Effect of Unilateral Functional Instability of the Ankle on Postural Sway and Inversion and Eversion Strength

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Abstract:

Objective: The purpose of this study was to determine if individuals with unilateral functional ankle instability had decreased ability to maintain postural sway, as well as decreased isokinetic eccentric strength of ankle evertors and invertors.

Design and Setting: Subjects with no previous history of ankle injury were compared with subjects with functional ankle instability on the following tests: isokinetic eccentric inversion and eversion strength and measures of single-limb postural sway.

Subjects: Eighteen subjects participated in this study: 9 subjects in the functional instability (FI) group (age = 22.89 ± 3.18 yr, ht = 181 ± 6.0 cm, wt = 80.25 ± 12.2 kg) and 9 noninjured (NI) controls (age = 26.22 ± 2.34 yr, ht = 170 ± 10.0 cm, wt = 65.08 ± 12.03 kg).

Measurements: Subjects performed postural sway assessment on a balance system under static and dynamic conditions. Ankle inversion and eversion eccentric strength were evaluated at 90°/sec using an isokinetic dynamometer. Additionally, we assessed the degree of mechanical instability in the Fl group with a series of stress radiographs.

Results: No significant differences in single-limb postural sway measures or in eversion strength between limbs in the Fl group or between groups were found. A significant group-bylimb interaction was present in inversion peak torque; however, post hoc testing revealed the only difference to be between the dominant and nondominant limbs of the NI group.

Conclusions: Postural sway and inversion and eversion eccentric peak torque are not affected by functional instability of the ankle. Alternate methods of postural sway assessment and ankle strength measurement are discussed as possible areas for future study.

Article:

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Residual ankle disability following an acute inversion sprain is well documented.[1-7] Symptoms include loss of strength,[1] decreased joint position sense,[8] decreased postural stability as compared with the uninjured limbs and as compared with a noninjured group of subjects,[7-9] and functional instability.[3,10]

Freeman[3] described functional instability as a "feeling of giving way." It is a symptom often found in individuals who suffer repeated inversion ankle sprains. Despite conservative or surgical treatment, or both, functional instability remains an ongoing symptom in many individuals who have sustained acute ankle sprains and appears unrelated to mechanical instability (ligament elongation or rupture) .[4,10-12]

The relationship between functional instability and decreased postural stability was first suggested by Freeman et al,[5] who found decreased postural stability in subjects with unilateral instability of the ankle. They assessed postural stability using a modified Romberg test in a static position. These results were later corroborated by Lentell et al[13] using a similar test. Brunt et a1[14] suggested that dynamic postural sway may be more appropriate to assess the function of an athlete with instability of the ankle.

Previous research has attempted to document decreased postural stability using quantitative measures.[7,9,15] Tropp et al[15] used stabilometry, a method of measuring postural equilibrium, to assess postural sway in 127 soccer players. They found no significant differences in postural sway between a reference group and subjects with a history of ankle injury. However, they reported that subjects with abnormal stabilometry values had a greater risk of ankle injury during the following season.[15] In a subsequent study, Tropp et a1[9] reported that subjects with functional instability showed increased postural sway over subjects with no prior history of ankle injury, and Tropp,[7] in 1986, found a significant difference in ankle evertors between injured and uninjured limbs of subjects with functional instability.

While some studies reported decreased strength of ankle evertors after inversion sprain when tested manually[1,11] or isokinetically,[7] another[13] found no decrease in strength as compared with uninjured ankles when tested isokinetically. Most assessments of ankle inversion and eversion strength have tested concentric muscle strength.[7,13,16-20] However, ankle sprains often involve high-speed eccentric muscle activity[13] of the peroneals. As such, assessment of eccentric strength is indicated.

The purpose of this study was to determine if individuals with unilateral functional instability of the ankle had decreased ability to maintain static and dynamic postural sway, as well as decreased isokinetic eccentric strength of the ankle evertors and invertors. A second purpose was to determine if a relationship existed among strength, postural stability, and the degree of mechanical instability of the ankle as measured by stress radiographs.

METHODS

Eighteen subjects participated in this study. One female and eight males (age = 22.89 ± 3.18 yr, ht = 181 ± 6.0 cm, wt = 80.25 ± 12.2 kg) made up the functional instability (FI) group. They had a history of significant ankle inversion sprains requiring crutches or preventing participation in activity, followed by repeated episodes of "giving way," but no other history of ankle, foot, knee, or hip injury. All nine subjects in this group suffered unilateral functional instability of the ankle. Four additional subjects initially included in the study were later found on the stress radiographs to have bilateral mechanical instability and were eliminated from the analysis. Due to the lack of dominant (DOM) versus nondominant (NOND) limb data for postural sway index, as well as eccentric inversion and eversion peak torque, we assessed a noninjured group (NI) to determine if differences were present between limbs. The NI group consisted of six women and three men (age = 26.22 ± 2.34 yr, ht = 170 ± 10.0 cm, wt = 65.08 ± 12.03 kg) with no prior history of lower extremity injury.

The time span from initial injury to the study for the subjects in the FI group ranged from 2 to 15 years. All subjects reported repeated episodes of chronic reinjury due to FI within the last year, with the most recent episode 4 months before testing. All subjects were pain free and complained only of the feeling of instability and of recurring injury.

PROCEDURES

All subjects were informed of the procedures and signed a consent form before participating. Subjects reported to the University of Virginia Sports Medicine Research Laboratory for testing. They performed balance testing first, followed by isokinetic strength testing to avoid the effects of fatigue during balance testing. In a separate session, each subject from the FI group reported to the University of Virginia Hospital for assessment of mechanical instability.

Postural Stability

Subjects performed static and dynamic postural stability assessment using the Balance System (Chattanooga Group Inc, Hixson, TN) (Fig 1). They removed their shoes and stood on the balance platform with their feet in a comfortable position (approximately shoulder-width apart). The subjects then stepped off the platform and the force plates were moved to the position of comfort by the investigator. Subjects were repositioned and a safety harness was used. They performed a 1-minute practice session, followed by a 2-minute rest, and finally the test sessions. During testing, the subjects completed dual-limb and single-limb stance protocols with eyes open and eyes closed under static and dynamic conditions.[21-24] During static testing, the platform remained stable. Dynamic testing included perturbations through the use of a tilting platform that forced the ankles into a position of inversion or eversion and a linear platform that slid left and right. To avoid the effects of fatigue, all subjects performed dual-limb stance testing first,

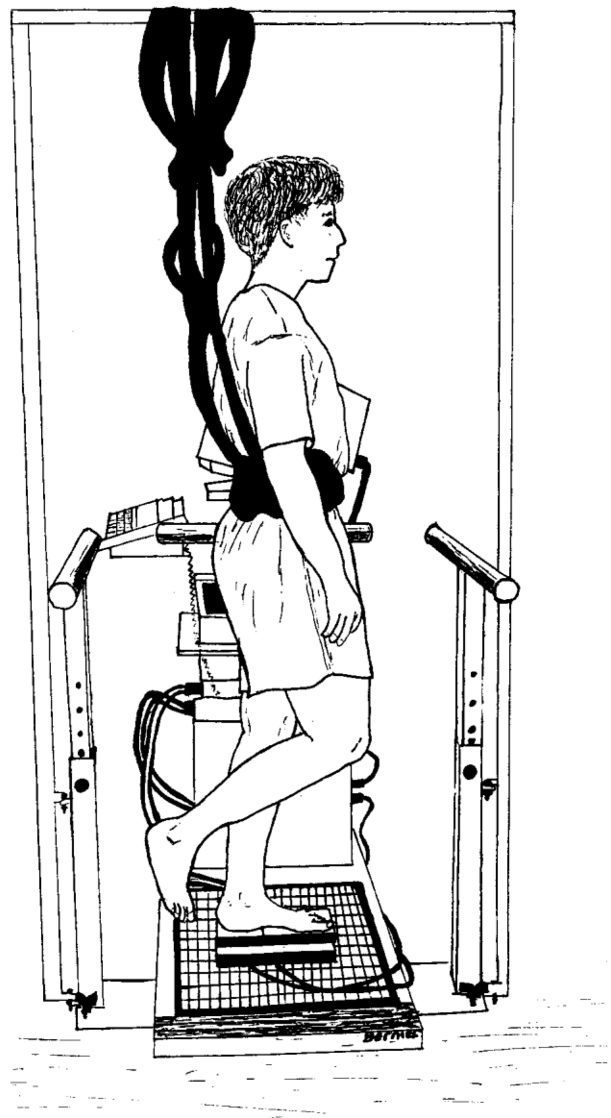


Fig 1. Subject positioning for postural sway measures. Force transducers are located in the foot plate. The foot plate is adjusted to the subject's foot length. The platform (shown with a grid pattern) can be used as a stable platform or as a perturbable platform in a tilting or linear gliding motion.

followed by single-limb stance testing. When testing single- limb stance, limb order was alternated (Table 1).

At the start of each trial, the subjects were instructed to gain their balance and say "ready" when they had attained a feeling of balance. During testing, the subjects held their arms in a relaxed position at their sides. We allowed subjects to move their arms as a strategy to regain balance, but instructed them to return their arms to a relaxed position immediately after sway was controlled. This movement was allowed to represent balance strategies used during activity. During single-limb stance testing, subjects held the knee of the nonweightbearing limb in approximately 15° of flexion. Each trial lasted 10 seconds. The angular displacement for medial and lateral tilting of the platform was ± 4°, with a cycle time of 0.5 seconds per degree of tilt. The medial and lateral linear displacement was ± 1.91 cm, with a cycle time of 0.31 sec/cm.[21]

Table 1. Order of Dual-Limb Stance and Single-Limb Stance Balance Testing

Dual-Limb Stance			Single-Limb Stance		
Trial	Strategy		Trial	Strategy	
1	platform stable	eyes open	1	platform stable	eyes open
2	platform stable	eyes closed	2	platform stable	eyes closed
3	platform tilting left/right (ankles moving inversion/eversion)	eyes open	3	platform tilting left/right (ankle moving inversion/eversion)	eyes open
4	platform tilting left/right	eyes closed	4	platform gliding linearly left/right	eyes open
5	platform sliding linearly left/right	eyes open			
6	platform sliding linearly left/right	eyes closed			

Sway index (SI) was the dependent measure for dual-limb and single-limb postural sway. The Chattanooga Group Inc (J. Pohl, written communication, July 21, 1993) defines sway index as "a numerical value of the standard deviation of the time and distance the subject spent away from his/her center of balance."[21] Center of balance is described as the center of the base of support such that 25% of the body weight remains in each of the quadrants.

Isokinetic Assessment

Subjects performed isokinetic testing on a Kin-Corn II isokinetic dynamometer (Chattanooga Group Inc, Hixson, TN) using software version 2.3. Based on prior work by Cawthorn et al [16] and Lentell et a1,[13] a table was modified so that the subjects could be placed supine on a bench with the knee in 20° of flexion and the ankle in 20° of plantar flexion. We stabilized the lower leg with a strap below the knee over the proximal tibial plateau. Two straps placed on the foot, one just distal to the ankle joint and one over the metatarsals, stabilized the foot to the force plate. The axis of the dynamometer was aligned with the ankle joint according to the manufacturer's specifications. Each subject's personal data were obtained and entered into the computer for subsequent analysis.

Inversion and eversion range of motion were set within the subject's available range. We used a 20-N preload for all testing to eliminate the "overshoot phenomenon" as described by Sapega et al[25] and Jensen et al.[26] Subjects performed eccentric testing for inversion and eversion peak torque at a velocity of 90°/sec. They performed 3 submaximal and one maximal warm-up repetition of either the ankle invertors (INV) or evertors (EV). They rested for 30 seconds and then performed 3 maximal eccentric test repetitions. The subjects then rested 3 minutes before performing this procedure again for the antagonistic muscle group. An additional 3-minute rest was given before they repeated this procedure for the opposite limb. Test order was alternated for limb (injured versus uninjured) and muscle group (INV versus EV). Peak torque was calculated for ankle inversion and eversion from the average of three trials (Table 2).

Mechanical Instability

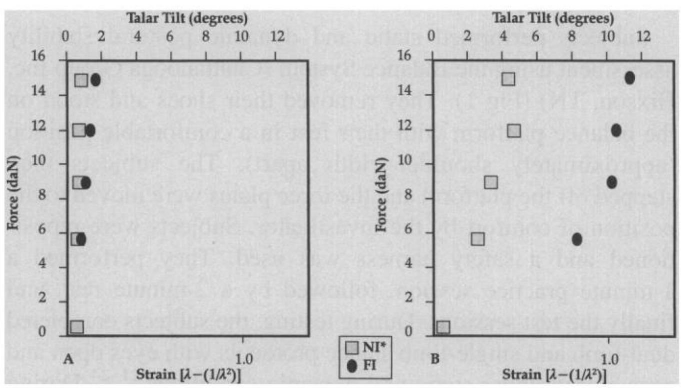
The degree of ankle mechanical instability was measured on stress radiographs using a Telos GA-II/E device (Austin & Associates, Inc, Fallston, MD) with a previously described procedure.[6,27] The Telos GA-II/E device allows the clinician to calculate the elongation of the anterior talofibular (ATF) ligament and calcaneofibular (CF) ligament from a direct measurement of the talar tilt angle.[6] Radiographs were taken at 0, 6, 9, 12, and 15 decaNewtons (daN; 1 daN = 10 N) of force. Rijke et a1[27] reported that the reduction in the slope of the line from the injured to the noninjured ankle is proportional to the percentage of the ATF torn, with a 50% reduction in slope corresponding to complete rupture of the ATF.[6] For rupture of both the ATF and the CF, the line moves to the right and does not begin at the origin (Fig 2).[6]

DATA ANALYSIS

All data were analyzed using SPSS for Windows, version 6.01 (SPSS Inc, Chicago, IL). A two-way repeated-measures analysis of variance (ANOVA) (group X platform strategy) was used to determine if differences were present in dual-limb stance. A three-way repeated-measures ANOVA (group X limb X platform strategy) was used to determine if differences were present in single-limb postural sway. Separate two-way repeated-measures ANOVAs (group X limb) were used to determine if differences were present in eccentric eversion and inversion strength.

A Pearson product moment correlation analysis was performed to test for a relationship among the degree of mechan-

Fig 2. examples OT I egos stress test timings tor two subjects. (A) Subject No. 1 shows functionally unstable ankle is within normal limits (ie, no mechanical instability). (B) Subject No. 7 indicates 100% rupture of anterior talofibular ligament (ATF) and calcaneofibular ligament (CF) (ie, gross mechanical instability). *NI = noninjured, Fl = injured.



ical instability, eccentric strength of the invertors and evertors, and postural sway.

RESULTS

Postural sway measurements for dual-limb stance revealed no significant group-by-platform strategy interactions ($F(5,80) = 0.81$, $p = .546$) (Fig 3). A three-way ANOVA (group X limb X platform strategy) performed on single-limb stance postural sway data also failed to reveal any significant groupby-limb interactions ($F(1,16) = 1.45$, $p = .246$) or three-way interactions ($F(3,48) = 0.44$, $p = 0.722$) (Figs 4 and 5).

For the eccentric strength data analysis, we normalized peak torque to body weight (BW), Nm/(kg BW) (Table 2). There were no significant group-by-limb interactions for eversion peak torque ($F(1,16) = 0.61$, $p = .447$). There was a significant group-by-limb interaction for inversion peak torque ($F(1,16) = 5.29$, $p = .035$). Tukey post hoc testing revealed the only significant difference was between the dominant and nondominant limbs of the NI group ($p < .05$). The nondominant limb showed significantly greater peak torque than the dominant limb.

On stress radiographs, two subjects showed no mechanical instability, three subjects showed complete rupture of the ATF and CF ligaments, and the remaining four subjects showed from 35% to 73% rupture of the ATF (Table 3).

Pearson product moment correlation revealed very low to moderate relationships between the relative degree of mechanical instability and strength deficits or postural stability. Results ranged from $r = 0.06$ for eversion strength deficit to $r = 0.71$ ($p < .05$) for inversion strength deficit. The correlation between relative instability and postural sway ranged from $r = 0.02$ for linear perturbations to $r = 0.35$ for postural sway when the subjects were stable with eyes open.

DISCUSSION

The number of subjects included in our study was limited due to the cost of the stress radiographs. We were unable to

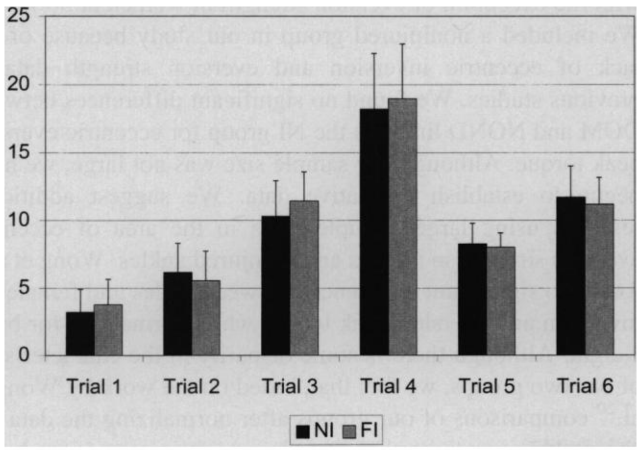


Fig 3. Sway index for balance tests of dual-limb stance in functional instability (FI) and noninjured (NI) groups: trial 1, stable, eyes open (eo); trial 2, stable, eyes closed (ec); trial 3, medial/lateral tilt (eo); trial 4, medial/lateral tilt (ec); trial 5, linear left/right (eo); trial 6, linear left/right (ec). SD = standard deviation.

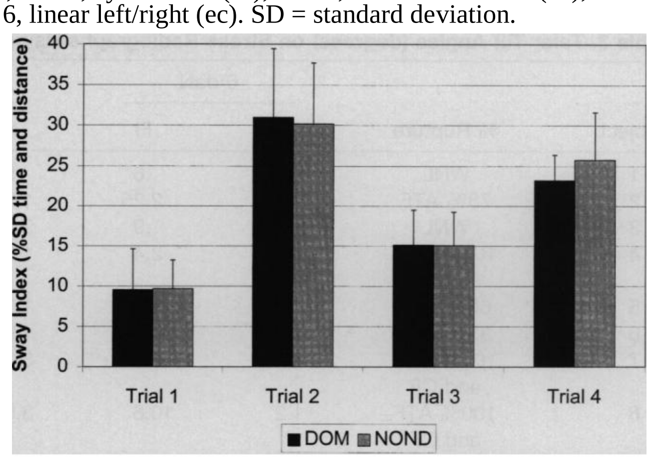


Fig 4. Sway index for balance tests of single-limb stance in the noninjured (NI) group by dominance: trial 1, stable, eyes open (eo); trial 2, stable, eyes closed (ec); trial 3, medial/lateral tilt (eo); trial 4, linear left/right (eo). DOM = dominant, NOND = nondominant. SD = standard deviation.

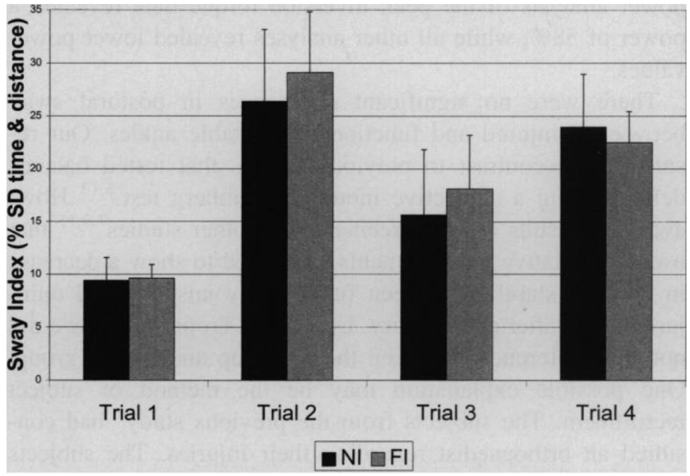


Fig 5. Sway index for balance tests of single limb-stance in the functional instability (FI) group: trial 1, stable and eyes open (eo); trial 2, stable and eyes closed (ec); trial 3, medial/lateral tilt (eo); trial 4, linear left/right (eo). NI = noninjured, Fl = injured.

Table 2. Ankle Eversion and Inversion Eccentric Isokinetic Peak Torque (Nm) at 90°/sec

NI by Dominance		FI by Injury	
Limb	Peak torque	Limb	Peak torque
Eversion			
DOM*	29.22 ± 6.94	Uninjured	35.56 ± 14.15
NOND	29.89 ± 7.92	Injured	34.22 ± 13.36
Inversion			
DOM	30.89 ± 10.26	Uninjured	41.00 ± 8.11
NOND	34.44 ± 11.21	Injured	37.78 ± 9.38

*DOM=dominant, NOND = nondominant.

perform a power analysis a priori for sway index because at the time of this study, we could find no statistically significant values published in the literature. We were, however, able to perform a priori power analysis for concentric strength data. Based on the findings of Wong et al[20] and using the most conservative estimate of power, we determined the statistical

Table 3. Talar Tilt Angles (degrees) on Stress Radiographs Using Telos IIGA Stress Device at 0, 6, 9, 12, and 15 daN of Force*

		6 daN		9 daN		12 daN		15 daN	
Subject	% Rupture	NI	FI	NI	FI	NI	FI	NI	FI
1	WNL	.43	.6	.54	.9	.63	1.4	.75	1.7
2	73% ATF	.40	2.25	1.7	3.19	2.41	4.29	3.37	5.14
3	WNL	1.3	.9	2.2	1.8	2.8	1.5	3.1	3.5
4	100% ATF and CF	...	2.4	1.9	4.9	2.7	5.9	3.4	6.9
5	60% ATF	.5	1.6	1.7	2.6	2.1	3.1	2.8	3.9
6	35% ATF	1.3	1.9	1.9	2.8	3.3	4.3	4.9	6.4
7	100% ATF and CF	3.1	8.0	3.2	10	4.7	10.2	4.1	11.3
8	100% ATF and CF	1.2	10.6	3.0	15.0	4.0	21.5	4.6	24.9
9	50% ATF	1.0	2.5	2.7	2.8	3.0	4.4	3.9	6.1

* NI = noninjured, FI = injured, WNL = normal limits, ATF = anterior talofibular ligament, CF = calcaneofibular ligament, daN = decaNewtons.

power of our strength assessments to be 66%. A post hoc power analysis of the peak inversion torque data revealed a power of 58%, while all other analyses revealed lower power values.

There were no significant differences in postural sway between uninjured and functionally unstable ankles. Our results are in contrast to previous studies that tested balance deficits using a subjective modified Romberg test.[5,13] However, our results are in agreement with other studies[7,9,15] that used quantitative measurements and failed to show a decrease in postural stability between functionally unstable and uninjured limbs after ankle injury. Unlike the Tropp study, we did not find differences between the H group and the NI group. One possible explanation may be the method of subject recruitment. The subjects from the previous study had consulted an orthopaedist regarding their injuries. The subjects from our study suffered from functional instability, but were not in need of a physician at the time of the study. We chose our subject criteria because, although these subjects did not seek a physician's advice upon reinjury, they represented a population of individuals who are evaluated in athletic training rooms daily, who suffer from recurrent injury, and who endure residual ankle disability year after year.

We found very little relationship between the relative degree of mechanical instability and postural sway index. This is in agreement with Tropp et a1,[9] who found that mechanically unstable ankles did not show a decreased ability to maintain postural stability when measured with stabilometry under static conditions. The poor relationship between mechanical instability and postural sway in our study was surprising. We thought that there would be a positive relationship because if subjects' mechanoreceptors are disrupted from injury, postural response should be delayed, particularly when perturbed in a medial and lateral tilting direction. This finding suggests that factors other than damaged mechanoreceptors (due to ruptured ligaments) may be the cause of functional instability or perhaps that other afferents are compensating for the injured mechanoreceptors. Muscle and skin afferents may be providing adequate feedback while the foot is in a closed chain position and skin and muscles are being compressed.

Perhaps a closer relationship exists between functional instability and joint position sense than between functional instability and postural sway or peroneal muscle weakness. Glencross and Thornton[8] showed that subjects with mechanically unstable ankles were unable to correctly reproduce previously positioned joint angles of 30°, 40°, and 50° of plantar flexion. The more severe the injury, the greater the degree of error in joint replication.[8] In our study, the degree of instability appeared to have no effect on postural sway. In the Glencross and Thornton[8] study and the Glick et al[28] study, subjects performed tests in an open chain position, while our subjects performed postural sway in a closed chain position. The results of our study indicate that if decreased proprioception is a cause of functional instability, it is not apparent when the foot is in contact with the floor. Perhaps there is a decrease in proprioception during open chain activity that has an effect on foot placement before heel strike, but this decrease did not reveal itself in postural sway measures.

Previous studies have shown no strength differences in inversion and eversion concentric strength between dominant and nondominant ankles at 30° and 120°/sec19,20 and 60°/sec,7 with the exception of eversion strength in women at 30°/sec.[20] We included a noninjured group in our study because of the lack of eccentric inversion and eversion strength data in previous studies. We found no significant differences between DOM and NOND limbs in the NI group for eccentric eversion peak torque. Although our sample size was not large, we have begun to establish normative data. We suggest additional research using larger sample sizes in the area of eccentric eversion strength in injured and uninjured ankles. Wong et a1[20] found no significant differences between males and females in inversion and eversion peak torque when normalized for body weight. Although there is some disparity in the characteristics of our two groups, we feel that, based on the work by Wong et al,[20] comparisons of our groups after normalizing the data are acceptable.

We found that as the relative degree of mechanical instability increased, there was a decrease in inversion eccentric peak torque as compared with the uninjured limb (Pearson r = —0.71). This was in contrast to our expected results. We thought there would be a strong negative correlation with eversion strength deficits, and if there was a relationship with inversion strength, it would be a positive correlation (ie, as mechanical instability increases, inversion strength increases). An increase in inversion strength would cause a smaller evertor-to-invertor ratio, which may predispose the individual to inversion injury. It is unclear why the invertor strength of the FI group appeared to decrease as instability became greater.

We found no injured versus uninjured limb differences in inversion or eversion strength in the Fl group. We did not find any isokinetic eccentric eversion strength data in previous studies for comparison purposes. Previous research of ankle concentric eversion strength reveals variable results. In a retrospective study, Bosien et al[l] reported peroneal muscle weakness (through manual muscle testing) as the cause of chronic ankle symptoms. Lentell et a1[13] showed no significant differences between concentric isokinetic strength of the evertors in uninjured and chronically unstable ankles at 0° and 30°/sec. However, Tropp did find a significant difference in evertor muscles when tested concentrically at 30° and 120°/ sec.

Glick et a1[28] showed that subjects with mechanically unstable ankles exhibited increased degrees of inversion just before heel strike during normal walking. They further showed that, when ankles were taped, three of four subjects showed increased contraction time of the peroneus brevis before heel strike.[28] If an individual with an unstable ankle strikes the heel (during normal walking) in an inverted position or is following through the stance phase in a hypersupinated position, the ankle evertors must act to stabilize the ankle with every step. This could be one possible explanation for the lack of a significant decrease in evertor strength, despite not having participated in rehabilitation. If this is the case, however, those with severe mechanical instability may show even increased eversion strength. Regardless of foot position, the ankle musculature is called upon to act during every step. Although subjects did not perform rehabilitation before the testing, walking and functional activities alone may have acted to return muscle function in the injured ankle. Additionally, ankle sprains often involve high-speed contractions.[13] We evaluated eccentric strength at 90°/sec in an open chain position. We suggest further study involving higher-speed eccentric contractions and perhaps new methods of assessing closed chain strength about the ankle.

CONCLUSIONS

The results of this study revealed no significant difference between functionally unstable and noninjured subjects in either postural sway or inversion and eversion strength measures. Due to the small number of subjects and the corresponding low power, we recommend that this study be used as a model for future studies with a larger sample size.

Functional instability remains an ongoing symptom in subjects suffering acute lateral ankle sprains. The degree to which strength loss, proprioceptive deficits, and mechanical instability contribute to functional instability has not yet been deter mined. Future research should include analysis of proprioception in an open chain position in subjects with a functionally and/or mechanically unstable ankle and assessment of postural sway using various dependent measures, such as maximum sway distance, equilibrium scores, and a ratio of eyes-open to eyes-closed conditions. Additionally, strength testing in a closed chain position, eccentric testing at speeds greater than 90°/sec, analysis of the concentric-eccentric relationship of evertors, and angle of peak torque in the functionally unstable ankle should also receive attention.

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