,9,19]

Bracing and adhesive taping of the ankle are known to be of potential benefit and are commonly used to prevent and treat ankle injuries.[23–29] Nonetheless, although the effect of adhesive ankle tape remains inconclusive, in comparison to semirigid orthoses and braces, its use and acceptance is more favored and widely relied on among athletes and sports physicians.[9,26,30] This is irrespective of repeatedly confirmed disadvantages of taping, such as the necessity of a qualified applier or the material and provider costs of multiple applications together with the loss of effectiveness with time.[10,19,25,26,28,31–37] Because of its high acceptance among soccer professionals (approximately 70% before competitions), players often accentuate the advantages of taping, which allows a more individual adaptation to the ankle, thus providing greater wearing comfort and a sense of protection.[1] Furthermore, the majority of players fear a loss of soccer performance skills when using semirigid devices, lace-up devices, or even braces, even though not yet scientifically reasoned.[23]

The protective effects of ankle taping are described primarily as mechanical[19,24,32,38,39] and secondarily as postural,[16,19] proprioceptive,[19,38,40,41] and even psychological placebo effects.[25,36,42] It has even been suggested that enhancing the players' "belief" in the stability of tape might assure its effectiveness.[25,36]

Numerous studies investigated the effect of tape ankle support, many of them before and after exercise.[10,16,19,26,33,38,41,43–45] Independent of study design and despite the general agreement that there is a certain loss of mechanical effectiveness after exercise, so far, most researchers have also described a significant residual maintaining effect of tape even after vigorous exercise tests between 10 and 30 minutes.[8,25,35,44]

To date, no studies have tested the distinct mechanical properties of adhesive ankle tape before and after dynamic nonlaboratory training or match performance in professional soccer. In addition, despite a realistic exercise field intervention, the tape-related limitation of passive inversion range of motion with confirmed exclusion of any muscle-related stabilizing or proprioceptive component has yet not been examined. Last but not least, only few studies have evaluated the protective properties of tape beyond 30 minutes of exercise, which is when soccer athletes become increasingly fatigued and thus have a higher risk of injury.[15]

Consequently, we hypothesized that—during realistic competitive soccer performance reflecting a halftime of 45 minutes—ankle tape might lose most of its assumed initial mechanical effectiveness to reliably prevent ankle distortions.

The objective of this study was to quantify the distinct mechanical inversion restriction of ankle tape before and after a realistic amount of competitive professional soccer performance and consequently discuss the presupposed gain of adhesive tape in preventing ankle injuries in professional soccer athletes.

MATERIALS AND METHODS

Subjects

A prospective nonrandomized test–retest design was used. Seventeen professional, male premier league outfield soccer players [mean (±SD) age = 25.5 (±3.5) years; height = 180.6 (±7.7) cm; and mass = 77.5 (±6.6) kg] participated in the study. Only players with asymptomatic ankle joints (no signs of chronic instability before the study investigation) and without history of previous ankle sprains over the past 12 months were included. A history of ankle injury older than 12 months was documented but of no further relevance for the study itself if not chronically instable. Furthermore, all subjects were free from other injuries or physical complaints. All subjects had previously experienced tape protection during training or for matches periodically and thus were familiar with tape protection. All participants gave their informed written consent, and the study was approved by the Institutional Review Board of the Sports University of Cologne.

Testing Device

A self-developed measuring device was used to monitor passive ankle inversion movement. Participants lay on their side with the foot and lower leg completely fixated in the device. The upper body was positioned with the assistance of mats to allow the best possible orthogonal posture of the leg and ankle in relation to the testing apparatus. The position of the foot, the lower leg, and the ankle joint could be adjusted and fixed accurately in each plane to apply inversion torque to the ankle joint as definite as possible and without the possibility of evasive movements (Figure 1). After individual adjustment for each measuring cycle, the tilting platform was unlocked to invert the foot and locked at the end of each cycle. The instrument settings remained the same for the complete measuring cycle of 1 athlete. A weight of 1.5 kg was applied to a lever arm on the tilting platform, thus inverting the ankle until achieving limitation (Figure 2). An electric goniometer, recording 1000 measures per second, detected the range of inversion motion (Inv-ROM) over a period of 20 seconds. The first 3 and the last 5 seconds of each measuring cycle were discarded and not included in the subsequent analysis. To assure unlimited movement without any muscular stabilizing activity, the electrical activity of the evertor muscles was recorded using surface electromyography (EMG). For this purpose, the relevant muscles (long peroneal muscle and anterior tibial muscle) were exactly located using ultrasound. Surface electrodes were then applied to the shaved and cleaned skin. At the beginning of each testing cycle, the absence of mechanical artifacts of the leads was

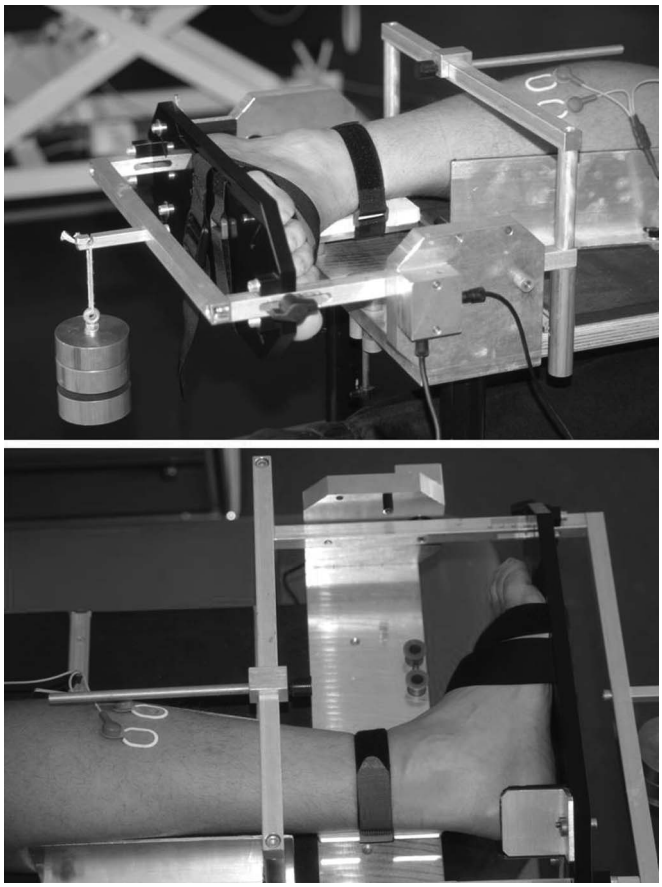

FIGURE 1. Adjusted position of the subject's foot and lower leg in the measuring device.

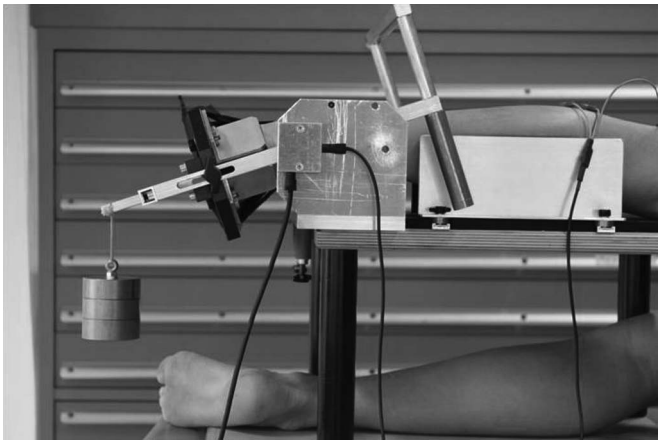

FIGURE 2. Passive ankle inversion.

assured, and the whole system was calibrated. Amplified EMG signal was measured during each testing cycle to assure muscular inactivity (Figure 3).

Before data collection, a reliability test [a test–retest (n = 12, retest after 7 days) and a trial-to-trial test (n = 12, 3 measurements)] were conducted. Reliability was estimated as the Pearson product–moment correlation coefficient. Pearson correlation coefficient (P_r) for the test–retest range of motion (ROM) was 0.931 ($P \leq 0.001$) and for the trial-to-trial ROM was 0.983 ($P \leq 0.001$).

Tape Application

The tapes were applied by a qualified experienced team physiotherapist with experience in professional soccer sports of approximately 1000 tapes per year over the past 20 years. Adhesive, nonelastic Leukotape Classic (3.75 cm × 10 m; BSN Medical, Hamburg, Germany) with an under wrap of cohesive elastic Gazofix fixation bandage (8 cm × 20 m; BSN Medical) was used. Upon personal preference, lubricated Cellona heel and lace cast edge pads (8 cm × 5 m; Lohmann & Rauscher, Neuwied, Germany) were placed over the Achilles tendon and the pretibial tendons. Prewrap was then applied circumferentially from the distal end of the midfoot to the base of the calf (Figure 4A). In accordance with other studies, the tapes were applied using a standardized technique with an average amount of 6.5-m tape.[19,35,39] Two semicircular anchors were placed slightly beyond the prewrap at the base of the calf and the distal end of the midfoot (Figure 4B). Tape was then applied in a standard basket weave pattern, using 3 medial to lateral inversion stirrups each followed by a circular anchor (Figure 4C, D). Finally, 2 heal locks and 2 figure eights were applied (Figure 4E). The tape was then finally completed by semicircular anchoring from the proximal to the distal midfoot (Figure 4F).

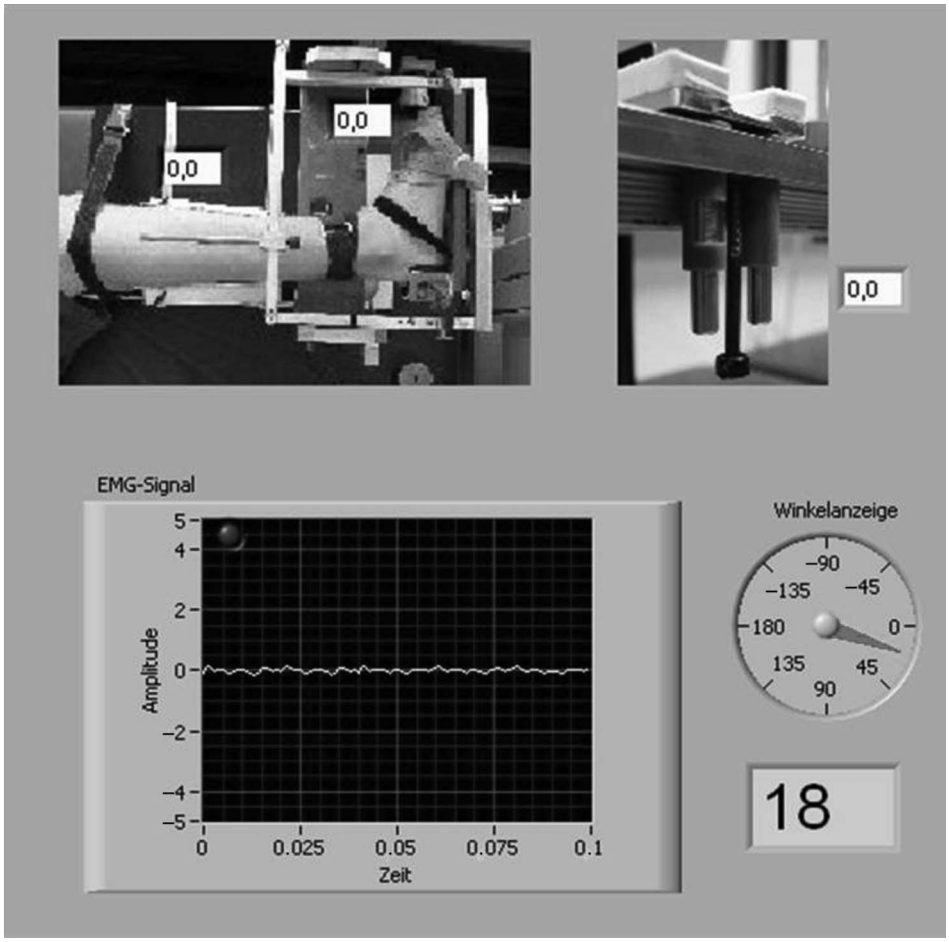

FIGURE 3. Monitoring of the stabilizing evertor muscles.

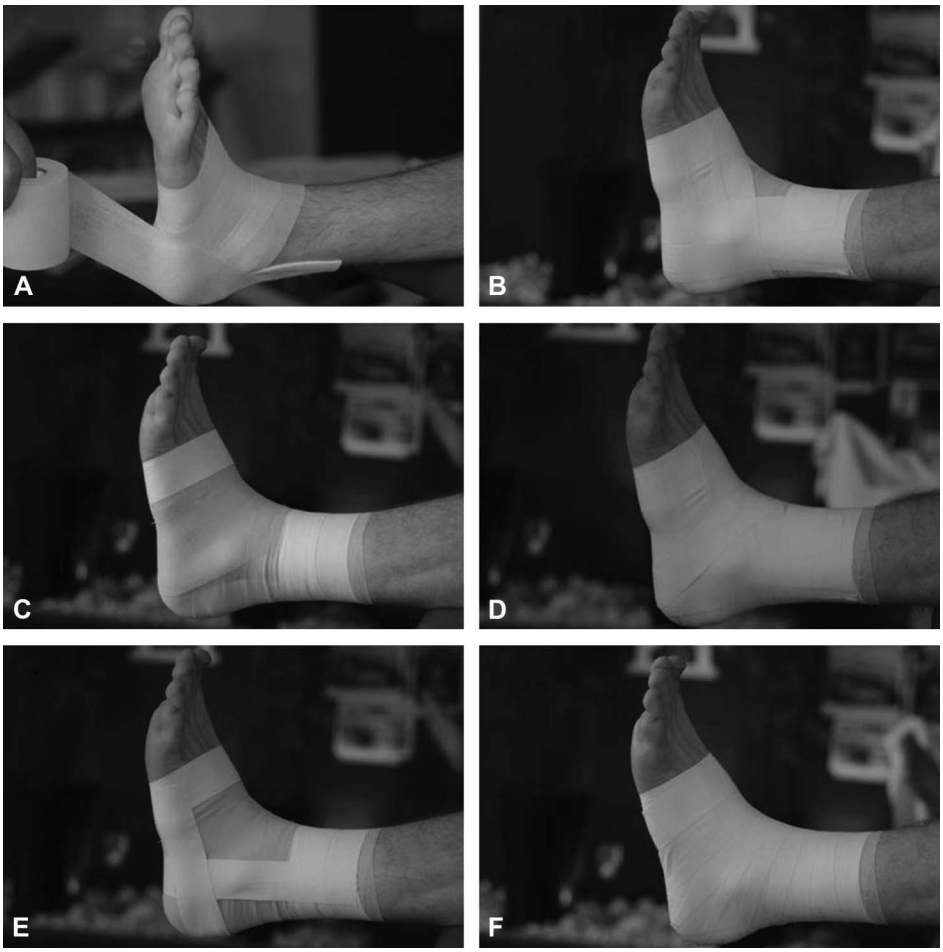

FIGURE 4. Tape application.

Training/Exercise Conditions

All soccer performance training sessions were completed during dry weather conditions with a comparable air temperature of 18 ± 6 °C. After tape application, all subjects participated in a normal soccer-specific training session on a natural grass pitch with the rest of their team. Training on test days consisted of a general warm-up (10-15 minutes of running and/or small ball-specific small-sided games) followed by different elements of soccer-specific training (10 vs 10, game rules, kicking, etc). Training sessions intending to train tactical performances (required standing phases due to interruptions by the coach up to 1 minute) or endurance-specific training was disregarded to imitate a match situation as closely as possible.

Testing Protocol

Initially, players were tested with the inversion apparatus before a training session without any tape protection (baseline). After application of the ankle tape, players were immediately retested after 3 minutes of normal walking (pretest). After walking over to the pitch (maximum distance, approximately 100 m), all players participated in the above-mentioned soccer-specific training. After 45 minutes of training, players were tested again while wearing the used tape (posttest), followed by a final retest (baseline retest) without tape.

Statistics

A Shapiro–Wilk test revealed a nonnormally distributed population in all measurements (W = baseline, 0.838; pretest, 0.702; postexercise, 0.863; and baseline retest, 0.813). Thus, for further data analysis a nonparametric Mann–Whitney–Wilcoxon test for differences in ROM between the single measurements was used.

RESULTS

Seventeen players were investigated, where 2 players dropped out because of an early abruption of training. Means and SDs for the Inv-ROM during the different test conditions of 15 subjects are provided in Figure 5.

The mean Inv-ROM decreased from 14.0-degree angle (SD, 5.0) to 7.0-degree angle (SD, 3.7) after tape application. This reflects a statistically highly significantly decrease in ROM decline of 50.3% ($P < 0.0001$). Ankle inversion range of motion increased statistically highly significantly ($P < 0.0001$) after 45 minutes of soccer performance from 7.0-degree angle (SD, 3.7) to 12.6-degree angle (SD, 3.7). This

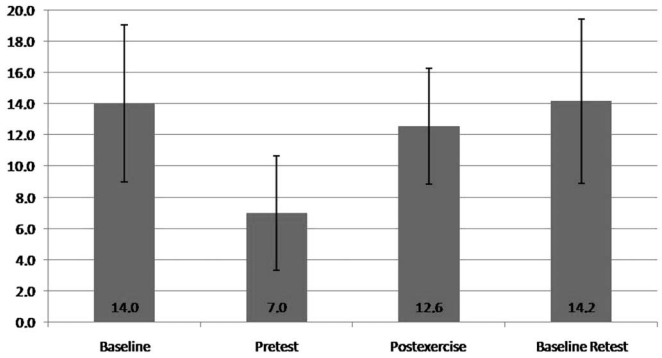

FIGURE 5. Means and SDs for the passive Inv-ROM during the different test conditions.

reflects 90.3% Inv-ROM of the primarily untapped situation (Table 1).

In congruence to the reliability testing before investigation, baseline test and baseline retest revealed no significant differences ($P = 0.7414$); and both postexercise test and baseline retest ($P = 0.3735$) and postexercise test and baseline test ($P = 0.4179$) showed no significant differences.

DISCUSSION

Our results clearly confirm a significant loss of mechanical inversion restriction after 45 minutes of competitive soccer performance. This finding itself is not surprising, as a certain decrease of inversion ROM restriction due to exercise has been described numerously in previous studies.[10,19,25,28,31–33,35–37,44] Nonetheless, the vast majority of these studies also report on a significant residual maintenance of stabilizing characteristics up to 50%, even after 20 to 30 minutes of vigorous controlled laboratory exercise.[8,10,25,35,44–47] In contrast, our findings after 45 minutes of soccer-specific training showed not only a partial but also quasi-complete loss of mechanical effectiveness with a negligible nonsignificant residual mechanical protection to the preexercise testing.

One of the main explanations for this clear outcome of course might be the duration and the type of exercise intervention. To the best of our knowledge, the majority of previous studies used laboratory exercise interventions of up to 30 minutes with or without attempting to replicate team sport situations as good as possible. For example, Meana et al[10] described a 40% loss of dynamic support using an agility course with 6 changes of direction and vertical jumps which the subjects completed for 30 minutes including warm-up, joint mobilization, and stretching. Alt et al[19] favored an exercise sequence of 2 × 10-minute treadmill running followed by jump exercises on a jumping platform, revealing a postexercise loss of effectiveness of only 4% to 14%. Purcell et al[35] investigated ankle-tape properties after a continuously repeated exercise routine of 20 minutes (excluding 5 minutes warm-up) including several shuffles, jumps, and stop and go movements. Their results showed more than 50% maintenance of the investigated adherent tapes' original restrictive properties. In one of the few studies considering soccer-specific activity over a period longer than 30 minutes, Lohkamp et al[16] tried to replicate the activity of soccer match play during a 45-minute treadmill protocol comprising 195 discrete bouts of activity based on work–rate profiles of professional soccer players and repeated for 3 times, tentatively reflecting a soccer halftime. Their findings focused on postural stability and only described a nonquantitative decrease of mechanical stability. In accordance with our results, Manfroy et al[25] did not find a significantly higher resistance of inversion moments under unipedal weight-bearing conditions after 40 minutes of standardized vigorous laboratory exercise on a treadmill and agility drills. Finally, after a comparable amount of laboratory exercise on a treadmill, Paris et al[8] revealed a residual restriction of passive inversion range of motion of 15% to 20% after 45 and 60 minutes, respectively. However, their experimental setup did not consider the isochronic influence of the stabilizing evertor muscles.

Consequently, we investigated the effect of 45 minutes of nonlaboratory exercise such as competitive soccer performance, comprising different running performances, ball contacts, kicking, match related shuffles, and/or tacklings. Using the same standard tape application as most other investigations, our study suggests that under real professional competitive soccer conditions, maintaining even some residual mechanical stability of an ankle tape over the complete period of a soccer halftime or soccer practice >30 minutes cannot be expected. Furthermore, as consciously all subjects were tested in dry weather conditions, one may expect an even higher loss of effectiveness in wet conditions.

This is consistent with Bragg et al,[32] who expect a tape in soccer sports to remain stable not longer than the warm-up or with Myburgh et al[47] who found no more protective effects of tape after a 1-hour squash match. Furthermore, Lohkamp et al[16] did not find a significant increase of postural stabilization in 10 taped male semiprofessional soccer players beyond the first 15 minutes of soccer-replicating exercise. Thus, the protective effect of ankle tape beyond the first 15 minutes of a soccer match and especially in the risky last third of a halftime has to be more than doubted. Far from it, as simultaneously the injury incidence almost triples toward the last third of a halftime,[15] the loss of protective effectiveness is even more severe.

It is important to take into account that a sudden inversion impact on the ankle joint might reveal different tape stabilization characteristics in comparison to a load control testing. For example, it is suggested that dynamic inversion might increase tape-to-skin contact, and thus the beneficial

TABLE 1. Tape Associated Percentaged Inv-ROM Restriction Before Intervention and Postexercise Inv-ROM Compared to Baseline

	Pretest ROM Restriction (%)	Postexercise ROM (%)	Adjusted Postexercise ROM (%)
Mean	50.3	91.7	90.3
Variance	140.6	127.1	86.2
SD	11.9	11.3	9.3

Few (n = 4) measurements showed nonsignificantly slightly higher Inv-ROM postexercise, according to >100% of baseline values (within test–retest variance, maximum 103%). At this, values were adjusted to 100% (third column).

sensory input.[25] Nevertheless, the high-angle velocity of up to 400 degrees/s in trauma conditions[19] anyway requires a passive nonfatiguing external support to allow an effective corrective response in time.

Several studies have quantified the maximum ankle ROM in the frontal and sagittal planes under weight-bearing conditions. They either used electric goniometers with the subjects on a tilting inversion platform to simulate the injury mechanism,[19] by 2- or 3-dimensional video analysis on an inversion platform,[26] or during exercise movements.[10] Additionally, some studies used surface electromyography[19,28] to record the level of activity of the peroneus longus and the tibialis anterior muscle to monitor preactivation and muscle guarding. It is important to remember that a tested athlete on an inversion platform or during test exercises is biased (he expects a "sudden" inversion or destabilization) which may cause his protective evertor muscles to be even more preactivated than usual.[42] Consequently, this influences the evaluation of distinct monitored ROM of the ankle. Therefore, we tested our subjects' ankle ROM passively with completely inactive stabilizing muscles to solely evaluate the effectiveness of the tape.

It could be argued that this articulate loss of mechanical properties might depend on the tape application technique or rather a direct application of tape to the skin without the use of a prewrap layer. Neither Ricard et al nor Manfroy et al found any significant differences in inversion restriction between taping to the skin and taping over prewrap.[25,26] Manfroy et al[25] even revealed a significantly more decreased ankle ROM using nonadhesive prewrap compared to taping to the skin.

A study limitation of course is the monodirectional instead of a multidirectional recording of ROM; for example, simultaneous recording of plantar flexion would have allowed a better 3-dimensional evaluation of the ankle joint kinematics, as plantar flexion increases the injury risk.[19] Nevertheless, regarding the clear results in the frontal plane, comparable to other studies, we do not expect a significant aberrant beneficial residual ROM restriction after 45 minutes.[35]

Furthermore, we could not resolve an exact resistance curve of the mechanical tape properties over the exercise period of 45 minutes. Paris et al[8] investigated their subjects after 15, 30, 45, and 60 minutes demonstrating the most remarkable loss of effectiveness of tape application after 15-minute treadmill activity. Though difficult to realize with a professional soccer team, further research should retest the subjects after 15 and 30 minutes of soccer performance to determine an exact resistance curve of loss of effectiveness.

In conclusion, although recent reviews suggest a decrease in injury rates using ankle tape in previously injured players,[48] ankle tape does not assure a protective mechanical effect against ankle sprains over the period of a soccer halftime. The results of the current study suggest that tape would have to be renewed at least twice per match (after warming up, halftime) to increase its preventive benefit.

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