

The Effect of Sudden Inversion Stress on EMG Activity of the Peroneal and Tibialis Anterior Muscles in the Chronically Unstable Ankle

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Ankle sprains perhaps are frequently the most common injury experienced by athletes. It has been documented that up to 85% of injuries to the ankle involve the lateral structures resulting from the combined motions of plantar flexion and inversion (2). Damage to the lateral structures often results in disability, which can be found in up to 40% of individuals who have experienced injury to the lateral ligaments of the ankle (1). The term "functional instability" was first suggested by Freeman et al (6) to describe ankles which suffered recurrent sprains or had the tendency to "give way." Although the etiology of this chronic disability is still unknown, several causes have been suggested, including mechanical instability, muscle weakness, and proprioceptive deficits resulting in motor incoordination, thereby predisposing the ankle to functional instability (4,6,7). Previous studies have suggested that muscle weakness, particularly in the peroneal muscles, may play a significant role in the etiology of functional instability, although this notion is still under debate (1,11,13). Some have also proposed that the reflex time of the peroneal muscles as opposed to the absolute strength

Residual symptoms resulting from recurrent episodes of inversion-type ankle sprains may be attributed to a decreased neuromuscular response of the peroneal or tibialis anterior muscles, thereby increasing the probability for reinjury. The purpose of this study was to examine the electromyographic (EMG) response time of the peroneal and tibialis anterior muscles in response to sudden plantar flexion/inversion stress in the chronically functional unstable and normal ankle. Subjects for this study consisted of 13 athletically active individuals (five males and eight females, mean age = 19.2 ± 1.51 years) with a previous history of a unilateral inversion-type ankle sprain. A specially designed platform that allows each foot to drop into plantar flexion/inversion from a standing neutral position was used. Reaction time in milliseconds for the peroneal and tibialis anterior muscles to sudden plantar flexion/inversion was measured via surface EMG. A paired t test was performed with the Bonferroni-Dunn correction factor to determine differences between the peroneal and tibialis anterior as well as between the chronically unstable and contralateral normal ankle. The results indicated no significant differences between the stable and unstable ankles for the peroneal or the tibialis anterior muscles. The results also indicated no significant differences existed between the tibialis anterior and peroneal muscles in either the stable or unstable ankles. The findings from the present study suggest that self-reported functional ankle instability may not result in a diminished reflex response time of the peroneal and tibialis anterior muscles to sudden plantar flexion/inversion stress.

Key Words: electromyography, ankle, inversion, instability

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of these muscles may be a more important indicator for providing a dynamic muscular restraint to sudden plantar flexion and inversion (9,12). The conflicting results from these studies continue to question the role of the peroneal muscles as well as the anterior tibialis muscle as dynamic stabilizers of the ankle joint.

Reflex muscle activation following sudden inversion stress may be adversely affected following ligamentous trauma. Such a reduction in the muscles' ability to reflexively protect the joint from excessive motion may contribute to a chronic pattern of reinjury. Therefore, the purpose of this study was to examine the electro-

myographic (EMG) response time of the peroneal and tibialis anterior muscles in response to sudden plan-

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tar flexion/inversion stress in the self-reported chronically functional unstable ankle.

MATERIALS AND METHODS

Subjects for this study consisted of 13 athletically active individuals (five males, eight females, mean age = 19.2 ± 1.51 years) with a history of a unilateral inversion-type ankle sprain. Each subject must have required protective weight bearing and/or immobilization to the previously injured ankle. At the time of testing, each subject was full weight bearing without a limp and did not report any significant trauma at least 2 months prior to testing. All subjects completed a questionnaire relating to the history of their ankle sprain and rehabilitation activities. Each subject's self-perception of a chronic, functionally unstable ankle, in addition to the criteria previously stated, was used as a means to identify suitability for inclusion into the study. Prior to participation in the study, all subjects provided written informed consent approved by the Biomedical Institutional Review Board, University of Pittsburgh, Pittsburgh, PA.

Range of motion for ankle dorsiflexion, plantar flexion, inversion, and eversion was assessed with a standard goniometer. Plantar flexion and dorsiflexion motion was assessed by

placing the axis of the goniometer over the midpoint of the lateral malleolus with the stationary arm along a line between the head of the fibula and the lateral malleolus. The movable arm of the goniometer was aligned parallel to the fifth metatarsal. Range of motion for inversion and eversion was assessed with the foot of each subject in a position of plantar flexion. The axis of the goniometer was placed over a point midway between the medial and lateral malleoli with the stationary arm aligned along the longitudinal axis of the lower leg. The movable arm was aligned over the second metatarsal. The same investigator performed all range of motion tests and the average of three measures for each motion was used for analysis.

Instrumentation

A specially designed platform that allows each foot to drop into plantar flexion/inversion from a standing neutral position was used (Figure). The platform on which each foot of the subject was placed upon during standing was held in position by a small, spring plunger that was connected to a bicycle lever that released each platform independently when triggered. The standing platform was connected to two compression springs that pushed each plate of the platform down into plantar flexion/inversion faster than gravity would accomplish alone. The vertical displacement of the platform from the level position to the inverted position was 5 cm. Since this distance was constant for each trial, the speed of displacement was assumed to be consistent. The axis of rotation was 3 inches above the standing platform so that it was relatively close to the inversion pivot line of most human ankles in an attempt to create a realistic representation of this motion. In the transverse plane, the axis of motion of the platform was located at a 20° angle to the midline of the foot, passing between the



FIGURE. Standing neutral position and ankle and foot position following platform release into plantar flexion/inversion.

malleoli of the ankle from an anterior medial position to a posterior lateral position. Upon release of the platform, the ankle would then be forced into combined plantar flexion and inversion. A mechanical stop under the platform prevented the ankles from moving beyond a safe range of motion. An activation switch located adjacent to the release mechanism transferred the signal of release to an analog to digital (A/D) converter which processed the information for analysis to an IBM microprocessor.

Electromyographic Assessment

Electromyographic activity for the peroneal and tibialis anterior muscles was measured using bipolar surface (Ag-Ag/Cl) electrodes that were placed over the bellies of each muscle. The areas over the muscle bellies of each subject were shaved and cleansed with isopropyl alcohol in order to reduce skin impedance and ensure proper electrode fixation. Data acquisition was carried out with an amplifier/processor module

(Therapeutics Unlimited EMG-67, Iowa City, IA) that consisted of on-site preamplifiers and an amplifier/processor. Raw EMG signals were converted to a root mean square value using a time constant of 55 msec. The root mean square EMG signals were then converted from analog to digital at a sampling rate of 75 Hz using an A/D converter (WATSCOPE, Northern Digital Inc., Waterloo, Canada). The digitized signal was collected by the WATSMART (Waterloo Spatial Motion Analysis Recording Technique, Northern Digital Inc., Waterloo, Canada) software system interfaced to an IBM microprocessor. Visual inspection was used to determine the onset of EMG activity above the resting baseline level. The latency time between platform release and onset of EMG activity was calculated in milliseconds.

Plantar Flexion/Inversion Trial

Each subject was asked to stand barefoot in a comfortable position on each plate of the platform with their body weight evenly distributed on each foot. Subjects were positioned with their backs to the investigator in order to eliminate visual cues to platform release. The platform for either ankle was then released randomly with three trials for each ankle.

Statistical Analysis

Paired *t* tests were used to determine statistically significant differences between the ankle condition (unstable vs. noninjured) and the muscle onset time (peroneus longus vs. tibialis anterior). This method of analysis was utilized in order to simplify the comparisons in a clinically applicable manner. The Bonferroni-Dunn correction factor was used to adjust the nominal alpha level of $p < 0.05$ to $p < 0.0125$ to control the overall Type I error rate. A paired *t* test was also used to assess range of motion differences between the unstable and noninjured ankles.

Comparison	\bar{X}	SD	<i>t</i> value	<i>p</i>
Unstable PER	58.6	11.0	-2.13	0.054
Unstable TA	67.9	14.0		
Stable PER	65.3	17.0	-2.31	0.039
Stable TA	71.6	14.0		
Unstable PER	58.6	11.0	-1.24	0.238
Stable PER	65.3	17.0		
Unstable TA	67.9	14.0	-0.75	0.467
Stable TA	71.6	14.0		

PER = Peroneal muscles.

TA = Tibialis anterior muscles.

TABLE. Electromyographic (EMG) response time (milliseconds) of the peroneal and tibialis anterior muscles in the self-reported chronically unstable and contralateral uninjured ankle following sudden plantar flexion/inversion stress.

RESULTS

The results for the mean firing time for the peroneus longus and the tibialis anterior muscles in both the unstable and noninjured ankles are presented in the Table. The results indicated no statistically significant differences in the mean firing time between the noninjured and unstable ankles for both the peroneus longus ($t_{12} = 1.24$, $p = 0.238$) or the tibialis anterior ($t_{12} = 0.75$, $p = 0.467$) muscles. The results also showed no significant differences to exist between the tibialis anterior and peroneal muscles in both the noninjured ($t_{12} = 2.31$, $p = 0.039$) and unstable ($t_{12} = 2.13$, $p = 0.054$) ankles.

The results also demonstrated no significant differences between the unstable and noninjured ankle for plantar flexion ($t_{12} = 0.79$, $p = 0.44$), dorsiflexion ($t_{12} = 1.35$, $p = 0.202$), inversion ($t_{12} = 0.66$, $p = 0.52$), and eversion ($t_{12} = 1.08$, $p = 0.299$).

Results from the questionnaire revealed that the subjects in the present study experienced an average of two ankle sprains (range = 1–6), with a mean time of 7.4 months (range = 1–24 months) from the most recent injury. The average time from completion of the most recent rehabilitation period to the time of

testing was 3.5 weeks (range = 2–8 weeks). All subjects reported that rehabilitation consisted of activities to improve range of motion and flexibility as well as strength and single leg balance.

DISCUSSION

The role of the peroneal and tibialis anterior muscles in providing a dynamic restraint to sudden plantar flexion and inversion has yet to be clearly defined. The purpose of this study was to examine the reflex response time of these muscles to sudden plantar flexion/inversion stress in subjects with a chronic unilateral functionally unstable ankle. The results from this investigation revealed no statistically significant differences between the chronically functional unstable ankle and contralateral uninjured ankle.

The loss of ligamentous integrity resulting in varus instability of the talus in the ankle mortise, thereby attributing to malalignment of the ankle joint, has been defined as mechanical instability (6,12). It must be noted, however, that the subjects in the present study were evaluated based on their self-reported functionally unstable ankle. Since the purpose of this study was to evaluate the re-

Peripheral neural pathology may not have been present in this sample of subjects.

sponse time of the peroneal and the tibialis anterior muscles to sudden inversion stress, the presence or quantification of mechanical ankle instability was not investigated. It could, therefore, be hypothesized that peripheral neural pathology may not have been present in this sample of subjects. In addition, the assess-

ment of reflex muscle response during a sudden inversion stress simulation could have been accomplished under more functional tasks such as walking or running in the present investigation. The instrumentation utilized in this study limited this assessment to a standing position with no movement by the subject.

An early study conducted by Freeman (5) demonstrated no relationship between functional instability and mechanical problems in adult male soldiers. The results from the present study appear to follow a similar pattern as there was no difference in peroneal and tibialis anterior reaction time between the unstable and stable ankles. To reiterate this notion, Isakov et al (8) found that reflexive contraction of the peroneal muscles played no role in protecting the ankle joint during a sprain. Nawoczinski et al (12) also examined peroneal response to sudden inversion stress and found no statistical differences between injured and non-injured ankles. Konradsen and Raven (10), however, found a prolonged reaction time in the peroneal muscles in a group of soccer players and cross country runners with unilateral ankle instability. Although the studies cited used only inversion stress with varying degrees of displacement (20–35° of inversion), the literature has thus far demonstrated findings suggesting that the reflex response time of the peroneal and tibialis anterior muscles may not be affected by ligamentous laxity in the ankle.

Freeman et al (6) theorized that mechanical instability resulting in functional instability of the ankle can be due to motor incoordination due to articular deafferentation of the mechanoreceptors as a result of injury to the ligaments and/or joint capsule. Normally, proprioceptors are stimulated when the structures of the ankle are stretched during sudden displacement (10). The central effect of this stimulation elicits reflex responses which cause the muscles to fire and stabilize the joints (10). If an

extreme amount of inversion occurs, damage to nerve fibers, ligaments, and the joint capsule can cause a disturbance of these reflexes (8). Damage to the nerve fibers in these structures can have central effects, including changes in the activity of neighboring muscles. The results from the present study, however, do not support this theory as there did not appear to be any differences between the unstable and stable ankles or between the peroneal and tibialis anterior muscles. Once again, though, the lack of documented mechanical instability may have been a factor in this outcome. It should be noted that all of the subjects in this study had undergone some type of proprioceptive rehabilitation following their injuries as outlined by their completed questionnaires in addition to being athletically active at the time of testing. These two findings may partially explain the lack of differences between the unstable and stable ankles since proprioceptive training may have helped to re-establish the deficits that have occurred with the injury. This theory supports the findings of Evans et al (3), who determined that patients with symptoms of functional instability benefited from a peroneal muscle strengthening and coordination program up to 2 years following the initial injury.

Although strength of the peroneal and tibialis anterior muscles was not measured in the present study, it is important to note that inconsistencies within the literature are also evident. Bosien et al (1) reported the presence of peroneal weakness in 66% of subjects with chronic instability. Staples' (13) findings supported Bosien et al's (1), where peroneal weakness was noted in subjects with functional instability. The measurement of strength in these studies was carried out with manual muscle testing, thereby allowing the influence of subjective error. Lentell et al (11), however, objectively measured isometric and isokinetic muscle strength at 30°/sec and found that neither evtor

nor invertor weakness was associated with chronic ankle instability.

The findings of the present study appear to indicate that the reflex response time of the peroneal and tibialis anterior muscles do not differ between the chronically functional unstable and normal ankle. The literature also seems to support the finding that absolute strength of the ankle is not affected by chronic ankle instability. Future research should be directed toward identifying the role of muscle force generation or reaction time as compensatory mechanisms in ankles demonstrating mechanical instability. Such documentation may aid the clinician in critical decision making with respect to exercise prescription for rehabilitation in athletes with the chronically unstable ankle. In addition, the relationship between quantifiable mechanical ankle instability, possibly through graded stress radiography, and functional outcome is necessary to generate definitive conclusions regarding this association.

SUMMARY

Injury to the lateral ligamentous complex of the ankle continues to be a chronic problem for many athletes. The ability to control excessive articular movement under conditions of inversion stress have been suggested to be impaired as a result of a reduction in reflex muscular contraction. Contrary to this hypothesis, the results from the present investigation demonstrate that reflex response time of the anterior tibialis and peroneal muscles following inversion stress does not differ between the self-reported unstable ankle vs. the contralateral noninjured ankle. The inclusion of a comprehensive rehabilitation program following injury may have played a critical role in the results of this study. Further investigation into the effects of functional activities on motor response of the ankle musculature may provide re-

searchers and clinicians with evidence regarding the efficacy of such rehabilitative modalities. JOSPT

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