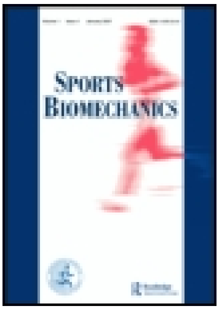

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Effects of previous lateral ankle sprain and taping on the latency of the peroneus longus

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Effects of previous lateral ankle sprain and taping on the latency of the peroneus longus

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Abstract
The latency of the peroneus longus may be a key factor in the prevention of lateral ankle sprains (LASs). In addition, ankle taping is often applied to help prevent LASs. The purpose of this study was to determine the effects of a previous LAS and ankle taping on the latency of the peroneus longus after an inversion perturbation. Twenty-six participants, including 13 participants with no previous history of a LAS and 13 participants with a history of a single LAS completed the testing. Ankle taping was applied in a closed basket weave technique on one of the two testing days. The latency of the peroneus longus was determined by the onset of muscle activity exceeding 10 *SD* from baseline activity, after initiation of the 25° inversion perturbation. A significant main effect ($p < 0.05$) was present for the ankle support condition, with ankle taping causing a significant reduction in latency of the peroneus longus (65.04 ± 10.81 to 57.70 ± 9.39 ms). There was no difference ($p > 0.05$) in latency between the injury groups. Ankle taping, immediately after application, reduces the latency of the peroneus longus among participants with and without a history of a LAS.

Keywords: *Inversion perturbation, reaction time, injury, lower extremity*

Introduction

The lateral ankle sprain (LAS) is the most common injury in athletics (Shima et al., 2005) and the most commonly reported injury in National Collegiate Athletic Association (NCAA) athletics (Hootman et al., 2007). Approximately 25,000 people sprain an ankle daily in the USA (Olmstead et al., 2004) and half of the general population will sustain at least one ankle sprain in their lifetime (Nyska et al., 2003). A recent study found that during the 2005–2006 school year, ankle injuries accounted for 22.6% of all injuries among high school athletes, and those sports that involved jumping and landing near other players and quick changes of direction placed athletes at the greatest risk for an ankle sprain (Nelson et al., 2007).

When the ankle is forced into inversion, both intrinsic and extrinsic factors help protect against a LAS. Intrinsic factors include (but are not limited to) lateral ankle ligaments, joint capsule, bony structures, and muscles/tendons that cross the joint (Hertel, 2002). The peroneus longus muscle has been labeled by many as the primary dynamic defense against

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a LAS (Ashton-Miller et al., 1996; Konradsen et al., 1997; Cordova et al., 2002; Hertel, 2002; Heckman et al., 2008), as it provides the greatest contribution to hindfoot eversion strength and helps limit the amount of inversion (Heckman et al., 2008). When the ankle is rapidly forced into inversion, muscle spindles in the peroneus longus are activated and cause a reflexive contraction to counteract this lengthening. This reflex is employed in an effort to prevent damage to lateral structures of the ankle (Jackson et al., 2009). In addition to the latency of the peroneus longus, the electromechanical delay of this muscle, which is the time from the onset of muscle activity to the development of tension within the muscle, must also be considered. Previous research (Konradsen et al., 1997) has indicated that once the electromechanical delay of the peroneus longus is added to latency, dynamic protection begins at approximately 126 ms after the perturbation, which is likely not quick enough to prevent a LAS (Konradsen et al., 1997). However, it has been argued that timely activation of the peroneus longus is critical to maximize stability of the ankle (Palmieri-Smith et al., 2009). A previous ankle sprain may result in proprioceptive deficits (Mitchell et al., 2008), which could lead to longer peroneal latencies, a reduction in the dynamic stabilization of the joint, and an increased risk of re-injury (Midgley et al., 2007). It is difficult to be definitive regarding the influence of previous LAS on the latency of the peroneus longus as some studies have found an increase in the latency following injury (Konradsen & Ravn, 1991; Karlsson & Andreasson, 1992; Mitchell et al., 2008), while others found no difference in the latency of the peroneus longus between healthy participants and those with a previous injury (Johnson & Johnson, 1993; Ebig et al., 1997; Vaes et al., 2002).

Of the extrinsic factors that may help prevent a LAS, ankle taping is one of the most common (Refshauge et al., 2008). Ankle taping helps limit excessive range of motion and protects the ankle ligaments against excessive strain (Ashton-Miller et al., 1996; Wilkerson, 2002), and past research has found that ankle taping and bracing are effective at preventing recurrent ankle sprains (Beynnon et al., 2002). It has also been theorized that ankle taping increases the excitability of the motoneuron pool by increasing cutaneous input (Lohrer et al., 1999), thus reducing latency of the peroneus longus. A meta-analysis by Cordova et al. (2002) identified research prior to 2002 that examined the effects of ankle taping on the latency of the peroneus longus. Two studies reported that ankle taping reduced the latency of the peroneus longus (Karlsson & Andreasson, 1992; Lohrer et al., 1999), three reported no effect on latency (Sprigings et al., 1981; Alt et al., 1999; Midgley et al., 2007), and another reported that ankle taping increased the latency of the peroneus longus (Shima et al., 2005). It is in light of these conflicting results that this project was undertaken.

The effect of chronic ankle instability (CAI) on the latency of the peroneus longus has received considerable attention. However, long-term effects of a single LAS on the latency of the peroneus longus have not been examined. Although the recurrence rate of LAS is between 70% and 80% (Ashton-Miller et al., 1996), not all people who sustain a LAS develop CAI, as this percentage has been reported between 32% and 40% (Mitchell et al., 2008). Thus, a person that sustains a LAS may not develop CAI, but are still at risk of a recurrent ankle sprain. Furthermore, ankle taping may be a method that could reduce the latency of the peroneus longus after an injury and help prevent recurrent ankle sprains. A timely response by the peroneus longus is critical after the ankle is forced into inversion (Palmieri-Smith et al., 2009) and if ankle taping can shorten this response, it may be a way to help prevent recurrent LASs (Lohrer et al., 1999). The specific purpose of this study was to determine the effects of a previous single LAS and ankle taping on the latency of the peroneus longus by using an outer sole with fulcrum mechanism to force the ankle into inversion and replicate the mechanism of a LAS that occurs when landing on the foot of another person (Ubell et al., 2003; Midgley et al., 2007). The authors hypothesized that the peroneus longus of the previous injury group would have a greater latency than the no injury group, and that ankle taping would significantly reduce the latency of the peroneus longus when compared with no ankle taping for both groups.

Methods

Twenty-six healthy, physically active participants completed the study. All participants were free of any current lower body injury or any previous history of surgery or fracture to the lower extremity. Thirteen participants (nine males and four females) with no previous history of a LAS comprised the control (CT) group (age = 21.6 ± 1.2 years; mass = 72.53 ± 14.53 kg; height = 1.75 ± 0.09 m), and 13 participants (five males and eight females) comprised the previous LAS group (age = 21.3 ± 1.2 years; mass = 75.32 ± 15.01 kg; height = 1.75 ± 0.08 m). Each participant in the LAS group had suffered a single LAS of one ankle, as diagnosed by a physician, had missed at least one day of practice/physical activity due to the injury, had no ankle/foot injury of the contralateral leg, and stated that he/she had completed a supervised rehabilitation program. All participants were free of any symptoms of CAI. The average amount of time from occurrence of the ankle sprain to testing was 4.2 ± 1.2 years. The authors' institutional review board approved the study and all participants signed an informed consent statement.

A left and right outer sole, made of orthoplast, was developed for US men's shoe size 10–11 and US women's shoe size 8–9, which corresponded to the shoe size of the participants. To produce 25° of inversion upon landing, a 6-mm thick and 30-mm high fulcrum was placed 20 mm from the medial border of the outer sole and ran the length of the outer sole (Figure 1). A similar mechanism had been used (Ubell et al., 2003) to force the ankle into inversion, but not to measure latency. The outer sole was attached to a low top, flat soled athletic shoe of the participants using Velcro™ straps. A left and right men's and women's flat outer sole was also made out of orthoplast. The flat outer sole was randomly interchanged with the outer sole with fulcrum to prevent anticipation of the inversion perturbation.

The muscle activity was recorded with a multichannel electromyography (EMG) amplifier/processor unit (MyoClinical, Noraxon USA, Inc., Scottsdale, AZ, USA) using wet gelled bipolar Ag–AgCl disk surface electrode pairs (Blue Sensor SE, Ambu, Inc., Ballerup, Denmark) interfaced with a notebook computer. The raw EMG signal was amplified with an input impedance of 10 MΩ, with the gain set at 1000 ×, with a common mode rejection ratio > 115 dB. Electrode placement sites were shaved, abraded with sandpaper, and cleaned with rubbing alcohol. Surface EMG electrodes were placed over the most prominent part of the muscle belly of the peroneus longus with a 2-cm inter-electrode distance (Hopkins et al., 2007; Kernozek et al., 2008). The reference electrode was placed over the tibial tuberosity. Proper electrode placement was verified by observing the EMG signal on a computer monitor during maximum voluntary ankle eversion and plantar flexion to ensure that there was no crosstalk present from adjacent muscles (Kernozek et al., 2008).

A metal landing surface (Figure 1) was constructed, and metal was also attached to the fulcrum and lateral border of the outer sole. When the fulcrum made contact with the landing area, a signal was sent to one of the EMG channels, indicating ground contact and coinciding with the beginning of the inversion moment. When the lateral border of the outer sole made contact with the landing area (Figure 2), a second signal was sent to a different EMG channel, indicating that the participant completed the 25° of inversion.

Participants reported for testing on two separate days, 48 h apart, and electrode placement sites were marked with a permanent marker. Two testing days were necessary in order to reduce the impact of fatigue on latency measures and due to safety concerns. Other studies examining latency have compared EMG data across days (Lynch et al., 1996; Lohrer et al.,

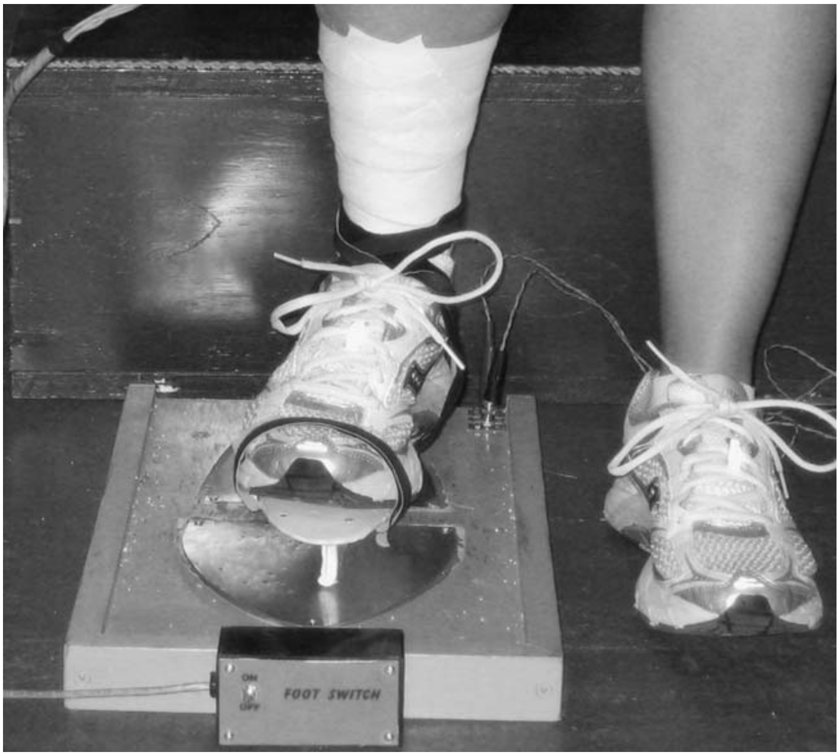

Figure 1. Participant landing on the fulcrum, initiating the 25° inversion perturbation.

1999) or even weeks (Cordova et al., 2000; Midgley et al., 2007). On day one of testing, 12 participants were randomly assigned to the ankle taping group, and 14 participants were randomly assigned to the no ankle taping group. On day two, the participants completed testing under the other support condition (14 ankle taping, 12 no ankle taping). On the day ankle taping was assigned, each participant had his or her ankles taped in a closed basket weave (Gibney) technique by the same certified athletic trainer. Foam pre-wrap (Z – wrap, Johnson & Johnson, Langhorne, PA, USA) was applied first, followed by 1.5 inch Coach™ Tape by Johnson and Johnson. After the pre-wrap was applied, two anchor strips of tape were placed just distal to the base of the gastrocnemius, followed by one anchor strip around the mid-foot just proximal to the base of the fifth metatarsal. Three stirrups and three horseshoes were then applied in an alternating manner, proceeding from the medial side to the lateral side. Next, two horseshoes and two figure eights were applied. To complete the taping, closure strips were applied to any open areas.

Once prepared for testing, the participants stood on a 27-cm high box (this height was chosen for safety reasons) on the non-testing leg, and moved the foot of the testing leg behind them by flexing the knee and extending the hip (this prevented the participant from viewing outer sole assignment). Next, either the outer sole with fulcrum or flat outer sole was secured to the participants shoe with Velcro™, in random order (weights of the flat and the fulcrum outer soles were comparable to avoid anticipation). After the outer sole was secured, the participant was instructed to swing his or her leg forward and allow the foot to hang down in front of them in a natural position. After visually confirming that there was no pre-activity in the peroneus longus, the participants were instructed to step down off the box onto the

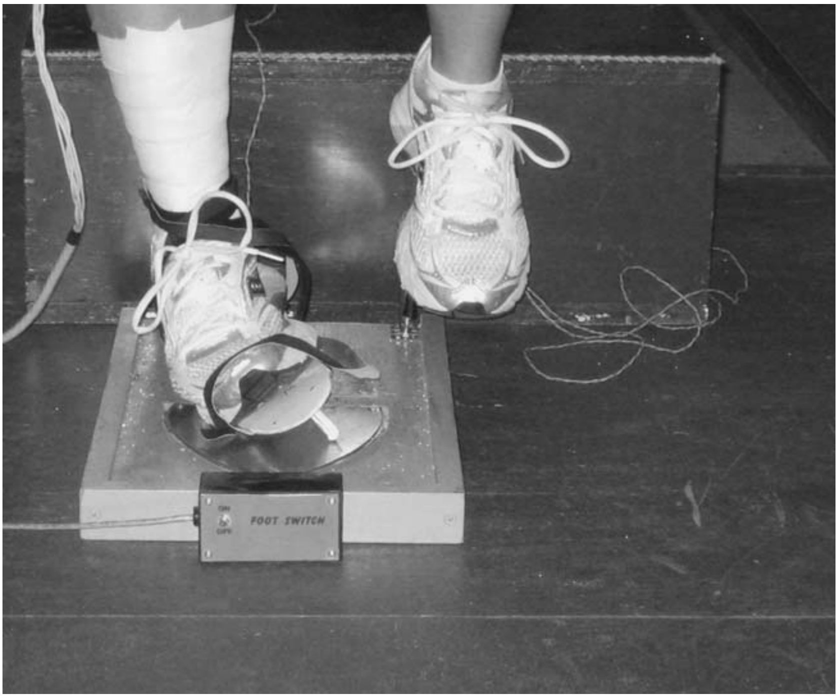

Figure 2. Contact of lateral border of outer sole with metal landing area, indicating completion of the 25° of inversion.

testing leg. Trials in which the participant flexed the non-testing knee or hip to lower themselves down from the box were excluded. Participants were instructed to land flat footed in order to keep the initiation of the inversion moment as consistent as possible. Participants were also instructed to look straight ahead and not down at his or her foot during the entire testing protocol, even though the bottom of the outer sole could not be viewed by the participant. The 25° of inversion was completed when the lateral border of the outer sole made contact with the landing area. Spotters were present in case the participant lost his or her balance. After landing, the outer sole was removed and placed behind the participant. The same procedure was followed until 10 inversion trials had been performed. The latency of each of the 10 trials for the outer sole with fulcrum was averaged separately for each leg.

The EMG signal was band pass filtered (6th-order Butterworth, with cut-off frequencies of 8 and 535 Hz), and full wave rectified. The dependent variable was latency, in milliseconds, of the peroneus longus. Latency was defined as the time from contact of the fulcrum with the landing area to the time of muscle activity exceeding 10 *SD* (Lynch et al., 1996; Kernozek et al., 2008; Jackson et al., 2009) from a baseline muscle activity, which was taken 200 ms before landing. This latency variable is a measure of the amount of time it takes a main evertor of the foot/ankle complex to become active after the initiation of forced inversion of the foot/ankle complex. The more conservative criteria of 10 *SD* above baseline activity were chosen as opposed to 2 *SD* employed in other studies (Lynch et al., 1996; Hopkins et al., 2007; Midgley et al., 2007) in order to apply the most rigorous evaluation of latency. However, this does not include the electromechanical delay, which is the time from the beginning of EMG activity to force production in the muscle. Although the latency of the peroneus longus is a component of the protective mechanism, only when it is combined with

Table I. Results of statistical analyses and descriptive statistics.

Effects	SS (sum of squares)	*df*	Mean squares	*F*	*p*	η_p^2	Variable	Latency (ms)	95% Confidence interval Lower bound	Upper bound
Injury history	121.10	1	121.10	0.776	0.387	0.031	No injury	63.9 ± 12.1	58.92	68.91
							LAS	62.5 ± 10.7	57.51	67.49
Error	3746.91	24	156.12							
Support	700.01	1	700.01	13.430	0.001	0.359	No tape	65.0 ± 10.8	60.6	69.49
							Tape	57.7 ± 9.4	53.91	61.49
Error	1250.64	24	52.11							
Injury × support	9.92	1	9.92	0.190	0.667	0.008				
Error	1250.64	24	52.11							

Notes: These data are expressed as *M* ± *SD*. LAS, lateral ankle sprain.

the electromechanical delay can a full picture of the protective mechanism be evaluated. The electromechanical delay should be considered in future research but is beyond the scope of this initial investigation. All data were visually inspected for signs of anticipation (spikes in muscle activity before contact with the landing area) and the trial was discarded if there was excessive activity prior to contact of the fulcrum with the landing area.

Independent samples *t*-tests were performed to assess differences in age, height, and mass between the two injury groups. It has been suggested that there is a central deficit present after a previous ankle sprain, and therefore comparisons should only be made with a healthy control group (Vaes et al., 2002). Therefore, individuals with previously injured ankles were matched with healthy controls of a similar mass (±3 kg) and height (±5 cm), and were also matched with the side of injury (dominant and non-dominant). A 2 (injury group) × 2 (ankle support) analysis of variance with repeated measures on the last variable was conducted to determine whether there was a significant difference in the latency of the peroneus longus among the different injury groups and different ankle support conditions. Partial η^2 values were calculated as a measure of effect size. Tukey's HSD was used to detect any *post hoc* difference. The a priori α level was set at $p < 0.05$. All statistical analyses were conducted with the Statistical Package for Social Sciences v 16.0 (SPSS Inc., Chicago, IL, USA) for Windows.

Results

The *t*-tests revealed no significant differences between the age ($p = 0.515$), height ($p = 0.635$), and mass ($p = 0.943$) of the participants in the no injury and previous injury groups.

For the latency data, the results revealed no significant interaction between ankle support condition and injury condition ($p > 0.05$), and no significant main effects for injury group ($p > 0.05$). There was a significant main effect for ankle taping ($F_{1,24} = 13.43$, $p < 0.01$, $\eta_p^2 = 0.359$), where ankle taping caused a significant mean reduction from 65.04 to 57.70 ms. The results of all statistical analyses and the means, SD, and 95% confidence intervals are given in Table I.

Discussion

The clinically relevant findings of the current study include the reduction in latency of the peroneus longus immediately after ankle taping. These results support the use of ankle taping as a way to reduce the latency of the peroneus longus and possibly increase dynamic stabilization of the ankle when exposed to an inversion perturbation immediately after application. Latency and electromechanical delay (Konradsen et al., 1997) are a measure of the ability of the peroneus longus to respond quickly enough to an inversion perturbation to prevent a LAS or limit the damage to the lateral ankle structures. Therefore, a reduction in latency as well as a reduction in range of motion caused by ankle taping (Wilkerson, 2002) may work together to reduce the likelihood of LASs.

Ankle taping did cause a significant reduction in the latency of the peroneus longus (Table I) among both groups of participants. While this finding was significant, the effect size was small to moderate. This may be due to the inclusion criteria for the LAS group limiting the sample size, the conservative criteria used to determine the onset of the peroneus longus (10 *SD* as opposed to 5 *SD* or 2 *SD*), and the large SD. This finding of a reduction in peroneal latency after the application of ankle taping is in agreement with previous work by Karlsson and Andreasson (1992) and Lohrer et al. (1999). However, other research did not report a significant difference in the latency of the peroneus longus after ankle taping (Sprigings et al., 1981; Alt et al., 1999; Midgley et al., 2007), and one study found an increase in peroneal latency after the application of ankle taping (Shima et al., 2005). Again, these conflicting findings may partially be the result of methodological differences, such as the mechanism used to cause inversion at the ankle and criteria to determine the onset of the peroneus longus. However, the majority of research, including the present study, has reported that ankle taping does not have a negative impact on the latency of the peroneus longus (Sprigings et al., 1981; Karlsson & Andreasson, 1992; Alt et al., 1999; Lohrer et al., 1999; Midgley et al., 2007). Since the present study did not measure electromechanical delay, a definitive conclusion regarding the protective measure of ankle taping on peroneal latency cannot be made. However, a reduction in peroneal latency, when added to the electromechanical delay, would increase the protective mechanism of the peroneus longus if the time of this response is shorter than the amount of time it takes the ankle to reach a degree of inversion significant enough to cause injury (Vaes et al., 2002). Future research should examine the effects of ankle taping on peroneal latency and electromechanical delay under dynamic conditions and after a bout of exercise.

Much of the previous work investigating the influence of previous ankle sprains on latency of the peroneus longus has examined participants with CAI (Johnson & Johnson, 1993; Ebig et al., 1997; Vaes et al., 2002; Mitchell et al., 2008); however, the long-term effects of a single LAS that does not cause CAI are relatively unknown. It has been suggested that as much as half of the general population will sustain an ankle sprain during their lifetime (Ashton-Miller et al., 1996; Nyska et al., 2003) and many people view this injury as trivial and do not seek medical treatment for ankle sprains (Ashton-Miller et al., 1996). The long-term effects of these seemingly 'minor' ankle sprains deserve more attention. Although there was not a difference in the latency of the peroneus longus between the two injury groups, ankle taping did cause a significant reduction in latency among healthy participants and those with a history of a LAS. Since the greatest predictor of a LAS is a previous history of a LAS (McKay et al., 2001), applying ankle tape before physical activity helps reduce the latency of the peroneus longus, provides additional mechanical support, and may reduce the potential of a recurrent or initial LAS. However, without knowing the electromechanical delay of the peroneus longus under the current experimental conditions, it is not clear whether this reduction in latency caused by ankle taping could actually provide a clinically significant reduction in lateral ankle sprains.

The present study did not find a difference in latency of the peroneus longus between the two injury groups across. This is in agreement with some previous work that failed to find a difference between healthy ankles and previously injured ankles (Johnson & Johnson, 1993;

Ebig et al., 1997; Vaes et al., 2002), and dissimilar to work that did find a difference in latency (Konradsen & Ravn, 1991; Karlsson & Andreasson, 1992; Mitchell et al., 2008). The discrepancy in the results between these studies is likely due to several factors, including different inclusion factors for a previous injury and different testing methodologies (Vaes et al., 2002). Another factor is the criteria to determine the onset of the peroneus longus after the initiation of the inversion moment. The criteria adopted in this study of 10 *SD* above baseline muscle activity were chosen because it is a more conservative measure of latency of the peroneus longus, and has been used in recent research studies examining latency of the peroneus longus (Lynch et al., 1996; Kernozek et al., 2008; Jackson et al., 2009).

There were three primary limitations in the present study. The first is that the participants were only tested immediately after ankle taping. Future research should measure latency of the peroneus longus after physical activity to see whether tape degradation has an effect on this measure, although one study found that 24 h after tape application, latency of the peroneus longus was still reduced (Lohrer et al., 1999). The second limitation was that the outer sole with fulcrum only forced the ankle into inversion upon landing, while some lateral ankle sprains occur as a result of inversion and plantar flexion. Future research should examine a combined mechanism of inversion and plantar flexion. The third limitation was the lack of a measurement of electromechanical delay. This time delay must be considered when determining whether the peroneus longus can act quickly enough to prevent a LAS when the ankle is forced into inversion. It was not included in this study as this was the first step to compare previous literature on peroneal latency and ankle taping with a new methodology (outer sole with fulcrum). The electromechanical delay should be considered and will serve as the basis for future research.

Conclusions

The results of this study indicate that immediately after ankle taping, there is a reduction in the latency of the peroneus longus among both participants who have and have not previously suffered a LAS. This reduction may help prevent recurrent lateral ankle sprains. Future research should examine how long this reduction in latency persists, as well as the electromechanical delay of the peroneus longus using this new methodology.

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