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Ipsilateral Hip Abductor Weakness After Inversion Ankle Sprain

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Context: Hip stability and strength are important for proper gait mechanics and foot position during heel strike.

Objective: To determine the relationships between hip muscle strength and chronic ankle sprains and hip muscle strength and ankle range of motion.

Design: Ex post facto design with the uninvolved limb serving as the control.

Setting: Laboratory.

Patients or Other Participants: A total of 23 subjects with unilateral chronic ankle sprain were recruited. Subjects had at least 2 ipsilateral ankle sprains and were bearing full weight, with the most recent injury occurring at least 3 months earlier. They were not undergoing formal or informal rehabilitation at the time of the study.

Main Outcome Measure(s): We obtained goniometric measurements for all planes of motion at the ankle. Handheld dynamometry was used to assess the strength of the hip abductor and hip extensor muscles in both limbs.

Results: Hip abductor muscle strength and plantar flexion were significantly less on the involved side than the uninvolved side ($P < .001$ in each case). Strength of the involved hip abductor and hip extensor muscles was significantly correlated ($r = 0.539$, $P < .01$). No significant difference was noted in hip extensor muscle strength between sides ($P = .19$).

Conclusions: Our subjects with unilateral chronic ankle sprains had weaker hip abduction strength and less plantarflexion range of motion on the involved sides. Clinicians should consider exercises to increase hip abduction strength when developing rehabilitation programs for patients with ankle sprains.

Key Words: muscle strength, ankle biomechanics, gluteal muscles

The ankle is the most frequently injured joint in both athletics and in daily life.[1] Ankle sprains are the most common athletic injury,[2] and 70% to 85% of these sprains are inversion-type sprains.[1] It has been reported that 10% to 30% of people with acute inversion-type sprains develop chronic mechanical instabilities[1] and approximately 80% of ankle sprains recur.[3]

The mechanics of the ankle and ankle injury have been studied frequently,[4–8] and a relationship has been shown between the mechanics at the ankle and the mechanics of more proximal joints. Previous authors[9–11] have found that control at the hip is vital for maintaining control at the ankle. Postural stability[8] and muscle recruitment patterns at the hip and ankle[10,11] can be altered after ankle injury, which may have an effect on future episodes of injury. However, despite this apparent relationship, we found only one report,[12] involving a study of 11 subjects, that specifically addressed the strength of the hip abductor muscles and their relationship to chronic inversion ankle sprain and other foot problems. Those authors found ipsilateral hip abductor weakness in people with chronic ankle injury.

Stability of the hip and hip strength are important for proper gait mechanics and foot position during heel strike. Because of the intricate, interwoven nature of lower extremity kinematics, it is important to consider the patency of all the leg joints for stability during gait. Foot placement at heel strike may be altered with a change in the hip abductor or adductor moments generated during the swing phase of gait.[9] This change in foot placement may leave the foot and ankle complex in a vulnerable position, leading to injury. Therefore, if we can show that hip weakness is associated with ankle sprains, increasing hip strength in people with chronic ankle sprains may help to thwart future problems.

We developed our study to build on prior work[9–12] and to investigate whether a difference exists in hip muscle strength, specifically in the hip abductors and hip extensors, between the involved and uninvolved limbs in subjects with unilateral chronic inversion ankle injury. We hypothesized that weakness would be significant on the side with chronic injury, without specifically attempting to demonstrate cause and effect.

Lastly, we wanted to discern whether any of the measures of range of motion (ROM) were correlated with hip muscle strength. Ankle sprains occur with the lower limb in a weight-bearing position. With changes in ankle ROM, as may be seen with a prior injury, other joints must compensate for decreased ankle motion to avoid gait deviations. These subtle, but possible, changes in hip position during gait and upright activities may change the muscle firing at the hip, which may be man-

Table 1. Strength and Range-of-Motion Differences*

	Involved Limb, Mean ± SD	Uninvolved Limb, Mean ± SD	t	P	Power	SEM
Hip abductors (N)	246.96 ± 53.11	266.68 ± 54.04	−3.8	.001	NA	5.23
Hip extensors (N)	237.67 ± 54.34	246.19 ± 53.69	−1.3	.19	.25	6.31
Passive plantar-flexion ROM (°)	45.1 ± 12.9	48.8 ± 10.7	2.2	.04	NA*	1.68
Passive dorsiflexion ROM (°)	17.6 ± 9.0	20.1 ± 8.7	1.7	.11	.36	1.49
Passive inversion ROM (°)	27.6 ± 9.3	26.6 ± 12.0	−.43	.67	.07	2.43
Passive eversion ROM (°)	9.3 ± 4.89	8.2 ± 5.4	−1.0	.33	.16	1.10

*NA indicates not applicable; ROM, range of motion.

ifested as changes in strength. Although further research investigating electromyographic activity would be needed to reach a conclusion, our preliminary, exploratory study was designed to look for changes in hip strength that may be associated with changes in ankle ROM.

METHODS

Subjects

We used an ex post facto design to assess differences in hip strength and ROM in subjects between the involved and uninvolved sides. A convenience sample of 23 people between the ages of 18 and 52 years (age = 26.65 ± 8.35 years) was recruited through flyers. The average time since the most recent injury was 2.96 ± 1.8 years, and the average number of ankle sprains was 3.48 ± 2.59 episodes. Inclusion criteria consisted of history of at least 2 ankle sprains to the same side without injury to the contralateral ankle, no trauma to the lower extremities for the 3 months prior to the study, full weight bearing without antalgia, and subjective reports that functional use of the ankle had maximized or plateaued since the last injury. Inclusion criteria were purposely kept loose to obtain a large number of subjects who might not recognize persisting impairments. Exclusion criteria consisted of current formal or informal rehabilitation to the ankle, history of neuromusculoskeletal disease, or prior surgery to the back or legs.[8] This study was approved by the Institutional Review Board of New York Institute of Technology, which also approved the informed consent document signed by each subject.

Each subject completed a demographics questionnaire, and then the measurement protocol began, with the participant's uninvolved limb serving as the control. All measurements were taken twice and averaged. Low[13] reported that repeating goniometric measures and calculating an average is more reliable than taking 1 measurement. The therapist performing the measures was unaware of which limb was involved. Because of prior published reports of poor interrater reliability for subtalar inversion and eversion,[14] 1 examiner (K.F.) performed those measures. The intraclass correlation coefficient (3,1) for intratester reliability was .96 for inversion and .86 for eversion.

Measurement Tools

Muscle Strength. Strength of the hip abductor muscles was measured with a handheld dynamometer (model 01160 Nicholas dynamometer; Lafayette Instruments, Lafayette, IN) as the supine participant abducted against resistance. Handheld dynamometry for assessment of lower extremity muscle strength has been shown to have acceptable validity and intertester reliability.[15,16] Strength of the hip extensor muscles was measured with a handheld dynamometer with subjects lying on the side contralateral to the limb being tested. The participant extended the hip against resistance with the knee flexed. For both measurements, the dynamometer was held just proximal to the knee joint, with the hip in neutral rotation. Strength was recorded in Newtons, as depicted on the digital display of the dynamometer. To obtain the measure, an isometric hold was performed for 4 seconds against maximal resistance. Subjects were given a 1-minute rest between the 2 trials.

Range of Motion. Range of motion, using a standard goniometer, was performed for dorsiflexion and plantar flexion according to the procedures outlined by Palmer and Epler[17] and for subtalar inversion and eversion according to Elveru et al.[18] Motion was recorded in degrees. High intertester reliability ($r < .75$) has been established in measures of the ankle in children with spastic cerebral palsy.[19] Rothstein et al[20] found high intertester reliability for lower extremity measures ($r = .57$ to .80).

Data Analysis

Data were recorded, entered into a spreadsheet, and analyzed by SPSS (version 10.0 for Windows; SPSS Inc, Chicago, IL). Paired t tests, with a 1-tailed alpha level of .05, were used to detect strength and ROM differences in each subject between the involved and uninvolved limbs. Bivariate correlational analysis was performed for all measured variables.

RESULTS

Tests of Differences

Strength of the hip abductors was significantly weaker on the involved side than on the uninvolved side ($P < .001$) (Table 1). No significant statistical difference was noted in hip extensor strength between sides ($P = .19$). Plantar-flexion ROM was significantly less in the injured limbs ($P < .004$).

Correlational Analysis

Strength in individuals was closely correlated from one hip to the other (hip abductors $r = .890$, $P < .001$; hip extensors $r = .843$, $P < .001$) and also in strength of involved hip extensors to involved hip abductors ($r = .539$, $P < .01$) (Table 2). Additionally, a significant correlation was seen between involved plantar-flexion ROM and involved inversion ROM ($r = .462$, $P < .026$) for individual participants. Other significant findings were as expected but unimportant for this analysis.

Table 2. Pearson Coefficients*

	Passive Plantar-Flexion ROM		Passive Inversion ROM		Hip Abductor Strength		Hip Extensor Strength	
	Uninvolved Limb	Involved Limb	Uninvolved Limb	Involved Limb	Involved Limb	Uninvolved Limb	Involved Limb	Uninvolved Limb
Uninvolved-limb passive plantar-flexion ROM	1.00							
P Value†	NA							
Involved-limb passive plantar-flexion ROM	.79	1.00						
P Value	.00	NA						
Uninvolved-limb passive inversion ROM	−.04	.02	1.00					
P Value	.84	.93	NA					
Involved-limb passive inversion ROM	.18	.46	.42	1.00				
P Value	.41	.03	.05	NA				
Involved-limb hip abductor strength	.14	−.09	.36	−.01	1.00			
P Value	.53	.70	.10	1.0	NA			
Uninvolved-limb hip abductor strength	−.16	−.31	.33	.02	.89	1.00		
P Value	.46	.15	.12	.92	.00	NA		
Involved-limb hip extensor strength	−.07	−.17	.20	.14	.54	.70	1.00	
P Value	.74	.45	.35	.51	.01	.00	NA	
Uninvolved-limb hip extensor strength	−.24	−.39	.15	.07	.52	.75	.84	1.00
P Value	.27	.07	.49	.76	.01	.00	.00	NA

*ROM indicates range of motion; NA, not applicable.
†Indicates 2-tailed *P* value.

DISCUSSION

Ankle sprains comprise a large percentage of injuries to patients seen in rehabilitation settings. Many authors have investigated the causes of ankle sprain and its sequelae. Given that the recurrence rate of ankle sprains is so high,[3] it seemed plausible to us to investigate confounding factors that may be contributing to repeat injuries. Anecdotal reports have linked proximal weakness with ankle sprain, but we found only 1 group[12] that noted hip abductor weakness as an associated factor in recurrent ankle sprain. Several prior groups[6,7,11,21] have established a link between altered function at the ankle joint and altered function at the hip joint.

According to Robbins and Waked,[4] lateral ankle sprains ‘‘occur during foot contact on landing or locomotion associated with either unanticipated foot placement on a sloped surface or inappropriate positioning of the foot in space before contact with a surface.’’ According to MacKinnon and Winter,[9] errors in foot placement are corrected at the subtalar or hip joint, which work in synergy; small errors in foot placement are corrected distally by the musculature of the foot, whereas large errors are corrected at the hip. Interactions between the supporting foot and hip musculature permit various strategies to be used to maintain balance. Control of pelvic motion is critical to maintaining total body balance because the weight of the head, arms, and trunk acts downward through the pelvis. Dynamic balance of the head, arms, and trunk about the supporting hip depends on the control of pelvic motion by the hip musculature.[9]

During normal ambulation, the gluteus medius muscle provides support to the hip in the frontal plane. It is particularly active from the time of foot flat to midstance in the gait cycle.[9,22] Additionally, foot placement depends on hip adductor and abductor moments generated during the swing phase of gait.[9] Subtalar inversion moments occur in response to medial foot placement errors.[9]

According to Cerny,[22] weakness in a stabilizing muscle, such as the gluteus medius, may produce deviations in joint motion and subsequent loss of stability. Our findings of weaker hip abductors in the involved limb of people with chronic ankle sprains supports this view[22] of a potential chronic loss of stability throughout the kinetic chain or compensations by the involved limb, thus contributing to repeat injury at the ankle.

After lower limb ligamentous injuries, dynamic postural stability of the lumbopelvic complex decreases.[8] The ability to detect motion in the foot and ankle is necessary to make the proper balance corrections in response to deviations in the center of gravity. These corrections, or postural sway, keep the center of mass of the body within the base of support during the gait cycle.[23] Small postural sway adjustments can be amplified and used as ankle strategies in maintaining balance. An ankle strategy is the use of the ankle to control for balance perturbations. During changes in balance, excessive lateral displacement of the center of gravity will result in increased lateral sway. This lateral sway causes the lateral border of the foot to act as a fulcrum, with subsequent inversion of the ankle.[24] When the ankle is unable to compensate adequately for this lateral sway, then a hip strategy is initiated,[23] which helps to prevent the ankle from excessive inversion movement. Bullock-Saxton[6] postulated that altered sensation in one joint can lead to muscle function changes in another, more proximal joint. If the firing, recruitment, and strength of the hip abductor muscles in people with ankle sprains have been altered because of the distal injury, the frontal-plane stability normally supplied by this muscle is lacking, and the risk for repeat injury increases. Weak hip abductors are unable to counteract the lateral sway, and an injury to the ankle may ensue.

The hip adductors initiate a lateral pelvic tilt during early double support in response to the lateral displacement of the mass of the head, arms, and trunk. For the remainder of stance, the hip abductors work to control the lateral pelvic tilt.[9] Hence, in the presence of hip abductor muscle weakness, the position of the foot at initial contact may be more adducted than normal. MacKinnon and Winter[9] found that the body uses several strategies to control body balance, and both distal and proximal components contribute to the fine tuning of the center-of-mass location as it relates to the support limb. Increases in subtalar inversion were associated with decreased hip abduction.

Our results on hip extensor strength did not reveal a statistically significant difference between the involved and uninvolved limbs of subjects with unilateral ankle instability. Although another author[6] has established a relationship between decreased vibration sense at the ankle and increased recruitment time for the gluteus maximus in a group of people with prior history of ankle sprains, strength differences are not apparent after ankle sprain. Because inversion ankle sprain is an injury that occurs primarily in the frontal plane, perhaps the hip extensors, which function primarily in the sagittal plane of motion, have less of a role in stability during hypersupination than do the hip abductors. Therefore, the strength of the hip extensors may be less affected and involved in this injury.

We also investigated whether ROM differences are associated with ankle injury. We found a significant decrease in passive ROM for plantar flexion of the involved limb compared with the uninvolved limb. According to Cerny,[22] ''because gait is not a static but a dynamic event, joint postures in one phase of gait tend to influence postures in the following phase.'' Perhaps decreased plantar-flexion ROM during late stance affects positioning during the next phase of gait, or swing phase, when foot placement during initial contact is determined. An explanation for decreased plantar-flexion ROM was offered by Liu et al.[25] They suggested that decreased ROM after ankle sprain could be related to formation of scar tissue. With the foot in the anatomical position, the anterior talofibular ligament runs essentially horizontally, but when the foot is plantar flexed, the ligament is nearly parallel to the long axis of the leg.[26] It is only in this plantar-flexed position that the ligament comes under strain and is vulnerable to injury, particularly when the foot is inverted.[26] Because of the nature of the fiber orientation of the anterior talofibular ligament, becoming taut in plantar flexion, scarring (which could occur with repeated inversion ankle sprains) with subsequent decreased flexibility as suggested by Liu et al,[25] can limit ROM into plantar flexion.

A correlation was noted between hip abductor and hip extensor strength on the involved side. This finding is not surprising, given that these muscles often function together during postural reactions, stance, and gait.[22] We also found a significant correlation between plantar-flexion ROM and inversion ROM on the involved side. The ankle joints work in concert to produce functional movement patterns, with inversion being an accessory motion to plantar flexion; both motions are implicated in an inversion ankle sprain.[27] Given these interrelationships involving muscle strength and ROM and their combined role in the mechanism of injury, it was not surprising to find a correlation between the motions. However, it is important to note that our strength measures were taken in an open kinetic chain position and, thus, extrapolation to closed chain situations is limited.

LIMITATIONS

Some limitations were associated with this study. First, because we used a retrospective design, we do not know whether the ankle injury caused weakness to the hip musculature or vice versa. A prospective study of injury-free participants would be needed for that analysis. Second, a control group of people without ankle injury should have been studied to determine if there are contralateral differences in hip strength in a similar population. Further research should be conducted with more subjects to determine if ankle hypomobility is a factor in the strength of the hip abductors. Additional subjects would have strengthened the validity of all of the results. Because of a limited time frame in which to perform all data collection, more subjects could not be recruited. Although the power of the results is low, we feel that the results of this pilot study lead to some interesting hypotheses that should be tested further. Last, we did not control for level of activity of subjects, which may have an effect on hip strength.

In conclusion, we found significant weakness in the hip abductor muscles on the involved side as compared with the uninvolved limb of subjects with chronic ankle sprain. We believe that this difference is associated with the characteristic impairments that result from chronic ankle sprain. These impairments may result in decreased stability during ambulation and a subsequent increased risk for repeat injury. Additionally, we found a correlation between plantar-flexion ROM and inversion ROM that we believe is due to the integrated role of these 2 actions during hypersupination of the ankle. Further research is indicated to determine if the difference in the strength of the hip extensor muscles is significant, which we did not find, and the relationship of hypermobility and hypomobility to hip strength. Moreover, a study should be undertaken to determine if a correlation exists between deviations of foot placement during gait and the presence of unilateral hip abductor weakness. More comprehensive treatment protocols, including hip strengthening, need to be implemented due to the established interrelationship between the ankle and the hip during the gait cycle. Because inversion ankle sprain is such a common injury, rehabilitation protocols may need to address the more proximal structures to allow for optimal balance and efficient biomechanical strategies to occur.

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