Journal of Applied Biomechanics, 2011, 27, 283-290

Effects of Inversion Perturbation After Step-Down on the Latency of the Peroneus Longus and Peroneus Brevis

Adam C. Knight[1] and Wendi H. Weimar[2]
[1]Mississippi State University; [2]Auburn University

The purpose of this investigation was to determine the effect of different types of ankle sprains on the response latency of the peroneus longus and peroneus brevis to an inversion perturbation, as well as the time to complete the perturbation (time to maximum inversion). To create a forced inversion moment of the ankle, an outer sole with fulcrum was used to cause 25 degrees of inversion at the ankle upon landing from a 27 cm step-down task. Forty participants completed the study: 15 participants had no history of any ankle sprain, 15 participants had a history of a lateral ankle sprain, and 10 participants had a history of a high ankle sprain. There was not a significant difference between the injury groups for the latency measurements or the time to maximum inversion. These findings indicate that a previous lateral ankle sprain or high ankle sprain does not affect the latency of the peroneal muscles or the time to complete the inversion range of motion.

Keywords: latency, inversion perturbation, lateral ankle sprain

The lateral, or inversion ankle sprain, which damages the lateral ligaments of the ankle complex, is the most common injury in athletics (Jackson et al., 2009; Beynnon et al., 2002; Hertel et al., 1999). The lateral ankle sprain is an injury that occurs when the ankle is forced into excessive inversion or a combination of inversion and plantar flexion (Moiler et al., 2007) and is often seen in sports that involve repeated starting, stopping, cutting, jumping, and landing. These movements put the ankle at risk because of the frequent opportunity for the foot to be placed on another player's foot, or to catch the lateral edge of the foot and "roll the ankle" (Thacker et al., 1999). A key component in the prevention of a lateral ankle sprain are the muscles and tendons that cross the foot/ankle complex and provide dynamic support through eccentric muscle actions, specifically the peroneus longus and peroneus brevis (Heckman et al., 2008). When the ankle is rapidly forced into inversion, the muscle spindles in the peroneal muscles are activated and cause a reflexive contraction of the peroneus longus and peroneus brevis to counteract this lengthening.

Once a person sustains a lateral ankle sprain, the chances of suffering a subsequent lateral ankle sprain are between 70 and 80% (Yeung et al., 1994). While many factors have been identified as possible causes of recurrent ankle sprains, this project endeavored to examine whether a limited ankle sprain history causes a delayed reaction time in the peroneal muscle group, as this has been identified as one of the causes of recurrent ankle sprains (Hertel 2002; Karlsson & Lansinger, 1993). To determine what effect ankle sprains have on the latency of the peroneal muscles, many laboratory experiments have replicated the mechanism of injury by using a tilt platform/runway with trap doors that randomly inverts the ankle to 30° while the latency of the peroneus longus and brevis is measured among both healthy participants and those with chronic or functional ankle instability (Ebig et al., 1997; Eechaute et al., 2009; Karlsson & Andreasson, 1992; Konradsen & Ravn, 1991; Konradsen et al., 1997, 1998; Löfvenberg et al., 1995; Mitchell et al., 2008: Shima et al., 2005, Vaes et al., 2002). Even though these experiments have made valuable progress toward the understanding of lateral ankle sprain mechanics, the validity of the tilt platform has been called into question (Hopkins et al., 2007; Mitchell et al., 2008; Shima et al., 2005).

In addition, high ankle sprains have received little attention in the literature, and there has been a call for research on the long-term affects of a high ankle sprain (Williams et al., 2007). While the most common mechanism of injury for a high ankle sprain is hyperdorsiflexion and external rotation, inversion has also been reported as a cause of high ankle sprains (Norkus & Floyd, 2001; Williams et al., 2007). This would potentially affect the latency of the peroneus longus and brevis and increase the likelihood of a lateral ankle sprain. Therefore, the latency of the peroneus longus and brevis warrants testing using a more dynamic mechanism to force the ankle into inversion among participants that have limited history of a high or lateral ankle sprain.

Adam C. Knight *(Corresponding Author)* is with the Department of Kinesiology, Mississippi State University, Mississippi State, MS. Wendi H. Weimar is with the Department of Kinesiology, Auburn University, Auburn, GA.

Previous research has indicated that the speed at which an ankle sprain occurs may contribute to the severity of injury (Eechaute et al., 2009; Lynch et al., 1996; Mitchell et al., 2008; Ricard et al., 2000; Vaes et al., 2002). Studies using a tilt platform to cause inversion at the ankle have measured the time it took participants to complete the inversion range of motion (Eechaute et al., 2009; Ricard et al., 2000; Vaes et al., 2002). Two of these studies (Eechaute et al., 2009; Vaes et al., 2002) compared healthy participants to those with a history of ankle instability, and did not find a difference between the groups. The third study (Ricard et al., 2000) reported that the time to maximum inversion was greater when the ankle was taped compared with no ankle tape. By using an outer sole with fulcrum to cause inversion at the subtalar joint, the amount of time it took the participants to complete the inversion range of motion can also be measured during an ankle sprain replication. This time is referred to as the *time to maximum inversion* (TMI), and it has direct implications to the capability of the participant to control the forced inversion. It also allows for calculation of the average angular velocity over this range of motion. A shorter time to complete the inversion range of motion indicates poorer control of the forced inversion, and would result in a higher inversion speed. A greater time to maximum inversion would result in lower angular inversion velocities and less strain on the lateral structures of the ankle (Vaes et al., 2002).

Therefore, the primary purpose of this study was to determine what effect a lateral ankle sprain or high ankle sprain (that does not cause chronic or functional ankle instability) has on the latency of the peroneus longus and brevis. The secondary purposes were to determine the time to maximum inversion and identify whether there were differences among the three injury groups. The authors hypothesized that participants with a history of a lateral ankle sprain would have a greater latency of the peroneus longus and brevis than participants with no history of an ankle sprain or a history of a high ankle sprain. In addition, the authors hypothesized that participants with a history of a lateral ankle sprain would have a shorter time to maximum inversion than participants with no history of an ankle sprain or a history of a high ankle sprain.

Methods

Participants

Forty participants (19 female, 21 male) completed the testing protocol. Participant characteristics can be found in Table 1. All participants were free of any current lower body injury (within 6 months before testing), free of any history of a fracture or surgery to the lower extremity, and physically active (30 min of moderate activity at least three times per week). The no-injury group comprised 15 participants. Participants in this group had never sustained an ankle sprain to either ankle. The lateral ankle sprain group comprised fifteen participants. Thirteen of these participants had sustained one lateral ankle sprain, and 2 of the 15 participants in this group had sustained two lateral ankle sprains of the same ankle, at least 1 year apart, and no injury to the contralateral ankle. Ten participants were in the high ankle sprain group. These participants had sustained one high ankle sprain of the same ankle and no ankle sprains of the contralateral ankle. All participants in either the lateral ankle sprain or high ankle sprain group reported that their ankle sprain was diagnosed by a physician, they missed at least one day of activity due to the ankle sprain, and they completed a supervised rehabilitation program. Each participant also reported no residual symptoms (instability) or multiple ankle sprains in the past year, which is common with chronic or functional ankle instability. Each participant signed an informed consent document approved by the authors' institutional ethics review board.

Instrumentation

Outer Sole. Eight detachable outer soles (four with fulcrum and four flat), made of Orthoplast, were developed for this project. A left and right outer sole was developed for the average men's shoe size and the average female shoe size. 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 has been used previously (Ubell et al., 2003) to force the ankle into inversion, but not to measure the latency of the ankle musculature. The outer sole was attached to

Table 1 Demographic characteristics of the participants

Group	*N*	Age (years)	Height (m)	Mass (kg)
No Injury	15	21.07 ± 1.10	1.69 ± .095	63.46 ± 11.97
Lateral Ankle Sprain	15	21.20 ± 1.26	1.75 ± .079	74.37 ± 14.40
High Ankle Sprain	10	22.50 ± 1.08	1.81 ± .063	86.39 ± 18.56
Total	40	21.48 ± 1.28	1.74 ± .094	73.29 ± 16.94

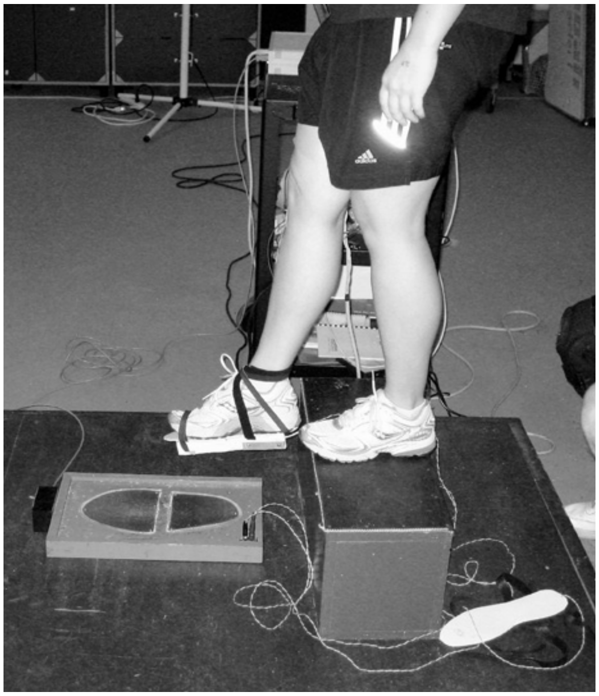

Figure 1 — Participant waiting to perform the task with outer sole, with fulcrum attached to the bottom of the shoe.

the athletic shoe of the participants using Velcro straps. All participants were required to wear low-top, flat-soled athletic shoes for testing.

This study was an initial attempt to use an outer sole with fulcrum to force the ankle into inversion and measure the latency of the peroneus longus and brevis. In addition, a recent study has questioned the role of plantar flexion in the mechanics of a lateral ankle sprain (Fong et al., 2009). Therefore, the authors attempted to isolate the influence of ankle inversion alone on the latency of the peroneus longus and peroneus brevis.

Electromyography. Muscle activity was recorded with a multichannel electromyography (EMG) amplifier / processor unit (MyoClinical, Noraxon USA Inc; Scottsdale, AZ) using wet gelled bipolar Ag-AgCl disc surface electrode pairs (Blue Sensor SE, Ambu Inc., Denmark) interfaced with a notebook computer. The raw EMG signal was amplified with an input impedance of 10 MΩ, the gain set at 1000×, and a common mode rejection ratio of >115 dB. Both EMG signals and the signal from the landing surface was band pass filtered (6th-order Butterworth, with cutoff frequencies of 8 and 535 Hz), and full wave rectified.

Surface EMG electrodes were placed over the most prominent part of the muscle bellies of the peroneus longus and peroneus brevis with a 2 cm interelectrode distance. Electrode placement sites were shaved, abraded, and cleaned according to standard electromyographic procedures. The electrode placement was similar to that used by Lynch et al. (1996) and Kernozek et al. (2008). Proper placement was verified by manual muscle testing. For the peroneus longus, the electrodes were placed at the junction of the proximal and middle thirds of the fibula over the palpable lateral compartment. For the peroneus brevis, the electrodes were placed one quarter of the distance between the lateral malleolus and fibular head, just anterior to the peroneus longus tendon.

Landing Surface. A landing surface was developed so that a circuit was completed when the fulcrum made contact with the landing area. This allowed the EMG signal to be synchronized with contact of the fulcrum to the ground, which indicated the beginning of the inversion moment. Two pieces of metal were placed on the landing area. Metal was also attached to the fulcrum and to the lateral border of the outer sole (Figure 1). When the fulcrum made contact with the landing area, a spike was produced in one of the EMG channels, indicating ground contact. When the lateral border of the outer sole made contact with the landing area, indicating failure (at preventing the foot from completing the complete inversion range of motion), a second spike was produced in a different EMG channel. Time to maximum inversion was calculated as the time between the first signal (touchdown of the fulcrum) and the second signal (contact of the lateral border of the outer sole with the landing platform).

Procedure

After proper electrode placement was confirmed, the participants began testing. The participants stood on a 27 cm high box on the nontesting leg, and moved the foot of the testing leg behind them by flexing their knee and extending their hip; this position prevented the participant from seeing which outer sole was affixed to the sole of their shoe. Next, either the outer sole with fulcrum or flat outer sole was secured to the participants shoe with Velcro, in random order. After the outer sole was secured, the participant was instructed to swing their leg through and allow the foot to hang down in front of them in a natural position (Figure 1). After waiting a random period of time and confirming there was no observed muscle activity in the peroneus longus and peroneus brevis, the participants were instructed (participants were given the signal "go" as the instruction to step down) to step down off the box onto the testing leg (Figure 2). The participants did not use flexion of the nontesting leg to lower themselves down. When instructed to step down, the participant leaned forward until he or she lost his or her balance and were forced to step down onto the testing foot. Participants were instructed to land normally, with the foot in a neutral position (flat footed). After landing, the outer sole was removed and placed behind the participant. The same procedure was followed until 10 trials had been performed with the outer sole and fulcrum. The flat outer sole was randomly interchanged with the outer sole and fulcrum, with the order of assignment determined by a coin flip. The purpose of the flat outer sole was to prevent anticipation of the inversion perturbation. The

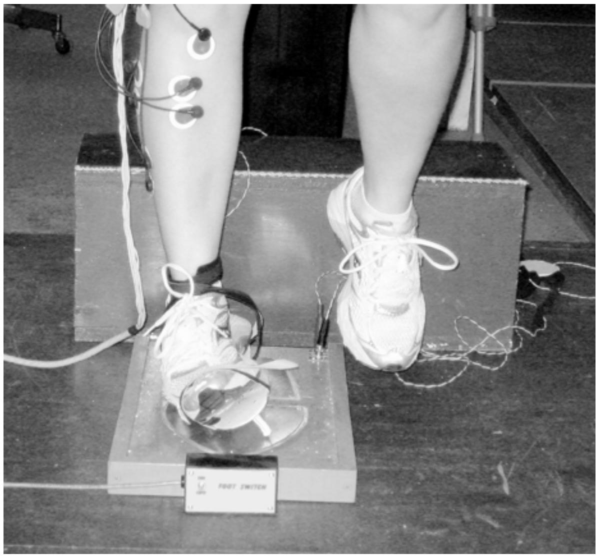

Figure 2 — Participant landing on fulcrum, causing 25° of inversion of the subtalar joint.

latency of each of the 10 trials for the outer sole with fulcrum was averaged for both the peroneus longus and peroneus brevis.

Measurements

The dependent variable was the latency, in milliseconds, of the peroneus longus and the peroneus brevis, analyzed separately. Latency was defined as the time from contact of the fulcrum with the landing area (initiation of inversion moment) to the time of muscle activity exceeding 5 *SD* 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 the main evertors of the foot/ankle complex to become active after the initiation of forced inversion of the foot/ankle complex. There has been little consistency in past research examining muscle latency at the ankle in determining when the muscles are considered on. Some studies have used 2 *SD* above resting levels to signal the onset of muscle activity (Hopkins et al., 2007; Konradsen et al., 1998; Midgley et al., 2007), whereas others have used 10 *SD* (Kernozek et al., 2008; Lynch et al., 1996). Other studies have defined the onset of muscle activity as the first “rise” or “peak” in EMG activity after the ankle is tilted (Cordova et al., 2000; Karlsson & Andreasson, 1992; Konradsen et al., 1997; Mitchell et al., 2008; Shima et al., 2005). This study used 5 *SD* because it is the opinion of the authors that 2 *SD* is not high enough a threshold (too sensitive), and 10 *SD* is too high a threshold, and using the first “rise” in EMG activity is not a standardized, objective measure.

When measuring muscle latency, it is difficult to prevent all anticipatory responses by the participants. The tilt platform allows the researcher to prevent some anticipatory responses, although preparatory activity has been reported among tilt platform research (Hopkins et al., 2007). The authors of the current study attempted to control for anticipatory responses and variance in latency by employing three different methods. First, a flat outer sole (mass = .134 kg) was randomly interchanged with the fulcrum outer sole (mass = .178 kg) to prevent the participants from “guessing” which outer sole was attached to his or her shoe. The participants were questioned after each testing session as to whether they could tell a difference between the two outer soles, and all participants reported they could not tell a difference. Second, after the participants had the outer sole attached to their shoe and placed the testing foot in front of the box, they were instructed to let the foot “dangle,” and were not instructed to step down until the authors verified there was no activity in the peroneus longus and peroneus brevis. Third, all data were visually inspected immediately after the trial was completed, and if any spikes were found in muscle activity before contact of the fulcrum with the landing area, the trial was discarded.

The time to maximum inversion for each of the participants was also calculated. This was the amount of time, in milliseconds, from contact of the fulcrum with the landing area to contact of the lateral border of the outer sole with the landing area.

The filtered and rectified EMG signal from a trial with the outer sole with fulcrum and a flat outer sole trial can be seen in Figures 3 and 4.

Data Analysis

The data were analyzed with three separate one-way ANOVAs to determine whether there was a difference in the latency of the peroneus longus, peroneus brevis, and time to maximum inversion among the three different injury groups. The dominant leg of the healthy participants was compared with the previously injured leg of the lateral ankle sprain and the high ankle sprain groups. In the case of significant differences, Fisher’s LSD test was used for post hoc analysis. The data were analyzed using SPSS software (version 16; SPSS Inc, Chicago, IL). Owing to multiple comparisons, a Bonferroni correction was made, and the a priori level was adjusted to $p < .0167$.

Results

The demographic characteristics of the participants (age, height, and mass) are summarized in Table 1. The mean latency of the peroneus longus across all three injury groups was 45.08 ± 11.71 ms and the mean latency of the peroneus brevis across all three injury groups was 54.40 ± 16.70 ms. For the peroneus longus, there was not a significant difference in latency among the three injury groups ($p = .990$), or for the peroneus brevis ($p = .781$). The means and standard deviations for each of the three injury groups for both the peroneus longus and peroneus brevis are presented in Table 2.

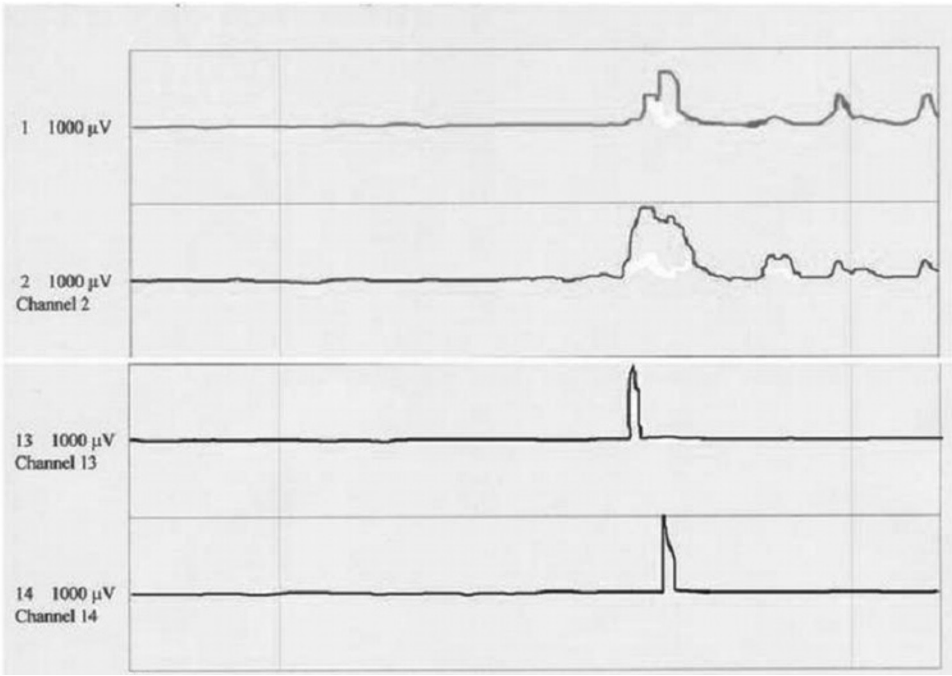

Figure 3 — Filtered and rectified signal from trial with outer sole with fulcrum. Channel 1 represents the peroneus longus, Channel 2 represents the peroneus brevis, Channel 13 represents contact of the fulcrum with the landing area (beginning of inversion perturbation), and Channel 14 represents contact of the lateral border of the outer sole with the landing area (completion of the 25° of inversion).

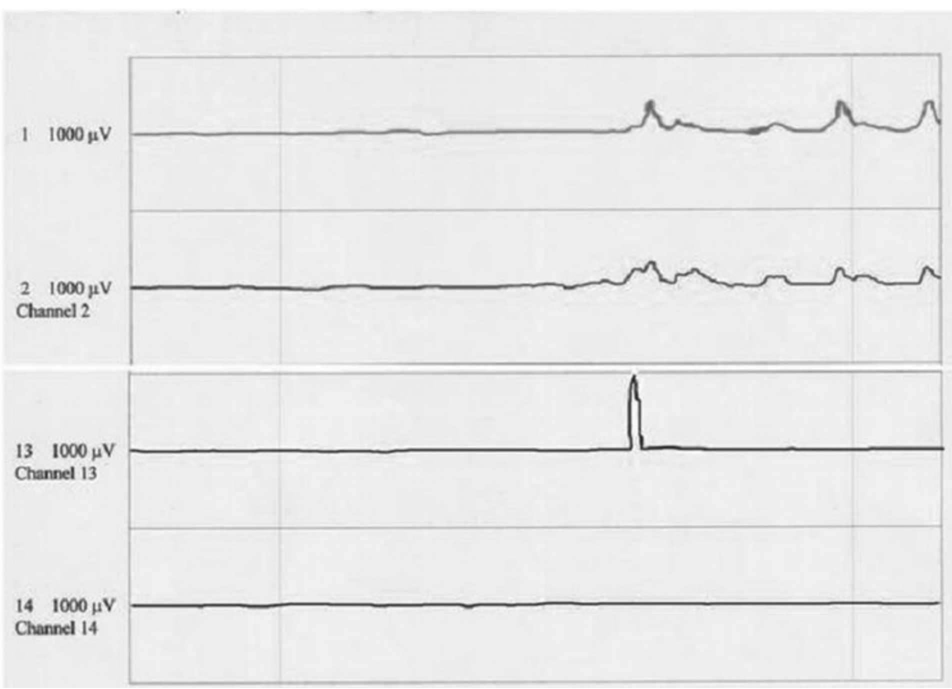

Figure 4 — Filtered and rectified signal from trial with flat outer sole. Channel 1 represents the peroneus longus, Channel 2 represents the peroneus brevis, and Channel 13 represents contact of the outer sole with the landing area.

Table 2 Descriptive statistics for latency and time to failure measurements, in milliseconds (ms), for the different injury groups

Injury Group	N	Peroneus Longus ($M \pm SD$)	Peroneus Brevis ($M \pm SD$)	Time to Failure ($M \pm SD$)
No Injury	15	44.89 ± 12.75	57.07 ± 19.41	51.56 ± 19.48
Lateral Ankle Sprain	15	45.43 ± 10.92	53.81 ± 15.50	38.96 ± 16.07
High Ankle Sprain	10	44.84 ± 12.46	51.28 ± 15.03	43.18 ± 11.92
Total	40	45.08 ± 11.71	54.40 ± 16.70	44.74 ± 17.12

The mean time to maximum inversion across all three injury groups was 44.74 ± 17.12 ms. There was not a significant difference in the time to maximum inversion among the three injury groups ($p = .123$). The means and standard deviations for each of the three injury groups are presented in Table 2.

Discussion

There was no difference in the latency of the peroneus longus and brevis between the no-injury group and the high ankle sprain group. Participants with a history of a high ankle sprain were examined because it has been reported that excessive inversion is a contributing factor in some high ankle sprains (Norkus & Floyd, 2001; Williams et al., 2007). The lack of difference between the high ankle sprain group and no-injury group is not surprising, as the most common mechanism of a high ankle sprain is hyperdorsiflexion and external rotation (Norkus & Floyd, 2001; Williams et al., 2007), which would not affect the lateral ankle structures.

There was also no difference in the latency of the peroneus longus and brevis between the no-injury group and lateral ankle sprain group. This is similar to the results of previous research that found no difference in peroneal latency between healthy participants and those with ankle instability (Ebig et al., 1997; Johnson & Johnson, 1993; Konradsen et al., 1997, 1998; Vaes et al., 2002), but different from studies that found an increased peroneal latency among participants with ankle instability (Karlsson & Andreasson, 1992; Löfvenberg et al., 1995; Mitchell et al., 2008). In addition to studying participants with lateral ankle instability, there is a need to examine participants with a limited ankle sprain history as well. Not every person who sustains an ankle sprain develops chronic ankle instability—in fact, only 30–40% of people who sustain a lateral ankle sprain develop chronic ankle instability (Bosien et al., 1955; Staples, 1972). One explanation for the lack of significant difference in the current study is that the participants did not develop chronic ankle instability after the initial lateral ankle sprain, and are likely considered "copers" (Wikstrom et al., 2010). Specifically, they did not display markers of permanent damage to the nervous system, as have participants in previous studies on persons with ankle instability that demonstrated a delayed peroneal reaction time (Karlsson & Andreasson, 1992; Löfvenberg et al., 1995; Mitchell et al., 2008). Future research should compare these "copers" to healthy participants as well as those with ankle instability to determine whether there is a difference in peroneal latency.

Similar to the latency findings, there was no difference in the time to maximum inversion among the different injury groups. This is in agreement with previous research that examined this variable using the tilt platform and found no difference between healthy participants and those with ankle instability (Eechaute et al., 2009; Vaes et al., 2002). The time to maximum inversion also allows for an indirect calculation of the angular velocity of the outer sole during the inversion perturbation. The average inversion velocity was calculated for each group by dividing 25° by the average time to maximum inversion. Previous research utilizing the tilt platform (Eechaute et al., 2009; Ricard et al., 2000) calculated the average inversion velocity using the same formula. In the current study, the no-injury group produced an average angular velocity of 556 deg/s. For the high ankle sprain group, the average angular velocity was 619 deg/s, and for the lateral ankle sprain group, the average angular velocity was 754 deg/s. These numbers are comparable to the angular inversion velocity during an actual laboratory lateral ankle sprain of 632 deg/s (Tik-Pui Fong et al., 2009), and higher than the average inversion velocity of 364 deg/s (Ricard et al., 2000) and 458.7 deg/s (Eechaute et al., 2009) previously reported using the tilt platform. It appears the outer sole with fulcrum methodology produces an average inversion velocity that closely resembles what occurs during an actual lateral ankle sprain. While the authors' concede that this variable has yet to be investigated for reliability and validity, it warrants future examination with additional participants to determine its implications on the risk of future ankle sprains.

There are several limitations to the current study. The range of inversion chosen was 25°, whereas most studies using the tilt platform inverted the foot/ankle complex 30°, although one study used only 20° (Wilson & Madigan, 2007) and another 25° (Jackson et al., 2009). This range was chosen to ensure the safety of the participants during the performance of this task. Electromechanical delay was not measured, and, to determine whether the ankle musculature can prevent an ankle sprain, this measurement needs to be taken in conjunction with the latency. The kinematics of the task was also not measured, and full lower body kinematics will be included with future research. The extensor digitorum longus is an additional muscle that may help prevent or attenuate the rate at which a lateral ankle sprain occurs. This muscle was not examined in the current study but should be examined in future work.

In conclusion, a previous lateral or high ankle sprain history did not result in a change in the latency of the peroneus longus or brevis, and it also did not affect the time to maximum inversion. Future research should compare participants with a history of ankle sprains that do not develop ankle instability to those with ankle instability. As the rate of recurrence ankle sprains remains high, other factors, such as the kinetics and kinematics of a lateral ankle sprain, need to be examined among participants with different ankle sprain histories to further shed light on this problem.

Acknowledgments

The authors would like to thank Justin Shroyer, Joanna Shroyer, Andrea Sumner, and Matthew Rooke for their tireless help with the data collection process.

References

Beynnon, B.D., Murphy, D.F., & Alosa, D.M. (2002). Predictive factors for lateral ankle sprains: A literature review. *Journal of Athletic Training, 37*(4), 376–380.

Bosien, W.R., Staples, O.S., & Russell, S.W. (1955). Residual disability following acute ankle sprains. *Journal of Bone and Joint Surgery, 37-A,* 1237–1243.

Cordova, M.L., Cardona, C.V., Ingersoll, C.D., & Sandrey, M.A. (2000). Long-term ankle brace use does not affect peroneus longus muscle latency during sudden inversion in normal subjects. *Journal of Athletic Training, 35,* 407–411.

Ebig, M., Lephart, S.M., Burdett, R.G., Miller, M.C., & Pincivero, D.M. (1997). The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in chronically unstable ankles. *The Journal of Orthopaedic and Sports Physical Therapy, 26,* 73–77.

Eechaute, C., Vaes, P., Duquet, W., & Van Gheluwe, B. (2009). Reliability and discriminative validity of sudden inversion measurements in patients with chronic ankle instability. *Gait & Posture, 30,* 82–86.

Fong, D.T., Hong, Y., Shima, Y., Krosshaug, T., Yung, P., & Chan, K. (2009). Biomechanics of supination ankle sprain. *American Journal of Sports Medicine, 37,* 822–827.

Heckman, D.S., Reddy, S., Pedowitz, D., Wapner, K.L., & Parekh, S.G. (2008). Operative treatment for peroneal tendon disorders. *Journal of Bone and Joint Surgery, 90,* 404–418.

Hertel, J. (2002). Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *Journal of Athletic Training, 37*(4), 364–375.

Hertel, J., Denegar, C.R., Monroe, M.M., & Stokes, W.L. (1999). Talocrual and subtalar joint instability after lateral ankle sprain. *Medicine and Science in Sports and Exercise, 31,* 1501–1508.

Hopkins, J.T., McLoda, T., & McCaw, S. (2007). Muscle activation following sudden ankle inversion during standing and walking. *European Journal of Applied Physiology, 99,* 371–378.

Jackson, N.D., Gutierez, G.M., & Kaminski, T. (2009). The effect of fatigue of and habituation on the stretch reflex of the ankle musculature. *Journal of Electromyography and Kinesiology, 19*(1), 75–84.

Johnson, M.B., & Johnson, C.L. (1993). Electromyographic response of peroneal muscles in surgical and nonsurgical injured ankles during sudden inversion. *The Journal of Orthopaedic and Sports Physical Therapy, 18,* 497–501.

Karlsson, J., & Andreasson, G.O. (1992). The effect of external ankle support in chronic lateral ankle joint instability. *American Journal of Sports Medicine, 20,* 257–261.

Karlsson, J., & Lansinger, O. (1993). Chronic lateral instability of the ankle. *Sports Medicine (Auckland, N.Z.), 16,* 355–366.

Kernozek, T.K., Durall, C.J., Friske, A., & Mussallem, M. (2008). Ankle bracing, plantar-flexion angle, and ankle muscle latencies during inversion stress in healthy participants. *Journal of Athletic Training, 43,* 37–43.

Konradsen, L., Olessen, S., & Hansen, H.M. (1998). Ankle sensorimotor control and eversion strength after acute ankle inversion injuries. *American Journal of Sports Medicine, 26*(1), 72–77.

Konradsen, L., & Ravn, J.B. (1991). Prolonged peroneal reaction time in ankle instability. *International Journal of Sports Medicine, 12,* 290–292.

Konradsen, L., Voigt, M., & Hojsgaard, C. (1997). Ankle inversion injuries: the role of the dynamic defense mechanism. *American Journal of Sports Medicine, 25*(1), 54–58.

Löfvenberg, R., Kärrholm, J., Sundelin, G., & Ahlgren, O. (1995). Prolonged reaction time in patients with chronic lateral instability of the ankle. *American Journal of Sports Medicine, 23,* 414–417.

Lynch, S.A., Eklund, U., Gottlieb, D., Renstrom, P., & Beynnon, B. (1996). Electromyographic latency changes in ankle musculature during inversion moments. *American Journal of Sports Medicine, 24,* 362–369.

Midgley, W., Hopkins, J.T., Feland, B., Kaiser, D., Merrill, G., & Hunter, I. (2007). The effects of external ankle support on dynamic restraint characteristics of the ankle in volleyball players. *Clinical Journal of Sport Medicine, 17,* 343–348.

Mitchell, A., Dyson, R., Hale, T., & Abraham, C. (2008). Biomechanics of ankle instability. Part 1: Reaction time to simulated ankle sprain. *Medicine and Science in Sports and Exercise, 40,* 1515–1521.

Moiler, K., Hall, T., & Robinson, K. (2006). The role of fibular tape in the prevention of ankle injury in basketball: A pilot study. *Journal of Orthopaedic & Sports Physical Therapy, 36*(9), 661–668.

Norkus, S.A., & Floyd, R.T. (2001). The anatomy of mechanisms of syndesmotic ankle sprains. *Journal of Athletic Training, 36*(1), 68–73.

Ricard, M.D., Sherwood, S.M., Schlthies, S.S., & Knight, K.L. (2000). Effects of tape and exercise on dynamic ankle inversion. *Journal of Athletic Training, 35*(1), 31–37.

Shima, N., Maeda, A., & Hirohashi, K. (2005). Delayed latency of peroneal reflex to sudden inversion with ankle taping and bracing. *International Journal of Sports Medicine, 26,* 476–480.

Staples, O.S. (1972). Result study of ruptures of lateral ligaments of the ankle. *Clinical Orthopaedics and Related Research, 85,* 50–58.

Thacker, S.B., Stroup, D.F., Branche, C.M., Gilchrist, J., Goodman, R.A., & Weitman, E.A. (1999). The prevention of ankle sprains in sports. *American Journal of Sports Medicine, 27*(6), 753–760.

Ubell, M.L., Boylan, J.P., Ashton-Miller, J.A., & Wojtys, E.M. (2003). The effect of ankle braces on the prevention of dynamic forced inversion. *American Journal of Sports Medicine, 31*(6), 935–940.

Vaes, P., Duquet, W., & Gheluwe, B.V. (2002). Peroneal reaction times and eversion motor response in healthy and unstable ankles. *Journal of Athletic Training, 37*(4), 475–480.

Wikstrom, E.A., Fournier, K.A., & McKeon, P.O. (2010). Postural control differs between those with and without chronic ankle instability. *Gait & Posture, 32,* 82–86.

Williams, G.N., Jones, M.H., & Amendola, A. (2007). Syndesmotic ankle sprains in athletes. *American Journal of Sports Medicine, 35,* 1197–1207.

Wilson, E.L., & Madigan, M.L. (2007). Effects of fatigue and gender on peroneal reflexes elicited by sudden ankle inversion. *Journal of Electromyography and Kinesiology, 17*(2), 160–166.

Yeung, M.S., Chan, K.M., So, C.H., & Yuan, W.Y. (1994). An epidemiological survey on ankle sprains. *British Journal of Sports Medicine, 28*(2), 112–116.