Ipsilateral Hip Abductor Weakness After Inversion Ankle Sprain

Karen Friel; Nancy McLean; Christine Myers; Maria Caceres

New York Institute of Technology, Old Westbury, NY

Karen Friel, PT, DHS, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Nancy McLean, DPT, contributed to conception and design, acquisition of the data, and drafting and final revision of the article. Christine Myers, DPT, contributed to conception and design; acquisition of the data; and drafting, critical revision, and final approval of the article. Maria Caceres, DPT, contributed to conception and design, acquisition of the data, and drafting and final approval of the article.

Address correspondence to Karen Friel, PT, DHS, Department of Physical Therapy, New York Institute of Technology, Room 501, Northern Boulevard, Old Westbury, NY 11568-8000. Address e-mail to kfriel@nyit.edu.

**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 plantar flexion 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. Ankle sprains are the most common athletic injury, and 70% to 85% of these sprains are inversion-type sprains. It has been reported that 10% to 30% of people with acute inversion-type sprains develop chronic mechanical instabilities and approximately 80% of ankle sprains recur.

The mechanics of the ankle and ankle injury have been studied frequently, and a relationship has been shown between the mechanics at the ankle and the mechanics of more proximal joints. Previous authors have found that control at the hip is vital for maintaining control at the ankle. Postural stability and muscle recruitment patterns at the hip and ankle 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, 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. 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 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-
ifest 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. Low13 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 intrarater reliability for subtalar inversion and eversion,14 1 examiner (K.F.) performed those measures. The intraclass correlation coefficient (3,1) for intrarater 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 intraterester 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 Epler17 and for subtal inversion and eversion according to Elveru et al.18 Motion was recorded in degrees. High intrarater reliability (r < .75) has been established in measures of the ankle in children with spastic cerebral palsy.19 Rothstein et al20 found high intrarater 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.
proximal weakness with ankle sprain, but we found only 1 contributing to repeat injuries. Anecdotal reports have linked plausible to us to investigate confounding factors that may be motion and subsequent loss of stability. Our findings of weaker 76 foot placement errors. Subtalar inversion moments occur in response to medial gait. Subtalar inversion moments occur in response to medial gait. The hip adductors work to control the lateral pelvic tilt. Hence, the hip abductors in the involved limb of people with chronic ankle sprains supports this view 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. 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. 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. When the ankle is unable to compensate adequately for this lateral sway, then a hip strategy is initiated, which helps to prevent the ankle from excessive inversion movement. Block-Saxton 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 abductors 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. 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 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 abduc-
tion.

Our results on hip extensor strength did not reveal a statisti-
cally significant difference between the involved and unin-
volved limbs of subjects with unilateral ankle instability. Al-
though another author6 has established a relationship between
decreased vibration sense at the ankle and increased recruit-
ment time for the gluteus maximus in a group of people with
prior history of ankle sprains, strength differences are not ap-
parent 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 hypersupi-
nation 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 associ-
ated with ankle injury. We found a significant decrease in pas-
sive ROM for plantar flexion of the involved limb compared
with the uninjured 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 af-
fects 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 liga-
ment 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 ex-
tensor strength on the involved side. This finding is not sur-
prising, given that these muscles often function together during
postural reactions, stance, and gait.22 We also found a signif-
icant 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 im-
licated in an inversion ankle sprain.27 Given these interrela-
tionships involving muscle strength and ROM and their com-
plied role in the mechanism of injury, it was not surprising
to find a correlation between the motions. However, it is im-
portant 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, be-
cause 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 de-
termine 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. Be-
cause 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 sub-
jects, which may have an effect on hip strength.

In conclusion, we found significant weakness in the hip ab-
ductor 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 im-
pairments 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 in-
version 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 hypo-
mobility to hip strength. Moreover, a study should be under-
taken to determine if a correlation exists between deviations
of foot placement during gait and the presence of unilateral
hip abductor weakness. More comprehensive treatment pro-
tocols, 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 bal-
ance and efficient biomechanical strategies to occur.

ACKNOWLEDGMENTS

We thank Snehal Gadkar, DPT, Francesco Ullo, DPT, and Jessica
Dimino, DPT, for their assistance with study design, literature review,
and data collection.

REFERENCES

1. Wolfe MW, Uhl TL, Mattacola CG, McCluskey LC. Management of an-
2. Garrick JG. The frequency of injury, mechanism of injury, and epide-
4. Robbins S, Waked E. Factors associated with ankle injuries: preventive
5. Vaes P, Daquet W, Casteleyn PP, Handelberg F, Opdecam P. Static and
dynamic roentgenographic analysis of ankle stability in braced and non-
26:692–702.
6. Bullock-Saxton J. Local sensation changes and altered hip muscle func-
7. Freeman MA, Wyke B. Articular reflexes at the ankle joint: an electro-
myographic study of normal and abnormal influences of ankle-joint
8. Lentell G, Baas B, Lopez D, McGuire L, Sarrel M, Snyder P. The con-
tributions of proprioceptive deficits, muscle function, and anatomic laxity
206–215.
9. MacKinnon CD, Winter DA. Control of whole body balance in the frontal


