ORIGINAL ARTICLE

Peroneus longus stretch reflex amplitude increases after ankle brace application

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Br J Sports Med 2003;**37**:258–262

Background: The use of external ankle support is widespread throughout sports medicine. However, the application of ankle bracing to a healthy ankle over a long period has been scrutinised because of possible neuromuscular adaptations resulting in diminished dynamic support offered by the peroneus longus.

Objective: To investigate the immediate and chronic effects of ankle brace application on the amplitude of peroneus longus stretch reflex.

Methods: Twenty physically active college students (mean (SD) age 23.6 (1.7) years, height 168.7 (8.4) cm, and mass 69.9 (12.0) kg) who had been free from lower extremity pathology for the 12 months preceding the study served as subjects. None had been involved in a strength training or conditioning programme in the six months preceding the study. A 3 × 3 × 2 (test condition × treatment condition × time) design with repeated measures on the first and third factor was used. The peroneus longus stretch reflex (% of maximum amplitude) during sudden foot inversion was evaluated under three ankle brace conditions (control, lace up, and semi-rigid) before and after eight weeks of ankle brace use.

Results: A 3 × 3 × 2 repeated measures analysis of variance showed that peroneus longus stretch reflex amplitude increased immediately after application of a lace up brace (67.1 (4.4)) compared with the semi-rigid (57.9 (4.3)) and control (59.0 (5.2)) conditions ($p<0.05$). Peroneus longus stretch reflex also increased after eight weeks of use of the semi-rigid brace compared with the lace up and control conditions ($p<0.05$).

Conclusions: Initial application of a lace up style ankle brace and chronic use of a semi-rigid brace facilitates the amplitude of the peroneus longus stretch reflex. It appears that initial and long term ankle brace use does not diminish the magnitude of this stretch reflex in the healthy ankle.

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Accepted 23 August 2002

Injuries to the ankle and foot are very common in sport.[1–3] A closer examination of these data shows that about 86% of these injuries involve the ligamentous and capsular structures of the associated joints.[2] Other epidemiological studies[4 5] have reported that ankle sprains are estimated to account for 15% of all injuries occurring in formal organised sport. Certified athletic trainers, among other allied healthcare professionals, advocate the use of external ankle support (ready made ankle stabilisers or adhesive tape) to prevent acute ankle sprains as well as chronic re-injury. The use of commercially available ankle braces has become widespread because of the ease of application and cost effectiveness. Essentially two types exist, lace up and semi-rigid braces.[6] Lace up braces are generally constructed of a soft canvas or nylon material, whereas semi-rigid braces use a stirrup consisting of a thermoplastic material.[6]

The musculature controlling the ankle and foot has an important stabilising role offering dynamic restraint against external forces. Because the primary mechanism of injury of an ankle sprain is concomitant talocrural plantar flexion with talocalcaneal inversion, the peroneus longus acts as the key defence mechanism against an inversion movement.[7] Because of the importance of the peroneus longus in this capacity, its neuromuscular response during quasistatic movement[7–13] and dynamic inversion stress[14] has been widely studied. Peroneal muscle reaction time and the magnitude of this response (electromyographic (EMG) activity) is believed to have an important role in preventing an inversion movement at the foot.[7 11] The time taken by the peroneus longus to respond to an inversion perturbation is useful information for characterising its role in dynamically stabilising against a common mechanism of ankle/foot injury. However, the amplitude of the reflex response may provide greater insight into the how the peroneus longus controls excessive joint motion. Specifically, evaluating peroneus longus amplitude during sudden inversion can provide information on the force produced by this muscle after this perturbation.

Some clinicians have questioned the long term use of external ankle stabilisers. It is thought that supporting a healthy ankle may lead to a diminished neuromuscular response and weakness in the surrounding muscles. Furthermore, the supporting structures may remodel themselves so that they become dependent on the external support. We have previously studied the potential effects of long term (eight weeks) ankle bracing on peroneus longus EMG latency during sudden inversion and found no difference between braced and control conditions.[15] Although the duration of the peroneus longus reflex response during sudden inversion has been extensively studied during various treatment conditions,[9–13 15–17] little is known about the magnitude of this reflexive response. Therefore, the purpose of this study was to evaluate the amplitude of the peroneus longus stretch reflex after acute and long term application of two ankle braces. We hypothesised that neuromuscular remodelling of the peroneus longus would occur as a result of dependency on the external support provided after long term application, as well as through acute application of an ankle brace. Such neuromuscular changes would be manifested as changes in the peroneus longus amplitude to the inversion stress as a result of a large muscle spindle response during the high rate change associated with the sudden inversion movement.

METHODS

A 3 × 3 × 2 factorial design guided this study. The first independent variable (within-subjects factor) was the test condition with three levels: control (no brace), semi-rigid (Active Ankle training brace; Active Ankle Systems, Inc, Louisville, Kentucky, USA), and lace up (McDavid 199; McDavid Knee Guard, Chicago, Illinois, USA). All subjects were tested before (pretest) and after long term application of each of these brace conditions. The second independent variable (between-subjects factor) was treatment with three levels: control (no brace), semi-rigid, and lace up. Subjects were randomly assigned to one of these treatment conditions after the pretest. The third independent variable (within-subjects factor) was time with two levels: before and after the treatment. The dependent variable measured was peroneus longus stretch reflex amplitude (% of maximum amplitude). The stretch reflex amplitude represents the magnitude of the peroneus longus in response to the inversion perturbation. This variable provides insight into the strength at which the peroneus longus responds to the controlled inversion stimulus. A heightened peroneus longus reflex amplitude indicates improved activity and excitation of the muscle.

Subjects

Twenty (12 men and eight women) physically active college students (mean (SD) age 23.6 (1.7) years, height 168.7 (8.4) cm, and mass 69.9 (12.0) kg) volunteered for this study. Through a self reported health history questionnaire, subjects identified no known ankle pathologies or lower extremity injuries in the 12 months preceding the study. Furthermore, no subjects were involved in a strength training or conditioning programme during the six months preceding the study that would have altered the physiological function of the peroneus longus. Radiographic evaluation of each test ankle was not performed to confirm ligament laxities. Each subject was required to report to the sports injury research laboratory on two separate occasions. Each subject read and signed an informed consent form. This study was approved by the School of Health and Human Performance human subjects review committee.

Instrumentation

A custom made platform was used to produce the sudden inversion movement. It was constructed similarly to one used in previous studies to evaluate peroneus longus response.[15 18 19] It consisted of two separate flat surfaces on which the subjects stood. At random, the platform was manually tilted to 35° of foot inversion by removing the primary vertical support.

A 16 channel biological signal acquisition system (MP100 MSW; Biopac Systems Inc, Santa Barbara, California, USA) interfaced to a controlling desktop computer recorded the electrical activity of the peroneus longus and an analogue signal derived from a switch positioned on the trap door. Disposable 10 mm Ag/AgCl surface electrodes (Ver Med, Bellows Falls, Vermont, USA) arranged in a bipolar configuration were used to detect the electrical activity and amplitude of the muscle during sudden foot inversion. The raw EMG signal was amplified (gain set at 1000), band passed filtered (10–500 Hz), and digitally converted at 1000 Hz. The analogue signal arising from the trap door was simultaneously sampled and time matched to the collected EMG signal. This analogue signal identified the start of the inversion movement, and allowed assessment of the reflex amplitude.

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 three ankle support conditions (control, semi-rigid, and lace up) in a counterbalanced fashion. The dominant extremity was defined as the one used preferentially to kick a soccer ball. Subjects performed this test while wearing a similar style cross training shoe. The same shoes were worn by the subjects for both assessments. The skin at the electrode site was shaved and cleaned with an alcohol preparation pad to reduce skin impedance. Disposable self adhesive Ag/AgCl electrodes were placed over the peroneus longus muscle belly of the dominant extremity as previously described.[20] Specifically, the electrodes were placed three fingers width distance distal to the fibular head. The reference electrode was placed over the lateral malleolus of the same extremity.

Subjects were instructed to stand on the platform on both legs with body weight evenly distributed. It was assumed that, for all subjects, the weight distribution was maintained throughout testing. The subjects' elbows were flexed with their hands placed on their hips. Once a subject was balanced, the platform under the dominant extremity (tested ankle) was randomly dropped to a 35° angle. The platform was randomly dropped (manually) to eliminate pre-motor activity of the peroneus longus, and to eliminate anticipation of the platform release (fig 1). Baseline activity of the peroneus longus was carefully evaluated to ensure that no heightened amplitude existed before initiation of the trap door, which would indicate pre-motor response. A spotter was placed on either side of the subject in case of loss of balance. The pretest consisted of five trials of sudden foot inversion in which peroneus longus amplitude was measured. To accurately assess peroneus longus amplitude, the release of the trap door was indicated by an analogue signal which was synchronised with the peroneus longus EMG activity. Peroneus longus latency was observed as the time between the initiation of the trap door release, and the heightened electrical activity above baseline of the muscle.[12 21] Once the latency had been established, the peak amplitude associated with the second component (M2) or long latency duration of this stretch reflex was measured.[22] The mean of the five scores for each test condition was normalised to the maximum amplitude obtained within that condition, and recorded as the mean pretest score for each subject.

After the pretest, subjects were randomly assigned to one of the three treatment conditions: semi-rigid (n = 6), lace up

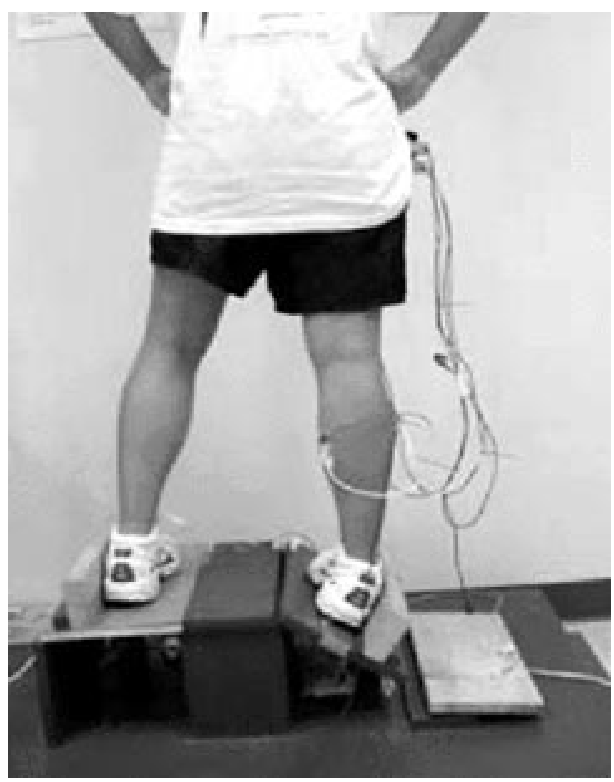

Figure 1 Trap door platform used to produce sudden inversion.

(n = 7), or control (n = 7). This was established to evaluate the potential long term effect of each brace condition. For each brace condition, subjects were required to wear the brace on the dominant extremity for a minimum of eight hours a day for five days a week over an eight week period. Braces were worn during an eight hour time period when subjects were active on their feet throughout the day. As it was difficult to ensure that subjects adhered to the treatment protocol during the weekends when they were not readily visible on campus, they were instructed to wear the braces from Monday to Friday only, resulting in better treatment compliance. Although we did not quantify the actual time the subjects wore the braces, regular interaction was made throughout the treatment period to ensure that the protocol was followed. 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 putting any emphasis on any particular activities.

Immediately after the eight week treatment period, peroneus longus amplitude was measured under the same conditions as before the treatment period. This allowed assessment of the treatment (between-subjects factor). The means of the five trials for each condition obtained before and after the treatment were used for statistical analysis.

Statistical analysis

To estimate the reliability of peroneus longus reflex amplitude, an intraclass correlation coefficient (2,1) was computed as described by Shrout and Fleiss.[23] The reliability coefficient was computed to assess the stability of peroneus longus amplitude of the control condition (no brace) over the treatment period. The standard error of the measurement was calculated to estimate the precision of our measurement using the formula: $\mathrm{SEM} = \mathrm{SD}\,(1-r_{xx})^{1/2}$. A three way repeated measures analysis of variance was used to determine if peroneus longus amplitude differed across levels of testing condition, treatment condition, and time. Simple main effects testing and the Tukey multiple comparison procedure was used to locate specific group differences. The level of significance was established a priori at $p \leq 0.05$.

RESULTS

Table 1 shows the mean (SEM) for peroneus longus stretch reflex amplitude by testing condition, treatment condition, and time. No significant three way interaction was observed between the independent variables on peroneus longus stretch reflex amplitude ($F_{(4,32)} = 1.68$, $p = 0.179$). A significant two way interaction was observed between test condition and time ($F_{(2,32)} = 4.43$, $p = 0.02$). Using simple main effects testing, the lace up brace group had a higher stretch reflex amplitude ($p<0.05$) than the semi-rigid brace and control groups immediately after application. No differences were noted between the semi-rigid brace and control groups immediately after application ($p>0.05$). In addition, simple main effects testing found that after eight weeks of use, stretch reflex amplitude had increased in the semi-rigid brace compared with the lace up brace and control groups ($p<0.05$). The lace up and control conditions did not differ from each other after eight weeks of use ($p>0.05$).

No significant two way interactions were found between test condition and treatment condition ($F_{(4,32)} = 1.75$, $p = 0.16$) or time and treatment condition ($F_{(2,32)} = 0.764$, $p = 0.48$). As for each main effect, there was no difference between test condition ($F_{(2,32)} = 0.928$, $p = 0.41$), treatment condition ($F_{(2,16)} = 0.075$, $p = 0.938$), and time ($F_{(1,16)} = 0.094$, $p = 0.76$) on peroneus longus stretch reflex amplitude (fig 2). The intraclass correlation coefficient of peroneus longus reflex amplitude was estimated at $r_{xx} = 0.70$, with a standard error of measurement of 6.2 (% of maximum amplitude).

Table 1 Peroneus longus stretch reflex amplitude by test condition, treatment, and time (% of maximum)

Treatment condition	Test condition: Semi-rigid	Lace up	Control
Semi-rigid			
Before	55.6 (5.4)	68.7 (1.4)	57.0 (2.5)
After	61.0 (7.2)	68.5 (5.5)	58.6 (5.9)
Lace up			
Before	64.3 (3.5)	63.5 (5.6)	65.5 (7.5)
After	64.7 (5.3)	56.5 (6.0)	60.8 (4.9)
Control			
Before	53.7 (4.1)	69.1 (6.3)	54.5 (5.5)
After	70.5 (3.7)	54.8 (4.3)	63.7 (5.7)

Values are mean (SEM).

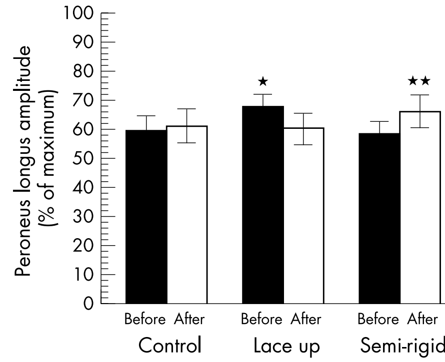

Figure 2 Peroneus longus stretch reflex amplitude illustrated across time and treatment condition. *p<0.05 compared with control and semi-rigid pretest conditions; **p<0.05 compared with the semi-rigid pretest condition.

DISCUSSION

Improving proprioceptive feedback is critical in establishing and maintaining functional joint stability.[24] The early work of Freeman and colleagues[25 26] suggested that chronic ankle injury can be attributed to mechanical instability and decreased afference from joint mechanoreceptors after injury. More recent work has supported this.[27] The various forms of ankle support (tape and braces) available are generally considered effective in providing mechanical stability while restricting joint range of motion.[28–32] Although the use of external ankle support is effective in providing joint mechanical stability, its effect on sensorimotor function is less well understood. Improvement in proprioception and sensorimotor function has been shown to occur, not only through the use of exercise and rehabilitation,[33–35] but also through stimulation of cutaneous mechanoreceptors near and around the ankle through the application of ankle support[36] and tape.[37]

We attempted to investigate the effects of long term use of ankle braces on the amplitude of the peroneus longus stretch reflex. The neuromuscular function of this muscle is critical to the dynamic support of the ankle/foot complex and the prevention of inversion injuries. As a result, peroneus longus reaction time (latency) during a simulated ankle sprain has been predominantly studied comparing normal and chronically unstable ankles,[7 9–13] whereas the effect of ankle support on peroneus longus function has not been as thoroughly investigated.[15 21 38] In all of these studies the duration of the peroneus longus stretch reflex is essentially being quantified. Previously, we found no associated changes in peroneus longus latency with external ankle support after eight weeks use.[15] In this investigation, it was our assertion that neuromuscular remodelling of the peroneus longus would occur because of reliance on the external support provided after long term application. We thought that such neuromuscular changes would be manifest in changes in the peroneus longus amplitude in response to the inversion stress. Although the exact mechanisms for this are not well understood, a couple of plausible explanations exist. Firstly, it can be hypothesised that this heightened activity is the large muscle spindle response during the high rate change associated with the sudden inversion movement. Owing to the relatively small changes in the length of the intrafusal and extrafusal fibres of the muscle spindle that accompanied brace wearing over an eight week period, it is theorised that this diminished the load placed on the muscle spindles, essentially, contributing very little length change between the intrafusal and extrafusal fibres of the spindles. Because muscle spindles are most sensitive to the rate of length change, we surmise that the increased amplitude occurred primarily through stimulation of extrafusal fibres during the sudden inversion movement.

Secondly, the increase in stretch reflex amplitude after an eight week application of the semi-rigid brace may be attributed to changes in the threshold for muscle spindle activation. Because the sensitivity of the muscle spindle is under central nervous system control, it can be modified.[39] Before the long term brace application, subjects were accustomed to talocrural and talocalcaneal range of motion changes. After the eight week brace application, talocalcaneal joint movement (frontal plane motion) was limited; thus it is surmised that neuromuscular adaptation resulted in a lower threshold setting for the muscle spindles to respond to the perturbation. The threshold setting is believed to be due to the neural input provided by the dynamic fusimotor neurons located in the spinal cord.[39] The dynamic fusimotor neurons control the primary group Ia afferents, and make them more sensitive to a dynamic stretch.[39] Given a lower threshold setting, the peroneus longus responded with a greater amplitude. The neuromuscular adaptations that occurred are thought to be primarily the result of the influence of the central nervous system at the spinal cord and not supraspinal centres. The characteristics of the ankle braces tested in limiting talocalcaneal joint motion is well known. These data are abundant in the literature, and their standardised effects on joint motion have been documented.[32] There is no question that the semi-rigid style is more restrictive than the lace up style because of its inherent construction. The restrictive properties of the ankle braces play a role as the physiological limit of joint motion is reached. However, the peroneus longus muscle is firing well before the physiological limit is reached. This may provide more evidence that the external ankle support offered may enhance cutaneous feedback in addition to the mechanical properties of the devices.

Another important finding of this study is that, after acute application, the lace up brace resulted in greater stretch reflex amplitude of the peroneus longus than the semi-rigid and control conditions. We hypothesise that this is due to increased afferent information provided to the central nervous system primarily by cutaneous mechanoreceptors, and perhaps other joint mechanoreceptors, although no other data exist on the influence of ankle bracing on peroneus longus reflex amplitude. Because the lace up brace covers more area than the semi-rigid brace, more receptors may be being stimulated. Our result is similar to that of Nishikawa and Grabiner,[40] who reported increased normalised peroneus longus H-reflex amplitude after application of a semi-rigid ankle brace. It should be noted that they electrically stimulated peroneus longus group Ia afferent nerve fibres percutaneously, and not through deformation of the muscle spindles (simulated ankle sprain) as in this study. This result may be viewed positively as it suggests that these types of braces have an excitatory effect on the peroneus longus. Although the lace up style produced greater peroneus longus activity than the control condition, the semi-rigid brace condition did not result in heightened peroneus longus activity compared with the control condition. It is not clear why this occurred, but we speculate that application of the semi-rigid brace does not result in the same stimulus of the cutaneous because of the decreased surface area offered by the brace. More research is needed to substantiate these findings.

Take home message

External ankle support may enhance the sensorimotor response of the peroneus longus muscle.

Conclusion

This study was designed to determine if long term ankle bracing affects peroneus longus neuromuscular response. The data provide evidence that peroneus longus amplitude in response to sudden inversion perturbation immediately after the application of a lace up style ankle brace is facilitated. It was also observed that peroneus longus amplitude was increased after an eight week application of a semi-rigid style ankle brace. The increased reflex response with an immediate application and extended use of external ankle support is a positive finding, as the neuromotor response from the primary musculature dynamically stabilising against lateral ankle sprain is enhanced. Although these results are encouraging, more studies are needed to understand the mechanisms by which these neurophysiological characteristics of the peroneus longus stretch reflex are effected. These results provide support for clinicians who advocate the use of prophylactic ankle support for extended periods of time, perhaps over the course of a sport season, in healthy subjects and in subjects who suffer from chronic ankle instability.

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