Journal of Athletic Training 2000;35(4):407–411

www.journalofathletictraining.org

Long-Term Ankle Brace Use Does Not Affect Peroneus Longus Muscle Latency During Sudden Inversion in Normal Subjects

Mitchell L. Cordova, PhD, ATC; Chris V. Cardona, MS, ATC; Christopher D. Ingersoll, PhD, ATC; Michelle A. Sandrey, PhD, ATC

Sports Injury Research Laboratory, Athletic Training Department, Indiana State University, Terre Haute, IN

Objective: External ankle supports are widely used in sports medicine. However, ankle bracing in a healthy ankle over a sustained period has been scrutinized due to possible neuromuscular adaptations resulting in diminished dynamic support offered by the peroneus longus muscle. Although this claim is anecdotal in nature, we sought to investigate the effects of long-term ankle bracing using 2 commonly available appliances on peroneus longus latency in normal subjects. Our second purpose was to evaluate the effects of ankle bracing on peroneus longus latency before a period of extended use.

Design and Setting: A 3 × 3 × 2 design with repeated measures on the first and third factors was used in this study. All data were collected in the Sports Injury Research Laboratory.

Subjects: Twenty (12 men and 8 women) physically active college students (age = 23.6 ± 1.7 years; height = 168.7 ± 8.4 cm; weight = 69.9 ± 12.0 kg) free of ankle or lower extremity injury in the 12 months before the study and not involved in a strength-training or conditioning program in the 6 months before the study.

Measurements: We evaluated peroneus longus latency by studying the electromyogram of the muscle after sudden foot inversion.

Results: Application of a lace-up or semirigid brace did not affect peroneus longus latency. Additionally, 8 weeks of long-term ankle appliance use had no effect on peroneus longus latency.

Conclusions: The duration of the peroneus longus stretch reflex (latency) is neither facilitated nor inhibited with extended use of an external ankle support. Proprioceptive input provided by the muscle spindles within the peroneus longus does not appear to be compromised with the long-term use of ankle braces.

Key Words: peroneus longus reaction time, stretch reflex, ankle bracing, electromyography

Trauma involving the ankle and foot complex remains among the most common injuries in sport[1–3]; of these injuries, approximately 86% are sprains.[2] Furthermore, it has been estimated that nearly 1 million people in the United States suffer from acute ankle injuries annually.[4] Over the years, health care professionals have tried to prevent acute ankle sprains and chronic reinjuries by using various prophylactic measures, such as adhesive taping and commercially available ankle stabilizers. In an effort to combat this epidemiologic problem, many manufacturers have developed protective braces to support the ankle. Of these prophylactic devices, 2 basic types exist: lace-up and semirigid braces.[5] Lace-up braces are generally constructed of a soft canvas or nylon material, whereas semirigid braces contain a stirrup consisting of a thermoplastic material.[5]

Independent of any protective device, the musculature controlling the ankle and foot acts to provide a dynamic restraint against external forces. Specifically, the peroneus longus muscle acts as the primary defense mechanism against an inversion moment applied to the foot.[6] Because the peroneus longus plays a critical role in the dynamic support of the ankle-foot complex, its neuromuscular response during quasi-static[6–12] and dynamic inversion stress[13] has been well studied. The use of external ankle supports has been scrutinized due to testimony suggesting that supporting a healthy ankle can lead to the development of weakness in the surrounding muscles. Clinicians have surmised that long-term application of an ankle brace may cause the ankle's supporting structures to weaken and remodel so that they become dependent on this support. With the extended use of an ankle brace, the leg musculature's ability to respond to an external stimulus or perturbation may be delayed, thereby diminishing neuromuscular function and potentially placing the ankle-foot complex at risk for injury. To our knowledge, the effects of long-term ankle bracing on peroneus longus neuromuscular function in the healthy and chronically unstable ankle have not been addressed. Therefore, our primary purpose was to evaluate the reaction time, or latency, of the peroneus longus after long-term application of 2 selected ankle braces. Second, we were interested in assessing if ankle bracing affected peroneus longus latency before a period of extended use.

Address correspondence to Mitchell L. Cordova, PhD, ATC, Athletic Training Department, Indiana State University, Terre Haute, IN 47809. E-mail address: m-cordova@indstate.edu

METHODS

A 3 × 3 × 2 factorial design was used to determine if peroneus longus latency differed with 3 ankle brace applications, 3 ankle brace treatments, and before and after 8 weeks of extended use. The first independent variable (within-subjects factor) was test condition, with 3 levels: control (no brace), Active Ankle Training brace (Active Ankle Systems, Inc, Louisville, KY), and McDavid 199 (McDavid Knee Guard, Chicago, IL). The second independent variable (between-subjects factor) was treatment, with 3 levels: control (no brace), Active Ankle Training brace, and McDavid 199. The third independent variable (within-subjects factor) was time, with 2 levels: pretest and posttest. The dependent variable was peroneus longus reaction time, or latency.

Subjects

Twenty (12 men and 8 women) physically active, college-aged subjects (age = 23.6 ± 1.7 yrs; height = 168.7 ± 8.4 cm; weight = 69.9 ± 12.0 kg) volunteered for this study. Subjects had incurred no known ankle or lower extremity injuries in the 12 months before the study. Furthermore, all subjects were screened with a preparticipation survey to ensure that they had not been involved in a strength-training or conditioning program that would have altered the physiologic function of the peroneus longus in the 6 months before the study. Each subject read and signed an informed consent form approved by the School of Health & Human Performance Human Subjects Review Committee, which also approved the study. Each subject was required to report to the research laboratory on 2 separate occasions.

Instrumentation

A 4-channel, telemetered, biological signal-acquisition system (MP 100, BIOPAC Systems Inc, Santa Barbara, CA) recorded the electric activity of the peroneus longus and an analog signal derived from a switch positioned on the trap door. Disposable 10-mm Ag-AgCl surface electrodes (Ver Med, Bellows Falls, VT) arranged in a bipolar configuration were used to detect the electric activity and reaction time of the peroneus longus during sudden foot inversion. The raw electromyogram signal was digitally converted at 1000 Hz, amplified (gain set at 1000), and interfaced to a controlling desktop computer. The analog signal arising from the trap door was simultaneously sampled and time matched to the collected electromyogram signal. This analog signal identified the start of the inversion movement and allowed for assessment of peroneus longus latency. A custom-made inversion platform was used to produce the inversion movement. This device was constructed similarly to an inversion platform used in previous studies evaluating peroneus longus response.[14,15] The subjects stood on 2 separate, flat surfaces. At random, the platform was abruptly tilted to 35° of foot inversion by removing the primary support.

Testing Procedures

Subjects were introduced to the instrumentation and had the testing procedures explained before the pretest. The dominant lower extremity of each subject was first tested under each of the 3 ankle support conditions: control (no brace), Active Ankle Training brace, and McDavid 199 in a counterbalanced fashion. The dominant extremity was defined as the preferred extremity the subject would use to kick a soccer ball. Additionally, subjects performed this testing while wearing a cross-training shoe. The skin over the muscle belly of the peroneus longus was prepared for electrode placement by shaving any hair and cleansing with an alcohol pad to reduce skin impedance. Disposable, self-adhesive Ag-AgCl electrodes were placed over the muscle belly of the peroneus longus of the dominant extremity, as previously described.[16] The reference electrode was placed over the lateral malleolus of the same extremity.

Each subject was instructed to stand on both legs with the weight evenly distributed on the platform. We assumed that the weight distribution for all subjects was maintained throughout testing. The subject's elbows were flexed, with the hands on the hips. Once the subject was balanced, the platform under the subject's dominant extremity (tested ankle) was randomly dropped to a 35° angle. Dropping of the platform was random to eliminate premotor activity of the peroneus longus, as well as to prevent the subject from anticipating the release. Baseline activity of the peroneus longus was carefully evaluated to ensure that no heightened amplitude existed before the trap door was released, which would indicate premotor response. For safety purposes, 1 spotter was placed on each side in case the subject lost his or her balance. The pretest consisted of having subjects perform 5 trials of sudden foot inversion in which peroneus longus latency was measured. To assess peroneus longus latency accurately, the release of the trapdoor was indicated by an analog signal, which was synchronized with the peroneus longus electromyographic activity. Peroneus longus latency was defined as the time between the initiation of trapdoor release and the initial firing of the peroneus longus muscle.[6,11] Specifically, we measured the duration between the release of the trapdoor and the electromyographic amplitude associated with the second component (M2) of the stretch reflex.[17] The 5 scores for each testing condition were totaled, averaged, and recorded as the mean pretest score for each subject.

After the pretest, each subject was randomly assigned to 1 of the 3 treatment conditions (control [n = 7], Active Ankle [n = 6], or McDavid [n = 7]), to evaluate the potential long-term effect of each condition. For each brace condition, the subject was required to wear the brace on the dominant extremity for a minimum of 8 h/d, 5 d/wk, for an 8-week period. The brace was worn during an 8-hour time period in which the subject was active on his or her feet, and subjects checked in with the investigators regularly. Because subjects were not readily available on campus during the weekends, it was difficult to ensure compliance with the treatment protocol. Thus, subjects were instructed to wear the braces Monday through Friday, which allowed for better treatment compliance. Although we did not quantify the actual time the subjects wore the braces, regular interaction occurred throughout the treatment period to ensure that the subjects followed the protocol. Subjects were instructed not to wear the braces while sleeping. During the control condition, subjects were instructed to participate in their normal activities of daily living without emphasizing any particular activities. Immediately after the 8-week treatment period, peroneus longus latency was measured under the same pretest conditions described above. This posttest measurement allowed for assessment of the treatment condition (between-subjects factor) after 8 weeks. The average of the 5 trials for each condition obtained during the pretest and posttest was used for statistical analysis.

Statistical Analysis

We used a 3-way, repeated-measures analysis of variance to determine if peroneus longus reaction time differed across levels of brace condition, treatment condition, and time. Simple main-effects testing and the Tukey multiple-comparisons procedure were used to identify group differences. The level of significance was established a priori at $P < .05$.

RESULTS

The means and standard deviations for peroneus longus latency by testing condition, treatment condition, and time are presented in the Table. No significant 3-way ($F_{4,32} = 0.731$, $P = .53$) interaction was observed among the independent variables. Similarly, no significant 2-way interactions were observed between test condition and treatment condition ($F_{2,32} = 0.57$, $P = .69$), time and test condition ($F_{2,32} = 0.142$, $P = .89$), or time and treatment condition ($F_{2,32} = 0.170$, $P = .84$). As for each main effect, no difference was found for test condition ($F_{2,32} = 0.427$, $P = .56$), treatment condition ($F_{2,16} = 1.51$, $P = .184$), or time ($F_{1,16} = 4.24$, $P = 0.06$) on peroneus longus latency (Figure).

DISCUSSION

An important component in establishing and maintaining functional joint stability is the ability to improve and facilitate proprioception.[18] With respect to the ankle-foot complex, Freeman and colleagues[19,20] postulated that chronic ankle injury is due to mechanical instability and decreased afference from joint mechanoreceptors after injury. This theory has also been supported by the work of Lentell et al.[21] The effects of ankle bracing on talocrural and subtalar joint ranges of motion have been studied extensively and recently statistically summarized using meta-analysis procedures.[22] Various forms of ankle supports (tape and braces) are effective in providing mechanical stability while restricting joint range of motion.[23–28] While external ankle supports are effective in providing mechanical stability, their effect on joint proprioception is less understood. Improvement in proprioception has been shown to occur not only through the use of exercise and rehabilitation[29–31] but also through stimulation of cutaneous mechanoreceptors near and around the ankle through the application of various types of ankle support.[32,33]

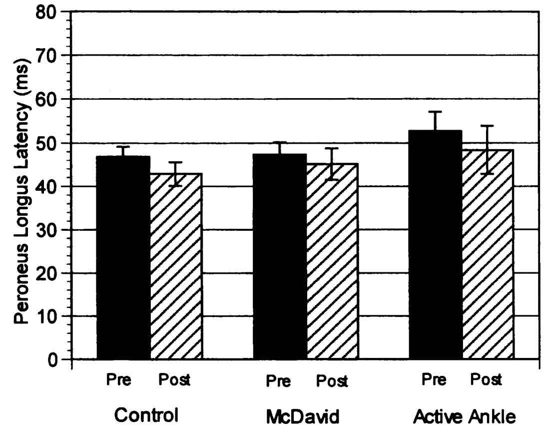
In our study, we attempted to investigate the effects of long-term ankle brace use on the duration of the peroneus longus stretch reflex. Our main objective was to assess the influence of long-term ankle brace application on peroneus longus latency. Peroneus longus neuromuscular function is critical in dynamically protecting the ankle-foot complex from inversion injuries. As a result, peroneus longus reaction time, or latency, during a simulated ankle sprain has generally been studied in unbraced normal and chronically unstable ankles[6,8–12]; therefore, the effects of ankle supports on peroneus longus function have not been elucidated.[34,35] In all of these studies, the duration of the peroneus longus stretch reflex was being quantified. The stretch reflex involves activation of the group Ia afferent fibers of the muscle spindle, which results in an efferent motor response and contraction of the same muscle.[36] We observed no changes in latency in subjects who were assigned to the lace-up and semirigid brace conditions when compared with controls. We hypothesized that with extended ankle brace use, peroneus longus latency would increase during a sudden inversion movement. Our underlying assumption was that neuromuscular remodeling of the peroneus longus would occur as a result of the dependence on the external support. Such neuromuscular changes were thought to manifest in delayed activation of the peroneus longus with inversion stress. Because our subjects were braced 8 h/d for 5 d/wk over an 8-week period, we speculate that changes in peroneus longus latency probably do not exist, especially during the shorter durations of use common in athletes. Perhaps other changes in neuromuscular function (eg, amplitude of stretch reflex) exist; however, more research is needed in this area.

The lack of difference in peroneus longus latency between groups assigned to bracing may be attributed to the amount of restriction offered by the braces. Without the dynamic stabilization provided by the muscles, the ankle support may be insufficient to protect against external forces applied to the ankle-foot complex. In other words, normal peroneus longus activation may exist despite the mechanical support offered by an external appliance. The main implication of this result is that athletes with healthy ankles who wish to wear external ankle supports prophylactically throughout the season do not appear at risk for compromising the peroneus longus response to sudden inversion. The subjects tested in this study did not represent an athletic population, although they were physically active. This can be viewed as a limitation of our study. Nevertheless, we are confident that these results can be generalized to healthy collegiate athletes (men and women).

Mean (±SD) Peroneus Longus Latency* by Test Condition and Treatment Condition

	Test Condition		
Treatment Condition	Control	Active Ankle	McDavid
Control			
Pretest	46.4 ± 1.9	48.1 ± 2.4	45.9 ± 1.7
Posttest	42.2 ± 2.0	45.3 ± 2.9	41.0 ± 4.3
Active Ankle			
Pretest	56.0 ± 4.3	47.5 ± 3.9	54.6 ± 3.3
Posttest	48.2 ± 4.8	49.3 ± 5.7	49.0 ± 4.3
McDavid			
Pretest	48.3 ± 4.4	47.8 ± 2.9	45.7 ± 1.3
Posttest	48.1 ± 3.0	43.3 ± 3.5	43.9 ± 3.6

*Milliseconds.



Peroneus longus latency across time and treatment conditions. No differences existed between treatment conditions and time ($P > .05$).

Although this outcome is promising to clinicians, more studies are needed to validate this result. It is difficult to surmise if the findings would be the same in a population with chronic ankle instability. Because no studies have evaluated the long-term effects of ankle bracing on peroneus longus latency in the healthy ankle, it would be pure speculation to discuss our results with respect to a pathologic condition. Furthermore, it is difficult to place the present findings in perspective with other literature.

Another objective of this study was to evaluate latency after the application of an external ankle support. The range of latency values observed across all conditions in our study (41.0 to 56.0 milliseconds) was consistent with those for a spinal reflex.[37] We found no difference among the 3 brace conditions on peroneus longus reaction time. This suggests that application of an external ankle support (lace-up or semirigid brace) does not affect the duration of the reflex circuitry of the muscle spindles within the peroneus longus during sudden inversion. Our result is in agreement with Nishikawa and Grabiner,[37] who found no change in peroneus longus H-reflex latency after application of a semirigid ankle brace. Although they electrically stimulated the peroneus longus group Ia afferent nerve fibers percutaneously and not through deformation of joint mechanoreceptors (simulated ankle sprain), similar conclusions can be drawn because the H-reflex latency represents an artificially evoked response of the muscle after a given stimulus using the same reflex circuitry. However, when evaluating the effects of external support on peroneus longus reaction time during sudden inversion, Karlsson and Andreasson[35] found increased peroneus longus reaction time. The increase in reaction time with adhesive tape was observed in patients who suffered from chronic ankle instability.

Whether neuromotor changes with ankle bracing are influenced by ankle injury has been questioned.[37] In other words, does long-term application of an external ankle support facilitate the stretch reflex (ie, shorten the duration) in patients who suffer from chronic ankle instability? Similarly, does long-term ankle support enhance the amplitude of the stretch reflex? Our results cannot address whether long-term ankle brace use affects the neuromuscular response of the peroneus longus in the chronically unstable ankle. However, studies implementing methods similar to ours, using subjects with chronically unstable ankles, would provide greater insight into these questions. The fact that we saw no changes in peroneus longus latency can be viewed in a positive manner. Although external ankle supports provided no heightened response, neither did they induce an inhibitory effect. More studies are needed to characterize these possible relationships.

CONCLUSIONS

This study was undertaken to evaluate a commonly asked question: does long-term ankle bracing affect the neuromotor response of the peroneus longus? Although limited to healthy subjects, our study demonstrated that peroneus longus latency in response to sudden inversion after the extended use of ankle bracing remained unaffected. Furthermore, we also observed that peroneus longus reaction time did not differ between ankle braces, independent of the 8-week treatment. These findings suggest that the extended use of external ankle supports did not induce neuromuscular changes within the primary musculature that dynamically stabilizes against lateral ankle sprain. These results are encouraging for clinicians who advocate the use of prophylactic ankle support for extended periods of time, perhaps over the course of a sport season. Although these results are favorable, more studies are needed to understand the neurophysiologic characteristics (ie, latency and amplitude) of the peroneus longus stretch reflex in normal subjects and in subjects who suffer from chronic ankle instability.

REFERENCES

1. Garrick JG, Requa RK. The epidemiology of foot and ankle injuries in sports. *Clin Sports Med.* 1988;7:29–36.
2. Garrick JG. The frequency of injury, mechanism of injury, and epidemiology of ankle sprains. *Am J Sports Med.* 1977;5:241–242.
3. Glick JM, Gordon RB, Nishimoto D. The prevention and treatment of ankle injuries. *Am J Sports Med.* 1976;4:136–141.
4. Miller EA, Hergenroeder AC. Prophylactic ankle bracing. *Pediatr Clin North Am.* 1990;37:1175–1185.
5. Sitler MR, Horodyski M. Effectiveness of prophylactic ankle stabilisers for prevention of ankle injuries. *Sports Med.* 1995;20:53–57.
6. Konradsen L, Voigt M, Hojsgaard C. Ankle inversion injuries: the role of the dynamic defense mechanism. *Am J Sports Med.* 1997;25:54–58.
7. Beckman SM, Buchanan TS. Ankle inversion injury and hypermobility: effect on hip and ankle muscle electromyography onset latency. *Arch Phys Med Rehabil.* 1995;76:1138–1143.
8. Ebig M, Lephart SM, Burdett RG, Miller MC, Pincivero DM. The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. *J Orthop Sports Phys Ther.* 1997;26:73–77.
9. Isakov E, Mizrahi J, Solzi P. Response of the peroneal muscles to sudden inversion of the ankle during standing. *Int J Sport Biomech.* 1986;2:100–109.
10. Johnson MB, Johnson CL. Electromyographic response of peroneal muscles in surgical and nonsurgical injured ankles during sudden inversion. *J Orthop Sports Phys Ther.* 1993;18:497–501.
11. Konradsen L, Ravn JB. Prolonged reaction time in ankle instability. *Int J Sports Med.* 1991;12:290–292.
12. Lofvenberg R, Karrholm J, Sundelin G, Ahlgren O. Prolonged reaction time in patients with chronic lateral instability of the ankle. *Am J Sports Med.* 1995;23:414–417.
13. Cordova ML, Armstrong CW, Rankin JM, Yeasting RA. Ground reaction forces and EMG activity with ankle bracing during inversion stress. *Med Sci Sports Exerc.* 1998;30:1363–1370.
14. Nawoczenski DA, Owen MG, Ecker ML, Altman B, Epler M. Objective evaluation of peroneal response to sudden inversion stress. *J Orthop Sports Phys Ther.* 1985;7:107–109.
15. Kimura IF, Nawoczenski DA, Epler M, Owen MG. Effect of the air stirrup in controlling ankle inversion stress. *J Orthop Sports Phys Ther.* 1987;9:190–193.
16. Delagi EF, Perroto A. *Anatomical Guide for the Electromyographer: The Limbs.* 2nd ed. Springfield, IL: Charles C. Thomas; 1981.
17. Matthews PB. The human stretch reflex and the motor cortex. *Trends Neurosci.* 1991;14:87–91.
18. Lephart SM, Pincivero DM, Rozzi SL. Proprioception of the ankle and knee. *Sports Med.* 1998;25:149–155.
19. Freeman MA. Treatment of ruptures of the lateral ligament of the ankle. *J Bone Joint Surg Br.* 1965;47:661–668.
20. Freeman MA, Dean MR, Hanham IW. The etiology and prevention of functional instability of the foot. *J Bone Joint Surg Br.* 1965;47:678–685.
21. Lentell G, Baas B, Lopez D, McGuire L, Sarrels M, Snyder P. The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle. *J Orthop Sports Phys Ther.* 1995;21:206–215.
22. Cordova ML, Ingersoll CD, LeBlanc MJ. Influence of ankle support on joint range of motion before and after exercise: a meta-analysis. *J Orthop Sports Phys Ther.* 2000;30:170–182.

23. Greene TA, Wight CR. A comparative support evaluation of three ankle orthoses before, during, and after exercise. *J Orthop Sports Phys Ther.* 1990;11:453–466.
24. Greene TA, Hillman SK. Comparison of support provided by a semirigid orthosis and adhesive ankle taping before, during, and after exercise. *Am J Sports Med.* 1990;18:498–506.
25. Gross MT, Bradshaw MK, Ventry LC, Weller KH. Comparion of support provided by ankle taping and semirigid orthosis. *J Orthop Sports Phys Ther.* 1987;9:33–39.
26. Gross MT, Lapp AK, Davis JM. Comparison of Swede-O universal ankle support and aircast sport-stirrup orthoses and ankle tape in restricting eversion-inversion before and after exercise. *J Orthop Sports Phys Ther.* 1991;13:11–19.
27. Gross MT, Ballard CL, Mears HG, Watkins EJ. Comparison of DonJoy ankle ligament protector and Aircast sport-stirrup orthoses in restricting foot and ankle motion before and after exercise. *J Orthop Sports Phys Ther.* 1992;16:60–67.
28. Gross MT, Batten AM, Lamm AL, et al. Comparison of DonJoy ankle ligament protector and subtalar sling ankle taping in restricting foot and ankle motion before and after exercise. *J Orthop Sports Phys Ther.* 1994;19:33–41.
29. Goldie PA, Evans OM, Bach TM. Postural control following inversion injuries of the ankle. *Arch Phys Med Rehabil.* 1994;75:969–975.
30. Sheth P, Yu B, Laskowski ER, An KN. Ankle disk training influences reaction times of selected muscles in a simulated ankle sprain. *Am J Sports Med.* 1997;25:538–543.
31. Docherty CL, Moore JH, Arnold BL. Effects of strength training on strength development and joint position sense in functionally unstable ankles. *J Athl Train.* 1998;33:310–314.
32. Feuerbach JW, Grabiner MD, Koh TJ, Weiker GG. Effect of an ankle orthosis and ankle ligament anesthesia on ankle joint proprioception. *Am J Sports Med.* 1994;22:223–229.
33. Simoneau GG, Degner RM, Kramper CA, Kittleson KH. Changes in ankle joint proprioception resulting from strips of athletic tape applied over the skin. *J Athl Train.* 1997;32:141–147.
34. Sprigings EJ, Pelton JD, Brandell BR. An EMG analysis of the effectiveness of external ankle support during sudden ankle inversion. *Can J Appl Sport Sci.* 1981;6:72–75.
35. Karlsson J, Andreasson GO. The effect of external ankle support in chronic lateral ankle joint instability: an electromyographic study. *Am J Sports Med.* 1992;20:257–261.
36. Leonard CT. *The Neuroscience of Human Movement.* St. Louis, MO: Mosby; 1998.
37. Nishikawa T, Grabiner MD. Peroneal motoneuron excitability increases immediately following application of a semirigid ankle brace. *J Orthop Sports Phys Ther.* 1999;29:168–173.