Comparison of Lower Extremity Propulsion Impulses between Recreational Athletes with Chronic Ankle Instability and Healthy Athletes During Single Leg Hop Tests

Stacy J. Fundenberger
Georgia Southern University

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COMPARISON OF LOWER EXTREMITY PROPULSION IMPULSES BETWEEN RECREATIONAL ATHLETES WITH CHRONIC ANKLE INSTABILITY AND HEALTHY ATHLETES DURING SINGLE LEG HOP TESTS

by

STACY J. FUNDENBERGER

(under the direction of Barry Munkasy)

ABSTRACT

This study examined propulsion net joint moment impulses during two single-leg hop tests (SLHTs) frequently used in athletic training as return-to-play criteria. Healthy recreational athletes were statistically compared to those with chronic ankle instability (CAI), during an anterior and a crossover SLHT, looking for differences, potentially leading to compensatory patterns. When comparing CAI to healthy participants there were no significant differences during the crossover SLHT. For the anterior SLHT, significant differences were found during ankle dorsiflexion, ankle inversion, and hip abduction. Statistical comparison was also made between the anterior and the crossover SLHT. Healthy participants had statistical difference in internal knee rotation when comparing anterior SLHTs to crossover SLHTs. No statistically significant differences were found between the anterior and crossover SLHT for CAI participants. These few significant differences allude to the SLHT being insufficient in determining CAI and leave room for other aspects of propulsion kinetics to be examined.

INDEX WORDS: Single-leg hop test, Crossover single-leg hop test, Propulsion kinetics, Chronic ankle instability
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by

STACY J. FUNDENBERGER

B.A., Whitworth College, 2001

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

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2009
COMPARISON OF LOWER EXTREMITY PROPULSION IMPULSES BETWEEN RECREATIONAL ATHLETES WITH CHRONIC ANKLE INSTABILITY AND HEALTHY ATHLETES DURING SINGLE LEG HOP TESTS

by

STACY J. FUNDENBERGER

Major Professor: Barry Munkasy
Committee: Barry Joyner, Thomas Buckley

Electronic Version Approved:
April 2009
DEDICATION

This is dedicated to all of the friends and family that wouldn’t let me quit and who believed that I could complete what I have started. I didn’t always visibly appreciate the concern, but looking back now, I know it was out of love. And I love you guys! Even if you did threaten my life.
ACKNOWLEDGMENTS

Thank you to Dr. Brian Reimann, Dr. Paul Geisler, Dr. Barry Munkasy, Dr. Barry Joyner and Dr. Charles Hardy.
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CHAPTER 1: INTRODUCTION

The sports medicine clinician is responsible for determining if and when an athlete is able to resume full participation after the occurrence of a musculoskeletal injury. Traditionally, this determination is aided by a series of functional tests that begin with general movements, such as running with cutting\(^1,2\) or hopping\(^3-5\) and progresses towards more complex movements while utilizing many different protocols. After completion of these general tests, the athlete may then progress to more sport specific tests. One purpose of these tests is, in a controlled environment, to assess the athlete’s recovery level and post injury ability to perform the sport specific physical demands required for participation.\(^1,3,6\) However, sports medicine clinicians may only be looking for satisfactory test outcomes without a proper understanding of the process by which the athlete is achieving that outcome.

Effective functional tests should be closed-chain, simulate functional activity,\(^7\) and be validated by research.\(^8\) The single-leg hop test (SLHT) is frequently used because it is simple to administer, reliable, and allows for bilateral comparison.\(^1,2,9,10,16\) SLHTs are traditionally single anterior (straight) hops for distance; some variations include hops for time,\(^1,12,13\) single crossover (diagonal) hop,\(^12,13\) and less frequently may include the vertical jump for height,\(^12\) and the triple hop for distance.\(^12,13\)

An injury often leading to the use of SLHT assessment is the inversion, or lateral, ankle sprain.\(^14\) Multiple sprains may cause chronic ankle instability (CAI) to occur.\(^15,16\) CAI reportedly affects 20-40% of individuals sustaining inversion
ankle sprains. Clinicians often use these tests when treating CAI because SLHTs allow for a bilateral comparison.

There are discrepancies between SLHTs and real-world performance. SLHTs are performed in an isolated, relatively non-competitive environment without opponents and the need to react to environmental changes. Still if SLHTs can detect differences between what would be considered healthy and unhealthy limbs, they would be of value. Little research has examined the sensitivity of SLHT to detect performance impairments of the lower extremity associated with CAI and the SLHT research has been unable to reveal bilateral asymmetry. Even though SLHTs have been unable to detect outcome differences thus far, this does not mean that there aren’t differences in the process used to achieve the outcome. Theoretically, an athlete may develop compensatory propulsion patterns that create similar outcomes and still possess the functional impairments associated with CAI such as proprioceptive deficits due to mechanoreceptor damage.

The effectiveness of functional tests has been approached in previous research examining sensitivity and specificity of the SLHT primarily regarding ankle, knee, and hip outcome measures. This outcome based research examined only how high, how far, or how fast an athlete completed the test but has not addressed anything further, such as joint kinetics or what effect a chronic condition might have in how the test is completed.

Recent research has quantified differences in ground reaction force parameters between an anterior hop and a crossover hop during take-off and
landing and found that a 15 cm medial or lateral dimension added to an anterior hop (crossover) was sufficient enough to illicit significant differences in the medial/lateral ground reaction.\textsuperscript{23}

Little research has focused on the specific demands at each joint and/or the possible existence of compensatory patterns that mask residual injury. This remains important to understand. The risk of reinjury or a new injury in the kinetic chain may be increased if the joint does not fully heal prior to such testing or if compensatory patterns develop. The outcome of the test may be satisfactory but the means of achieving the outcome may vary between injured and healthy. For example, if an injured athlete is unable to produce the necessary movement at the ankle, the knee and the hip will have to offset the change in order to achieve the same outcome. Thus, outcome measures used in traditional administration of the SLHT may not detect the compensations that the rest of the lower extremity makes in order to complete the hop tests.

Joint kinetics provides an indication of each joint’s contribution during the propulsion phase of the SLHT. A further look at joint kinetics is warranted to clarify the contribution and potential compensatory patterns at each joint in CAI and healthy athletes. Net joint moments indicate the net effect of forces over a perpendicular distance across a joint to produce the angular acceleration found. Net joint moment impulses summarize the effect of the net joint moment over time.

Propulsion kinetics are largely neglected in existing SLHT research. If a participant does not have the capability to properly take-off, the SLHT may not be
a true test of the rehabilitated joint. For example, if the ankle plantarflexion net joint moment is decreased, the knee extension net joint moment as well as the hip flexion net joint moment will be increased. If knee and hip net joint moments change, the potential for injury may change as well. Using a different pattern of net joint moment impulses may produce a similar outcome. We hypothesized that compensatory patterns may explain the non-significant results reported by Munn et al\textsuperscript{2}. The purpose of this study was to examine three-dimensional joint kinetics during the propulsion phase of the single-leg anterior hop and crossover hop between CAI and healthy participants by examining net joint moment impulses.
CHAPTER 2: METHODS

Participants

This study utilized a deliberate sampling of 19 CAI (10 males and 9 females) and 19 healthy participants (10 males and 9 females). Participants were recreational, physically active athletes from Georgia Southern University, ages 18-25. To avoid coercion, participants were not approached by anyone other than the researcher and participation was not required. Recreational athlete was defined as participating in physical activity at least three days a week for 20 minutes in duration, a score of five or better on the Tegner and Lysholm Activity Level Questionnaire (Appendix C), and a six or better on the Ankle Activity Score test (Appendix D)\(^\text{24}\). Participants in the CAI (experimental) group met the inclusion criteria if one of their ankles: 1) experienced at least two moderate ankle sprains that required medical attention or lead to activity level disruption to the same ankle no more than 12 months ago but greater than four weeks before beginning this study; 2) experienced weakness and/or pain from this sprain before but were completely asymptomatic at the time of this study; 3) scored less than 70 on the Ankle Score Scale (Appendix E)\(^\text{25}\). Participants’ height, mass, sex and activity level were ascertained and statistically compared to determine group similarity (Table 2.1). Healthy group participants were excluded if they had a current pathology or history of injury to the lower extremity or spine that would influence their ability to perform a single-leg hop test as reported on the completed medical history questionnaire (Appendix F).
Procedures

Each participant was informed of the study details and read, understood, and signed an informed consent approved by the Georgia Southern University Institutional Review Board prior to participation (Appendix G). Participants learned about proper hopping techniques by watching an instructional video and listening to a verbal description no more than a week before testing commenced (Appendix H). If a participant failed to qualify for the study, all associated documents were destroyed.

On the day of testing, participants were given time to stretch and warm up on a stationary bike for five minutes at 65% estimated maximal heart rate reserve. Participant’s estimated maximal heart rate reserve was determined by calculating 220 minus age and multiplying the result by 0.65. The hopping technique video was re-shown after warming up. Each participant completed five anterior practice hops (described below) under the instruction to give maximal effort with each hop, while allowing natural arm swing. It was important to encourage maximal effort so the participant could reproduce consistent movement and effort. An exact maximal distance was not possible to get with each jump, so the examiner measured the practice hops to attain an average of the five jumps. This also allowed the examiner a chance to make certain proper technique was employed before data collection began. The participant was given one minute in between each hop to recover. After completion of the anterior hop practice, the same was done for the crossover hop (described below) only with a line marked 15 cm lateral to the midline of the forceplate and
extending forward. Each participant completed five practice crossover hops under the instruction to give maximal effort, while allowing a natural arm swing.

The dominant limb was determined by asking which leg would most commonly be used to kick a soccer ball and was then used for the testing. The testing limb for the healthy participants was matched to the corresponding CAI participant. If the dominant leg was not the CAI limb, the CAI was used.

The period of interest for this analysis was the propulsion phase. The propulsion phase began at the end of the countermovement when the position of the total body center of mass (TBCM) reached its lowest point (Figure 2.1), and continued until the foot left the forceplate (Figure 2.2, Figure 2.3).

**Tests**

**Anterior (Straight) Hop for Distance.** The first test was an anterior SLHT. Take-off originated on a forceplate with a hop toward a target located a predetermined distance ahead of the participant. The location of the landing mark was established as the average maximal distance jumped during the five practice jumps from the warm-up session. The participant began by standing on a forceplate facing the taped mark identifying where the landing should be. The participant was allowed to use a self-selected arm swing technique to encourage a natural hop with maximal effort. The participant then jumped forward off the forceplate toward the taped mark. The trial was repeated if the landing occurred more than five cm lateral to a line extending from the center of the forceplate or if they stumbled upon ground contact.
**Crossover Hop for Distance.** The participant began on the forceplate facing straight ahead with a predetermined target slightly diagonal from the forceplate. The target was set by measuring the average diagonal distance hopped during the practice session and extended five cm in each direction. The participant was then instructed to hop diagonally off the forceplate and land within the predetermined target. This target ensured a lateral distance great enough to constitute a crossover, but remained within a small area for consistency. Landing outside of the five cm line or stumbling upon ground contact resulted in the trial being repeated.

**Instrumentation**

Participants wore standardized athletic shoes (NIKE, CityCourt Tennis Shoes) during all practice sessions as well as during the data collection.

Kinematic data were collected using an electromagnetic tracking system (Ascension Technologies; Burlington, VT) with the Motion Monitor commercially available acquisition and analysis software. At the core of the system is a transmitter with three orthogonal coils that are used to create an electromagnetic field. Sensors in the magnetic field record the magnetic flux and convey the signals to a base computer through cables. The Motion Monitor software calculates sensor position and orientation from data conveyed by the sensors. All settings were set in direct default mode. Sensor data was sampled by the computer at 100 Hz. Two non-conducting forceplates (Model OR6-5, Advanced Mechanical Technology, Inc., Watertown, MA) were used to collect ground reaction force data during all tests. Forceplate signals were amplified and
digitized using an analog to digital card (ComputerBoard DAS 1602-12, ComputerBoards, Inc., Middleboro, MA). During all tests, the signals from the forceplate were acquired with a sampling frequency of 1000 Hz and converted to force and moment components. An analog hand switch was used to synchronize the sensor and forceplate data. No reliability testing was conducted during this study and may be beneficial in future studies.

During participant set-up, sensors were firmly attached to the dorsum of the foot, the superior medial tibial tuberosity, the lateral thigh at a point midway between the anterior superior iliac spine and the lateral epicondyle of the femur, and the sacrum using a Velcro strap, double-sided tape, pre-wrap and 1 ½” athletic tape to minimize movement. Participants stood on the forceplate during sensor placement in anatomical position. The ankle, knee, and hip joint centers were calculated with respect to the secured foot, shank, and thigh sensors by taking the midpoint between two points digitized on contralateral aspects of the joint. Participant’s height and weight were used for the appropriate anthropometric calculations required for locating each segment’s center of mass and the TBCM using the Dempster parameters as reported by Winter²⁷.

**Data Reduction**

The period of interest for the analysis was the propulsion phase of each SLHT as defined earlier.

Kinematic and kinetic data were filtered using standard biomechanical techniques. Local coordinate systems for the feet, shanks, thighs, pelvis and
trunk were established according to the International Society of Biomechanics standardization recommendation.\(^{26}\)

Three-dimensional joint kinetic contributions to propulsion were analyzed using ankle, knee, and hip net joint moment impulse. Joint centers were digitized and segment lengths were calculated so that net joint moments at the ankle, knee, and hip could be computed using standard biomechanical practices.\(^{27}\) Net joint moment impulse was then calculated by integrating, using the trapezoid rule, the net joint moments during the period of interest.

**Data Analysis**

The data collected were analyzed using two separate independent t-tests. In the first independent t-test, the independent variable was the group (CAI or healthy) and in the second t-test, the independent variable was the test (crossover or anterior SLHT). The p-value was set at .05. Levene’s Test for Equality of Variances was used if necessary for each plane: flexion-extension, abduction-adduction, and medial-lateral rotation.
Tables

Table 2.1 Participant Demographic Information

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<th>Healthy (n=19)</th>
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<tr>
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<td>Female=9</td>
<td>Female=9</td>
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<tr>
<td>Age (years)</td>
<td>20.42 ± 1.89</td>
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<td>Height (cm)</td>
<td>179.13 ± 10.42</td>
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<td>Weight (kg)</td>
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<td>Activity Level*</td>
<td>7.53 ± 1.07</td>
<td>7.63 ± 1.01</td>
<td>.311</td>
<td>.758</td>
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* Activity level defined by Tegner & Lysholm Activity Score.\textsuperscript{24}
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Figure 2.2: Ground Reaction Force Equaling Zero Indicating the End of the Period of Interest
Figure 2.3 Period of Interest from Lowest Vertical TBCM Position to Ground Reaction Force Becoming Zero
CHAPTER 3: RESULTS

CAI vs. Healthy Participants

Our first hypothesis stated that participants with CAI would have significantly greater flexion-extension, abduction-adduction and medial-lateral net joint moment impulses at the knee and hip than healthy participants in both crossover and anterior SLHT.

Crossover SLHT. There were no significant differences for net joint moment impulses during the crossover SLHT between CAI and healthy participants when significance levels were set at less than .05. Crossover results are summarized in Table 3.1 and broken down by joint for ankle (Figure 3.1), knee (Figure 3.2) and hip (Figure 3.3).

Specifically, there was no significant net joint moment impulse mean difference between CAI and healthy participants in the crossover SLHT for ankle dorsiflexion and plantarflexion (representative trial shown in Figure 3.4); ankle abduction and adduction (representative trial shown in Figure 3.5); ankle inversion and eversion (representative trial shown in Figure 3.6); knee flexion and extension (representative trial shown in Figure 3.7); knee internal and external rotation (representative trial shown in Figure 3.8); knee abduction and adduction (representative trial shown in Figure 3.9); hip flexion and extension (representative trial shown in Figure 3.10); hip internal and external rotation (representative trial shown in Figure 3.11); and hip abduction and adduction (representative trial shown in Figure 3.12).
Generally, the net joint moments were the same for each of the tests, depending on the joint and the plane. For example, in the sagittal plane during the crossover SLHT (Figure 3.4), both CAI and healthy ankles moved from a large plantarflexion net joint moment to a possible slight dorsiflexion net joint moment at the time of takeoff. The knee (Figure 3.7) moved from a large extension net joint moment towards a flexion net joint moment at the time of takeoff. The hip (Figure 3.10) gradually moved from an extension net joint moment to a flexion net joint moment shortly before takeoff.

In the transverse plane (Figure 3.5), both CAI and healthy ankles moved from an abduction net joint moment towards an adduction net joint moment, however the peak abduction net joint moment was small. The knee (Figure 3.8) started with an external rotation net joint moment, which began to increase midway through the propulsion phase, but moved towards an internal rotation net joint moment at the time of takeoff. The hip (Figure 3.11) began with an external rotation net joint moment and moved to an internal rotation net joint moment during the propulsion phase.

In the frontal plane (Figure 3.6), both CAI and healthy ankles moved from a slight eversion to an inversion net joint moment midway through the propulsion phase, but returned closer to neutral at the time of takeoff. The knee (Figure 3.9) began in an adduction net joint moment which increased during the propulsion phase but moved towards an abduction net joint moment shortly before takeoff. The CAI hip (Figure 3.12) moved from a large adduction net joint moment towards an abduction net joint moment. The healthy hip did not appear to have
as large an adduction net joint moment impulse as CAI, although the difference was not statistically significant.

**Anterior SLHT.** Anterior SLHT results are summarized in Table 3.2 and are broken down by joint for ankle (Figure 3.13), knee (Figure 3.14) and hip (Figure 3.15). The anterior SLHT produced significantly different net joint moment impulses during ankle dorsiflexion ($P = .037$) (representative trial shown in Figure 3.16), ankle inversion ($P = .047$) (representative trial shown in Figure 3.17), and hip abduction ($P = .019$) (representative trial shown in Figure 3.18) between CAI and healthy. Significance levels were set at less than .05.

For ankle dorsiflexion, the CAI group mean had a greater magnitude at $0.082 \pm 0.059$ Nm/s than the healthy group at $0.047 \pm 0.037$ Nm/s. For ankle inversion, the CAI group mean had a greater magnitude at $6.029 \pm 4.65$ Nm/s than the healthy group at $3.506 \pm 2.64$ Nm/s. For hip abduction, the CAI group mean had a greater magnitude at $-2.257 \pm 3.39$ Nm/s than the healthy at $-0.346 \pm 0.298$ Nm/s.

For the following, there was no significant difference between CAI and healthy participants in the anterior SLHT: ankle plantarflexion (representative trial shown in Figure 3.16); ankle abduction and adduction (representative trial shown in Figure 3.19); ankle eversion (representative trial shown in Figure 3.17); knee flexion and extension (representative trial shown in Figure 3.20); knee internal and external rotation (representative trial shown in Figure 3.21); knee abduction and adduction (representative trial shown in Figure 3.22); hip flexion and extension (representative trial shown in Figure 3.23); hip internal and external
rotation (representative trial shown in Figure 3.24); and hip adduction (representative trial shown in Figure 3.18).

Statistically significant, in the sagittal plane the ankle (Figure 3.16) moved from a large plantarflexion net joint moment towards a dorsiflexion net joint moment at the time of takeoff. The dorsiflexion net joint moment impulse was significantly greater statistically in the CAI group compared to healthy, although the representative trial does not show this because the mean dorsiflexion was only $0.082 \pm 0.059$ Nm/s. In the frontal plane, the ankle (Figure 3.17) began in a slight eversion net joint moment and midway through moved to an inversion net joint moment, when the CAI group had a statistically greater net joint moment impulse compared to healthy. Shortly before takeoff, both groups moved towards an eversion net joint moment. The inversion net joint moment impulse for the CAI group was statistically significantly greater than the healthy group.

The hip (Figure 3.18) began in an adduction net joint moment and only decreased towards an abduction net joint moment shortly before takeoff. The CAI group had a statistically significant greater net joint moment impulse in adduction compared to the healthy group.

**Anterior vs. Crossover SLHT**

Our second hypothesis stated that medial-lateral net joint moment impulses would be significantly greater at the ankle, knee, and hip during propulsion in the crossover SLHT compared to the anterior SLHT for both groups.
**CAI Participants.** No significant net joint moment impulse differences were found between anterior and crossover SLHT for the CAI participants. Significance levels were set at less than .05. These results are summarized in Table 3.3 and broken down by joint for ankle (Figure 3.25), knee (Figure 3.26) and hip (Figure 3.27).

Specifically, there was no significant difference between SLHT anterior and crossover net joint moment impulse means in the CAI participants for ankle dorsiflexion and plantarflexion (representative trial shown in Figure 3.28); ankle abduction and adduction (representative trial shown in Figure 3.29); ankle inversion and eversion (representative trial shown in Figure 3.30); knee flexion and extension (representative trial shown in Figure 3.31); knee internal and external rotation (representative trial shown in Figure 3.32); knee abduction and adduction (representative trial shown in Figure 3.33); hip flexion and extension (representative trial shown in Figure 3.34); hip internal and external rotation (representative trial shown in Figure 3.35); and hip abduction and adduction (representative trial shown in Figure 3.36).

**Healthy Participants.** Healthy participant results are summarized in table 3.4 and are broken down by joint for ankle (figure 3.37), knee (Figure 3.38) and hip (Figure 3.39). For healthy participants, there was a significant difference in net joint moment impulses between anterior and crossover SLHT during knee internal rotation ($P = .038$) (representative trial shown in Figure 3.40). For knee internal rotation, the crossover hop net joint moment impulse mean had a
significantly greater magnitude at \(-0.156 \pm 0.129\) Nm/s than the anterior hop mean at \(-0.085 \pm 0.059\) Nm/s.

For the following, there was no significant difference between SLHT anterior and crossover net joint moment impulse means in the healthy participants: ankle dorsiflexion and plantarflexion (representative trial shown in Figure 3.41); ankle abduction and adduction (representative trial shown in Figure 3.42); ankle inversion and eversion (representative trial shown in Figure 3.43); knee flexion and extension (representative trial shown in Figure 3.44); knee external rotation (representative trial shown in Figure 3.40); knee abduction and adduction (representative trial shown in Figure 3.45); hip flexion and extension (representative trial shown in Figure 3.46); hip internal and external rotation (representative trial shown in Figure 3.47); and hip abduction and adduction (representative trial shown in Figure 3.48). Significance levels were set at less than .05. Results are summarized in Table 3.4.

In the transverse plane the knee (Figure 3.40) moved from an external rotation net joint moment and increased until shortly before takeoff when it moved to an internal rotation net joint moment. The internal rotation net joint moment was significantly greater during the crossover SLHT than during the anterior hop.
### Table 3.1: Net Joint Moment Impulses during Crossover SLHT in CAI and Healthy Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>CAI Mean</th>
<th>Healthy Mean</th>
<th>t-value</th>
<th>df</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion</td>
<td>0.092 ± 0.061</td>
<td>0.072 ± 0.058</td>
<td>-1.044</td>
<td>36</td>
<td>.304</td>
</tr>
<tr>
<td>Knee Extension</td>
<td>22.433 ± 9.694</td>
<td>24.677 ± 11.101</td>
<td>0.664</td>
<td>36</td>
<td>.511</td>
</tr>
<tr>
<td>Knee Flexion</td>
<td>-0.280 ± 0.475</td>
<td>-0.195 ± 0.192</td>
<td>0.728</td>
<td>36</td>
<td>.472</td>
</tr>
<tr>
<td>Hip Flexion</td>
<td>5.956 ± 2.180</td>
<td>7.099 ± 3.753</td>
<td>1.148</td>
<td>36</td>
<td>.259</td>
</tr>
<tr>
<td>Ankle Adduction</td>
<td>0.211 ± 0.559</td>
<td>0.037 ± 0.036</td>
<td>-1.354</td>
<td>36</td>
<td>.184</td>
</tr>
<tr>
<td>Ankle Abduction</td>
<td>-3.405 ± 2.123</td>
<td>-3.792 ± 1.509</td>
<td>-0.649</td>
<td>36</td>
<td>.521</td>
</tr>
<tr>
<td>Knee External Rotation</td>
<td>4.765 ± 2.397</td>
<td>4.635 ± 1.660</td>
<td>-0.194</td>
<td>36</td>
<td>.847</td>
</tr>
<tr>
<td>Knee Internal Rotation</td>
<td>-0.217 ± 0.359</td>
<td>-0.156 ± 0.129</td>
<td>0.694</td>
<td>36</td>
<td>.492</td>
</tr>
<tr>
<td>Hip Internal Rotation</td>
<td>2.414 ± 1.598</td>
<td>2.633 ± 1.957</td>
<td>0.377</td>
<td>36</td>
<td>.708</td>
</tr>
<tr>
<td>Hip External Rotation</td>
<td>-3.967 ± 3.433</td>
<td>-3.693 ± 4.030</td>
<td>0.225</td>
<td>36</td>
<td>.823</td>
</tr>
<tr>
<td>Ankle Inversion</td>
<td>4.751 ± 2.577</td>
<td>3.275 ± 2.252</td>
<td>-1.88</td>
<td>36</td>
<td>.068</td>
</tr>
<tr>
<td>Ankle Eversion</td>
<td>-1.614 ± 2.001</td>
<td>-2.140 ± 2.281</td>
<td>-0.755</td>
<td>36</td>
<td>.455</td>
</tr>
<tr>
<td>Knee Adduction</td>
<td>8.943 ± 5.870</td>
<td>9.393 ± 5.844</td>
<td>0.237</td>
<td>36</td>
<td>.814</td>
</tr>
<tr>
<td>Knee Abduction</td>
<td>-0.641 ± 1.560</td>
<td>-0.588 ± 1.042</td>
<td>0.122</td>
<td>36</td>
<td>.903</td>
</tr>
<tr>
<td>Hip Adduction</td>
<td>15.713 ± 8.409</td>
<td>15.504 ± 7.289</td>
<td>-0.082</td>
<td>36</td>
<td>.935</td>
</tr>
<tr>
<td>Hip Abduction</td>
<td>-1.520 ± 3.307</td>
<td>-0.668 ± 1.251</td>
<td>1.049</td>
<td>36</td>
<td>.301</td>
</tr>
</tbody>
</table>
Table 3.2: Net Joint Moment Impulses during Anterior SLHT in CAI and Healthy Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>CAI Mean</th>
<th>Healthy Mean</th>
<th>t-value</th>
<th>df</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion</td>
<td>0.082 ± 0.059</td>
<td>0.047 ± 0.037</td>
<td>-2.171</td>
<td>36</td>
<td>.037†</td>
</tr>
<tr>
<td>Knee Extension</td>
<td>21.051 ± 9.002</td>
<td>23.913 ± 10.271</td>
<td>0.914</td>
<td>36</td>
<td>.367</td>
</tr>
<tr>
<td>Knee Flexion</td>
<td>-0.266 ± 0.290</td>
<td>-0.129 ± 0.138</td>
<td>1.853</td>
<td>36</td>
<td>.072</td>
</tr>
<tr>
<td>Hip Flexion</td>
<td>5.746 ± 2.684</td>
<td>7.176 ± 3.278</td>
<td>1.471</td>
<td>36</td>
<td>.150</td>
</tr>
<tr>
<td>Ankle Adduction</td>
<td>0.229 ± 0.488</td>
<td>0.029 ± 0.031</td>
<td>-1.782</td>
<td>36</td>
<td>.083</td>
</tr>
<tr>
<td>Ankle Abduction</td>
<td>-3.025 ± 2.543</td>
<td>-4.013 ± 1.450</td>
<td>-1.471</td>
<td>36</td>
<td>.150</td>
</tr>
<tr>
<td>Knee External Rotation</td>
<td>4.123 ± 2.649</td>
<td>5.002 ± 2.026</td>
<td>1.150</td>
<td>36</td>
<td>.258</td>
</tr>
<tr>
<td>Knee Internal Rotation</td>
<td>-0.307 ± 0.490</td>
<td>-0.086 ± 0.059</td>
<td>1.952</td>
<td>36</td>
<td>.059</td>
</tr>
<tr>
<td>Hip Internal Rotation</td>
<td>2.206 ± 1.427</td>
<td>2.379 ± 1.604</td>
<td>0.351</td>
<td>36</td>
<td>.728</td>
</tr>
<tr>
<td>Hip External Rotation</td>
<td>-3.788 ± 4.442</td>
<td>-3.269 ± 2.625</td>
<td>0.438</td>
<td>36</td>
<td>.664</td>
</tr>
<tr>
<td>Ankle Inversion</td>
<td>6.030 ± 4.649</td>
<td>3.506 ± 2.642</td>
<td>-2.057</td>
<td>36</td>
<td>.047†</td>
</tr>
<tr>
<td>Ankle Eversion</td>
<td>-1.313 ± 1.874</td>
<td>-2.261 ± 2.229</td>
<td>-1.419</td>
<td>36</td>
<td>.164</td>
</tr>
<tr>
<td>Knee Adduction</td>
<td>8.473 ± 6.602</td>
<td>10.029 ± 5.477</td>
<td>0.79</td>
<td>36</td>
<td>.434</td>
</tr>
<tr>
<td>Knee Abduction</td>
<td>-0.917 ± 1.695</td>
<td>-0.499 ± 1.123</td>
<td>0.897</td>
<td>36</td>
<td>.376</td>
</tr>
<tr>
<td>Hip Abduction</td>
<td>-2.257 ± 3.391</td>
<td>-0.346 ± 0.298</td>
<td>2.447</td>
<td>36</td>
<td>.019†</td>
</tr>
</tbody>
</table>

† Indicates statistically significant
Table 3.3: Net Joint Moment Impulses in CAI Participants during Anterior and Crossover SLHT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Anterior Mean</th>
<th>Crossover Mean</th>
<th>t-value</th>
<th>df</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion</td>
<td>0.082 ± 0.059</td>
<td>0.092 ± 0.061</td>
<td>-0.506</td>
<td>36</td>
<td>.616</td>
</tr>
<tr>
<td>Knee Flexion</td>
<td>-0.266 ± 0.290</td>
<td>-0.280 ± 0.475</td>
<td>0.116</td>
<td>36</td>
<td>.908</td>
</tr>
<tr>
<td>Hip Flexion</td>
<td>5.746 ± 2.684</td>
<td>5.956 ± 2.180</td>
<td>-0.264</td>
<td>36</td>
<td>.793</td>
</tr>
<tr>
<td>Ankle Adduction</td>
<td>0.229 ± 0.488</td>
<td>0.211 ± 0.559</td>
<td>0.103</td>
<td>36</td>
<td>.918</td>
</tr>
<tr>
<td>Ankle Abduction</td>
<td>-3.025 ± 2.543</td>
<td>-3.405 ± 2.123</td>
<td>0.499</td>
<td>36</td>
<td>.621</td>
</tr>
<tr>
<td>Knee External Rotation</td>
<td>4.123 ± 2.649</td>
<td>4.765 ± 2.397</td>
<td>-0.784</td>
<td>36</td>
<td>.438</td>
</tr>
<tr>
<td>Knee Internal Rotation</td>
<td>-0.307 ± 0.490</td>
<td>-0.217 ± 0.359</td>
<td>-0.644</td>
<td>36</td>
<td>.523</td>
</tr>
<tr>
<td>Hip Internal Rotation</td>
<td>2.206 ± 1.427</td>
<td>2.414 ± 1.598</td>
<td>-0.423</td>
<td>36</td>
<td>.675</td>
</tr>
<tr>
<td>Hip External Rotation</td>
<td>-3.788 ± 4.442</td>
<td>-3.967 ± 3.433</td>
<td>0.139</td>
<td>36</td>
<td>.89</td>
</tr>
<tr>
<td>Ankle Inversion</td>
<td>6.030 ± 4.649</td>
<td>4.751 ± 2.577</td>
<td>1.049</td>
<td>36</td>
<td>.301</td>
</tr>
<tr>
<td>Ankle Eversion</td>
<td>-1.313 ± 1.874</td>
<td>-1.614 ± 2.001</td>
<td>0.479</td>
<td>36</td>
<td>.635</td>
</tr>
<tr>
<td>Knee Adduction</td>
<td>8.473 ± 6.602</td>
<td>8.943 ± 5.870</td>
<td>-0.232</td>
<td>36</td>
<td>.818</td>
</tr>
<tr>
<td>Knee Abduction</td>
<td>-0.917 ± 1.695</td>
<td>-0.641 ± 1.560</td>
<td>-0.522</td>
<td>36</td>
<td>.605</td>
</tr>
<tr>
<td>Hip Abduction</td>
<td>-2.257 ± 3.391</td>
<td>-1.520 ± 3.307</td>
<td>-0.679</td>
<td>36</td>
<td>.502</td>
</tr>
</tbody>
</table>
Table 3.4: Net Joint Moment Impulses in Healthy Participants during Anterior and Crossover SLHT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Anterior Mean</th>
<th>Crossover Mean</th>
<th>t-value</th>
<th>df</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle Dorsiflexion</td>
<td>0.047 ± 0.037</td>
<td>0.072 ± 0.058</td>
<td>-1.549</td>
<td>36</td>
<td>.13</td>
</tr>
<tr>
<td>Ankle Plantarflexion</td>
<td>-20.713 ± 7.290</td>
<td>-19.568 ± 6.077</td>
<td>-0.526</td>
<td>36</td>
<td>.602</td>
</tr>
<tr>
<td>Knee Extension</td>
<td>23.913 ± 10.271</td>
<td>24.677 ± 11.101</td>
<td>-0.22</td>
<td>36</td>
<td>.827</td>
</tr>
<tr>
<td>Knee Flexion</td>
<td>-0.129 ± 0.138</td>
<td>-0.195 ± 0.192</td>
<td>1.217</td>
<td>36</td>
<td>.232</td>
</tr>
<tr>
<td>Hip Flexion</td>
<td>7.176 ± 3.278</td>
<td>7.099 ± 3.753</td>
<td>0.068</td>
<td>36</td>
<td>.946</td>
</tr>
<tr>
<td>Hip Extension</td>
<td>-16.966 ± 10.111</td>
<td>-16.442 ± 8.289</td>
<td>-0.175</td>
<td>36</td>
<td>.862</td>
</tr>
<tr>
<td>Ankle Adduction</td>
<td>0.029 ± 0.031</td>
<td>0.038 ± 0.036</td>
<td>-0.779</td>
<td>36</td>
<td>.441</td>
</tr>
<tr>
<td>Ankle Abduction</td>
<td>-4.013 ± 1.450</td>
<td>-3.792 ± 1.509</td>
<td>-0.46</td>
<td>36</td>
<td>.648</td>
</tr>
<tr>
<td>Knee External Rotation</td>
<td>5.002 ± 2.026</td>
<td>4.635 ± 1.660</td>
<td>0.611</td>
<td>36</td>
<td>.545</td>
</tr>
<tr>
<td>Knee Internal Rotation</td>
<td>-0.086 ± 0.059</td>
<td>-0.156 ± 0.129</td>
<td>2.159</td>
<td>36</td>
<td>.038†</td>
</tr>
<tr>
<td>Hip Internal Rotation</td>
<td>2.379 ± 1.604</td>
<td>2.633 ± 1.957</td>
<td>-0.437</td>
<td>36</td>
<td>.664</td>
</tr>
<tr>
<td>Hip External Rotation</td>
<td>-3.269 ± 2.625</td>
<td>-3.693 ± 4.030</td>
<td>0.385</td>
<td>36</td>
<td>.702</td>
</tr>
<tr>
<td>Ankle Inversion</td>
<td>3.506 ± 2.642</td>
<td>3.275 ± 2.252</td>
<td>0.29</td>
<td>36</td>
<td>.773</td>
</tr>
<tr>
<td>Ankle Eversion</td>
<td>-2.261 ± 2.229</td>
<td>-2.140 ± 2.281</td>
<td>-0.166</td>
<td>36</td>
<td>.869</td>
</tr>
<tr>
<td>Knee Adduction</td>
<td>10.029 ± 5.477</td>
<td>9.393 ± 5.844</td>
<td>0.346</td>
<td>36</td>
<td>.731</td>
</tr>
<tr>
<td>Knee Abduction</td>
<td>-0.499 ± 1.123</td>
<td>-0.589 ± 1.042</td>
<td>0.256</td>
<td>36</td>
<td>.799</td>
</tr>
<tr>
<td>Hip Adduction</td>
<td>16.900 ± 6.595</td>
<td>15.504 ± 7.289</td>
<td>0.619</td>
<td>36</td>
<td>.54</td>
</tr>
<tr>
<td>Hip Abduction</td>
<td>-0.346 ± 0.298</td>
<td>-0.669 ± 1.251</td>
<td>1.093</td>
<td>36</td>
<td>.282</td>
</tr>
</tbody>
</table>

† Indicated statistically significant
Figures

Figure 3.1 Average Ankle Net Joint Moment Impulses during Crossover SLHT

Figure 3.2 Average Knee Net Joint Moment Impulses during Crossover SLHT

Figure 3.3 Average Hip Net Joint Moment Impulses during Crossover SLHT
Figure 3.4 Representative Comparison of CAI and Healthy Ankle Dorsiflexion and Plantarflexion Net Joint Moments during Crossover SLHT

Figure 3.5 Representative Comparison of CAI and Healthy Ankle Adduction and Abduction Net Joint Moments during Crossover SLHT

Figure 3.6 Representative Comparison of CAI and Healthy Ankle Inversion and Eversion Net Joint Moments during Crossover SLHT
Figure 3.7 Representative Comparison of CAI and Healthy Knee Extension and Flexion Net Joint Moments during Crossover SLHT

Figure 3.8 Representative Comparison of CAI and Healthy Knee External and Internal Rotation Net Joint Moments during Crossover SLHT

Figure 3.9 Representative Comparison of CAI and Healthy Knee Adduction and Abduction Net Joint Moments during Crossover SLHT
Figure 3.10 Representative Comparison of CAI and Healthy Hip Flexion and Extension Net Joint Moments during Crossover SLHT

Figure 3.11 Representative Comparison of CAI and Healthy Hip Internal and External Rotation Net Joint Moments during Crossover SLHT

Figure 3.12 Representative Comparison of CAI and Healthy Hip Adduction and Abduction Net Joint Moments during Crossover SLHT
Figure 3.13 Average Ankle Net Joint Moment Impulses during Anterior SLHT
(* denotes statistical significance)

Figure 3.14 Average Knee Net Joint Moment Impulses during Anterior SLHT

Figure 3.15 Average Hip Net Joint Moment Impulses during Anterior SLHT
(* denotes statistical significance)
Figure 3.16 Representative Comparison of CAI and Healthy Ankle Dorsiflexion and Plantarflexion Net Joint Moments during Anterior SLHT

Figure 3.17 Representative Comparison of CAI and Healthy Ankle Inversion and Eversion Net Joint Moments during Anterior SLHT

Figure 3.18 Representative Comparison of CAI and Healthy Hip Adduction and Abduction Net Joint Moments during Anterior SLHT
Figure 3.19 Representative Comparison of CAI and Healthy Ankle Adduction and Abduction Net Joint Moments during Anterior SLHT

Figure 3.20 Representative Comparison of CAI and Healthy Knee Extension and Flexion Net Joint Moments during Anterior SLHT

Figure 3.21 Representative Comparison of CAI and Healthy Knee External and Internal Rotation Net Joint Moments during Anterior SLHT
Figure 3.22 Representative Comparison of CAI and Healthy Knee Adduction and Abduction Net Joint Moments during Anterior SLHT

Figure 3.23 Representative Comparison of CAI and Healthy Hip Flexion and Extension Net Joint Moments during Anterior SLHT

Figure 3.24 Representative Comparison of CAI and Healthy Hip Internal and External Rotation Net Joint Moments during Anterior SLHT
Figure 3.25 Average Ankle Net Joint Moment Impulses in CAI Participants

Figure 3.26 Average Knee Net Joint Moment Impulses in CAI Participants

Figure 3.27 Average Hip Net Joint Moment Impulses in CAI Participants
Figure 3.28 Representative Comparison of Anterior and Crossover SLHT Ankle Dorsiflexion and Plantarflexion Net Joint Moments in CAI Participants

Figure 3.29 Representative Comparison of Anterior and Crossover SLHT Ankle Adduction and Abduction Net Joint Moments in CAI Participants

Figure 3.30 Representative Comparison of Anterior and Crossover SLHT Ankle Inversion and Eversion Net Joint Moments in CAI Participants
Figure 3.31 Representative Comparison of Anterior and Crossover SLHT Knee Extension and Flexion Net Joint Moments in CAI Participants

Figure 3.32 Representative Comparison of Anterior and Crossover SLHT Knee External and Internal Rotation Net Joint Moments in CAI Participants

Figure 3.33 Representative Comparison of Anterior and Crossover SLHT Knee Adduction and Abduction Net Joint Moments in CAI Participants
Figure 3.34 Representative Comparison of Anterior and Crossover SLHT Hip Flexion and Extension Net Joint Moments in CAI Participants

Figure 3.35 Representative Comparison of Anterior and Crossover SLHT Hip Internal and External Rotation Net Joint Moments in CAI Participants

Figure 3.36 Representative Comparison of Anterior and Crossover SLHT Hip Adduction and Abduction Net Joint Moments in CAI Participants
Figure 3.37 Average Ankle Net Joint Moment Impulses in Healthy Participants

Figure 3.38 Average Knee Net Joint Moment Impulses in Healthy Participants
(* denotes statistical significance)

Figure 3.39 Average Hip Net Joint Moment Impulses in Healthy Participants
Figure 3.40 Representative Comparison of Anterior and Crossover SLHT Knee External and Internal Rotation Net Joint Moments in Healthy Participants

Figure 3.41 Representative Comparison of Anterior and Crossover SLHT Ankle Dorsiflexion and Plantarflexion Net Joint Moments in Healthy Participants

Figure 3.42 Representative Comparison of Anterior and Crossover SLHT Ankle Adduction and Abduction Net Joint Moments in Healthy Participants
Figure 3.43 Representative Comparison of Anterior and Crossover SLHT Ankle Inversion and Eversion Net Joint Moments in Healthy Participants

Figure 3.44 Representative Comparison of Anterior and Crossover SLHT Knee Extension and Flexion Net Joint Moments in Healthy Participants

Figure 3.45 Representative Comparison of Anterior and Crossover SLHT Knee Adduction and Abduction Net Joint Moments in Healthy Participants
Figure 3.46 Representative Comparison of Anterior and Crossover SLHT Hip Flexion and Extension Net Joint Moments in Healthy Participants

Figure 3.47 Representative Comparison of Anterior and Crossover SLHT Hip Internal and External Rotation Net Joint Moments in Healthy Participants

Figure 3.48 Representative Comparison of Anterior and Crossover SLHT Hip Adduction and Abduction Net Joint Moments in Healthy Participants
CHAPTER 4: DISCUSSION

The purpose of this study was to determine differences in the joint kinetics in three planes at the ankle, knee, and hip during the propulsion phase of two different SLHTs. Specifically we tested CAI and healthy athletes, both groups completing an anterior hop and a crossover hop.

Participants

Similar to previous research,\textsuperscript{31} it was important to match participants according to sex, height, mass, and activity level as we wanted to control for effects these variables may have on the hopping process. There were no significant differences between the two groups in any of the demographic categories, therefore the two groups were considered appropriately matched.

CAI vs. Healthy Participants

We hypothesized, based on clinical experience, that participants with CAI would have significantly greater flexion-extension, abduction-adduction and medial-lateral net joint moment impulses at the knee and hip than healthy participants. However, we found this to be only partially correct as two of our three statistically significant findings were at the ankle. CAI participants in the anterior SLHT were found to have greater net joint moment impulses for ankle dorsiflexion, ankle inversion, and hip abduction than healthy participants. These athletes did not develop many significant compensations at the hip and knee, as anticipated, but did at the ankle in order to continue to complete the test.

Various studies have stated that the SLHT has not been able to differentiate between injured and uninjured limbs in outcome measures.\textsuperscript{2,18,30,31}
Worrell et al stated that no significant difference was found for three SLHTs with 22 participants when looking at distance jumped and time for completion. It was hoped that our study would show that just because the outcome was not different, the kinetics to complete the tests would show net joint moment impulse differences between CAI and healthy participants. We found this to be true in the few cases previously mentioned.

In previous research using outcome measures, SLHTs were not found to be an adequate functional test to discriminate between injured and uninjured ankles. Again, however, little research has examined joint kinetics. A recent study examined joint kinetics during a vertical landing test and a crossover landing test but still found no significant differences between CAI and healthy groups. Our study hoped to find that if the differences were not in the landing aspect of the SLHT, the differences might be found within the propulsion aspect of the SLHT.

The statistically significant differences we did find may be few, but they are still important to note. Specifically, the greater net joint moment impulses during ankle dorsiflexion and inversion could be attributable to a previous rehabilitation program which focused on isolated ankle movements that strengthened the ankle. The athlete may also be more aware of the ankle movement since there has been injury and time devoted to rehabilitation. The increased net joint moment impulse during hip abduction may be cause by the hip attempting to keep the ankle from a weak position.
However, in agreement to previous outcome measure based research, the SLHT does not appear to be adequate in determining chronic ankle instability. If and when a clinician uses a SLHT, it is important to keep in mind the potential differences we found at the ankle and hip during propulsion. Since most SLHTs occur on the court, field, or in the athletic training room where kinetic measurements are not possible, it is imperative for the clinician to be aware of potential differences.

It was originally hypothesized that there would be greater net joint moment impulses at the hip and the knee because the unstable ankle would not be able to provide a great enough net joint moment impulse. This demonstrates the importance of the rehabilitation program when working with CAI athletes, incorporating the entire lower kinetic chain.

**Anterior vs. Crossover SLHT**

We hypothesized based on clinical experience that medial-lateral net joint moment impulses would be significantly greater at the ankle, knee, and hip during propulsion in the crossover SLHT compared to the anterior SLHT for both CAI and healthy groups when analyzed separately. This hypothesis was not supported. There were no statistically significant differences for the CAI group when comparing anterior and crossover SLHT. For the healthy group, the only statistically significant difference was a greater net joint moment impulse during knee internal rotation for the crossover SLHT.

Previous research on crossover SLHTs, has found that for ground reaction forces, 15 cm is great enough to elicit increased medial/lateral ground reaction
forces during the crossover movement as it creates changes in the acceleration of the body’s center of mass.\textsuperscript{23} Again, the only statistically significant difference during the crossover SLHT was in the knee internal rotation and only in healthy athletes, which indicates that a standard of 15 cm is not adequate for significant net joint moment impulse changes during the crossover SLHT.

Our results suggest that the clinician would gain little information in regards to net joint moment impulses by using a crossover SLHT over an anterior SLHT.

**Propulsion Kinetics**

Propulsion kinetics have been largely neglected in previous research, as researchers have chosen to focus on landing. This narrow focus on landings has left a large part of the SLHT unexamined. One recent study that examined both propulsion as well as landing forces found significant differences between medial-lateral forces in a crossover SLHT as opposed to an anterior SLHT.\textsuperscript{23} However, we were unable to find many differences between CAI and healthy participants suggesting that the SLHT does not differentiate between CAI and healthy participants in propulsion.

The lack of significant differences found in this study could be due to multiple factors. First, the qualifications to be in the CAI group may have been too restrictive. Participants were not included in the study if they had a current knee or hip pathology as they could not complete the test with maximal effort without creating or increasing pain. It is possible that due to CAI, compensatory patterns had developed in the lower extremity. If these compensations are great
enough, it could affect the entire lower extremity thereby resulting in a hip or knee pathology. Hip and knee pathology excluded individuals from participation.

Additionally, ankle rehabilitation history was not examined for differences. Appropriateness and thoroughness of rehabilitation could assist in decreasing compensatory patterns if the rehabilitation was focused on adequate, functional ankle strengthening and movement. If the athlete is allowed to compensate with the knee or hip from the beginning of rehabilitation, the rehabilitation needs of the ankle may not have been appropriately addressed.

Future research could further examine our finding that ankle dorsiflexion and inversion were significantly greater in CAI participants than healthy participants in the anterior SLHT. We did not anticipate these differences to manifest at the ankle.

In this study, sexes were only matched and not compared. It may have been of assistance to see differences in propulsion kinetics in these tests between male and female participants.

A bilateral comparison within healthy participants would be useful to determine differences between dominant and non-dominant limbs. Similarly, a bilateral comparison within CAI participants to determine differences between CAI and healthy limbs could prove applicable. This would provide another perspective for potential differences. It would then provide additional applicable information on limb dominance and how that affects SLHT completion and it would not be necessary to match participants because of the within-subject comparisons.
The boundary of the target was outlined by a standard five cm in each direction from the average maximal test. It may have been more appropriate to use a percentage of hop distance as the distance for the target boundary.

**Conclusion**

This study did not find many significant differences in propulsion kinetics between CAI and healthy participants. This agrees with much of the previous literature on the lack of differences between CAI and healthy and lends further support that the SLHT is not an appropriate tool to use to determine lower extremity asymmetry associated with CAI. Athletic trainers should not use SLHTs as the sole determinant an athlete’s readiness to return to play. If possible, incorporating joint kinetic testing combined with functional testing would be advantageous to provide a more thorough approach.

We also did not find many statistically significant differences in propulsion kinetics between the anterior and crossover SLHT. The anterior SLHT is simpler to consistently administer but the clinician would need to keep in mind that it would not produce the same net joint moment impulse at the knee that a crossover SHLT would.

This study demonstrates that CAI athletes do not need to develop compensatory patterns at the hip and knee as originally thought in order to complete the SLHT.

However, propulsion remains a large part of functional tests and many aspects of propulsion kinetics are unexamined and could still provide statistically significant differences.
REFERENCES


29. Bauer A. *Ankle kinetics during landing tasks in participants with chronic ankle instability and uninjured controls.* Statesboro, GA: Graduate Studies, Kinesiology, Georgia Southern University; 2006.

30. Blum A. *Lower extremity coordination pattern stability during a single-leg hop for distance.* Statesboro, GA: Graduate Studies, Kinesiology, Georgia Southern University; 2005

APPENDICES

APPENDIX A: RESEARCH HYPOTHESES, OPERATIONAL DEFINITIONS, ASSUMPTIONS, LIMITATIONS, AND DELIMITATIONS
RESEARCH HYPOTHESES

1) Participants with chronic ankle instability (CAI) will have significantly greater flexion-extension, abduction-adduction and medial-lateral net joint moment impulses at the knee and hip than healthy participants.

2) Medial-lateral net joint moment impulses will be significantly greater at the ankle, knee, and hip during propulsion in the crossover SLHT compared to the anterior SLHT for both groups.

OPERATIONAL DEFINITIONS

Dominant Leg: as determined by the leg the subject would use to kick a soccer ball.

Propulsion: the propulsion phase begins at the end of countermovement.

Healthy: any athlete without recent history of injury or pathology within the previous three months to lower extremity to be used during testing or spinal or neural pathology.

Physically active: participating in physical activity at least three days a week for 20 minutes in duration, and a score of five or better on the Tegner and Lysholm\(^1\) activity level questionnaire (Appendix D) and a six or better on the Ankle Activity Score questionnaire (Appendix E)\(^2\).

Anterior SLHT: maximal hop straight ahead taking off from the dominant leg and landing on the dominant leg.

Crossover SLHT: maximal hop forward and diagonal 15 cm, taking off from the dominant leg and landing on the dominant leg.
Chronic Ankle Instability (CAI): instability of one of their ankles as described by:

1) Experienced at least two moderate ankle sprains (required medical attention or activity level disruption) to the same ankle no more than 12 months ago, but greater than four weeks before this study; 2) Experienced weakness and/or pain from this sprain before, but be completely asymptomatic at the time of this study; 3) A score of less than 65 on the Ankle Score Scale (Appendix F)\(^3\)

**ASSUMPTIONS**

It is assumed that each participant was honest in acknowledgement of previous medical history and each participant performed the tests as instructed and with maximal effort. It is also assumed that if the participant had any previous experience with a hop test during rehabilitation, that they completed the tests as instructed and not how they previously completed them.

**LIMITATIONS**

One limitation of this study was the small sample size. The sample was set at 20 males and 18 females with approximately half of each sex being a healthy control group and the other half with CAI. This is realistic for the given University, however it was still small. The set criteria also led to another limitation being a lack of randomization. The participants were healthy individuals or those with chronic ankle instability, therefore not truly random. Finally, CAI was not differentiated into those with/without mechanical instability and functional instability. An ankle that is mechanically unstable will move
physically beyond its normal limit whereas functional instability is a subjective report where the athlete feels as if the ankle will give out.

**DELIMITATIONS**

Only Georgia Southern University recreational athletes were used, ages 18-25. Healthy participants had no recent history of lower extremity injury to their dominant leg in the previous three months, head injury in the previous six months, or any spinal injury or balance disorder that would influence their ability to perform a SLHT as reported on the completed medical questionnaire. Participants in the CAI group had chronic ankle instability of one of their ankles as described by: 1) Experienced at least two moderate ankle sprains (required medical attention or activity level disruption) to the same ankle no more than 12 months ago, but greater than four weeks before this study; 2) Experienced weakness and/or pain from this sprain before, but be completely asymptomatic at the time of this study; 3) A score of less than 65 on the Ankle Score Scale (Appendix F).

**CLINICAL SIGNIFICANCE**

This study provides significant information to clinicians about the potential compensatory patterns developed in chronically unstable ankles by examining the joint kinetics during the propulsion phase of two SLHTs. By knowing and understanding the demands at each joint during propulsion of these tests, clinicians can appropriately choose to use these tests as return to play criteria.
**Functional Tests: Background and Traditional Uses**

Functional tests have long been used as criteria for athletic trainers to determine an athlete’s readiness to return to participation, as functional tests simulate stresses produced and imposed during participation. Even after a proper rehabilitation, many athletes may not be able to complete sports specific tests necessary for safe participation. A lack of sport specific competence may predispose them to further or prolonged injury. Evaluation for a safe return to participation necessitates adequate and accurate functional tests. These tests indirectly assess muscle strength and power through the performance of one maximal activity or series of activities.\(^4\) Much research and debate has examined functional tests in an attempt to establish which and how functional tests should be used.\(^5^9\) A general consensus has not been reached.

Common functional tests employed by clinicians include running, cutting, and jumping\(^5^6\) in simple forms, or in complex combination. In addition, there is a vast variety of tests that may be used. Researchers seeking validation for the commonly used functional tests have achieved moderate success\(^7^9\) showing some to be reliable and valid according to outcome measures.

Each individual functional test may be somewhat simple to perform and the many slight variations used make interpreting results across investigations difficult. The multiple methods and directions given to athletes may have a profound influence on test performance.\(^4\) Of all the functional tests available to athletic trainers, single leg hop tests (SLHT) are the most commonly used.\(^5^8^15\)
A basic question for functional tests remains whether the test should be open versus closed-chain kinetic.\textsuperscript{5,11,12,16-18} In theory, functional tests must be closed chain to be effective.\textsuperscript{17} There are limitations and benefits to both when considering open versus closed chain kinetics. Open-chain exercises may be more specific for targeting individual muscles but remain artificial in nature and can create increased dangerous shear forces. Closed chain techniques are more functional for the integration of multiple muscle groups and addressing the entire kinetic chain while decreasing shear forces while increasing joint compressive forces. However, they still are not without limitations such as other joints in the kinetic chain compensating for deficiencies in the effected joint.\textsuperscript{16} Closed-chain kinetic activities can provide the clinician with the option to select activities that include agonist and antagonist muscles with proper strength ratios.\textsuperscript{18} Closed chain kinetic exercises such as one-legged squats and step-ups have been shown to be effective for building quadriceps strength. While remaining simple to administer,\textsuperscript{16} they may allow for compensatory patterns throughout the lower extremity to complete the activity.

**Previous Research on SLHT**

Many of the SLHTs that athletic trainers call functional tests are neither truly sports specific nor are they performed at the intensity and frequency at which they would be in actual competition.\textsuperscript{4,23} Despite this, if performed correctly, functional tests can provide objective information to compare bilaterally or to show progression. Evaluation of the athlete should not be limited to a functional test’s performance outcome. Movement evaluation should include the quality of
the hop; watching particularly for symmetry, movement control, and athlete confidence during performance.\textsuperscript{4}

**SLHT Compared to Other Measures**

SLHT performance has been compared to other return to participation criteria including running activities,\textsuperscript{5,6,19} subjective questionnaires,\textsuperscript{6,10,12,13} isokinetic testing,\textsuperscript{10-13,20} laxity tests\textsuperscript{21} and proprioceptive tests\textsuperscript{15,22}. Functional tests appear to provide only a piece of the puzzle. Researchers seek to know which are the most accurate predictors of successful functional performance. Drouin and Riemann suggested that the lack of a strong relationship between functional hop tests and other clinical measures emphasizes the need to incorporate them as a part of the return to participation criteria.\textsuperscript{23} For instance, researchers compared performance of a six-meter shuttle run without a pivot and one with a pivot, SLHT for distance, SLHT for time, and vertical jump with statistical significance only found between the SLHT and self-assessment, SLHT and quadriceps weakness, and SLHT and patellofemoral compression pain.\textsuperscript{5} This demonstrates that performance of SLHT can reflect functional weakness.

**Joint Focus in Previous SLHT Research**

**Ankle.** Researchers have examined the appropriateness of SLHT for testing the ankle because of the prevalence of inversion ankle sprains in athletics. While functional tests are supported for ankle injuries\textsuperscript{18}, the value of SLHT has not been supported. Munn, et al did not identify the triple-crossover hop to be an adequate functional test to discriminate between injured and uninjured ankles and despite a sample size of 15 participants, the researchers
stated that there was statistical power of greater than 80% for both functional tests completed meaning that the study was applicable.\textsuperscript{6}

Furthermore, Worrell, et al examined three SLHTs and could not support the validity of a SLHT for distance, for time, or an agility hop as an indicator for ankle instability.\textsuperscript{27} This lack of validity was further supported in a more recent study where no significant difference was demonstrated between participants with chronic ankle instability and a control group for an agility hop test.\textsuperscript{19}

**Knee.** The majority of SLHT research has focused on the knee, specifically anterior cruciate ligament patients,\textsuperscript{5,9,20-26} with little regard given to the ankle,\textsuperscript{6,7,18,19,27} and especially the hip\textsuperscript{13}. ACL knee research has utilized a participant population that is either ACL deficient or post ACL reconstruction. However, SLHTs appear to determine a difference between people with an uninjured ACL and those with an injured ACL.\textsuperscript{5,9,24} Barber et al found ACL deficient participants score significantly lower than the normal participants in the completion of SLHTs for distance and for time.\textsuperscript{5}

Andrade et al had 14 males complete single and triple hop tests with each leg and found that after ACL reconstruction (ACL-R group) the participants did not regain normal capacity after eight months however there was a positive correlation between quadriceps performance and single hops with a weaker correlation between hamstring strength and hop tests.\textsuperscript{24} Similarly, 38 participants who had ACL reconstruction showed significant differences between the involved leg and the uninvolved leg during a triple jump test and were highly correlated with knee instability.\textsuperscript{9}
Mattacola, Perrin, Gansneder, Gieck et al examined dynamic postural stability, as determined by a Biodex Stability System, compared to SLHT as well as isokinetic evaluation. They found that their 20 ACL-R participants hopped significantly shorter distances with the involved limb than with the uninvolved limb and the ACL-R group performed significantly worse than the control group’s matching limb.20

**Landing vs. Take-off in Previous Research**

The majority of research done on SLHT considering more than just outcome measurements have focused on the landing portion of the test. Rarely has the take-off been considered in the majority of previous research. Previous research has primarily focused on the effects of various landing tests, not limited to the SLHT29-35 and just recently has research begun to examine take-offs32.

Chappell et al examined knee kinetics in both take-off and landing phases during three stop-jump tests and found differences in the medial-lateral joint forces in females during take-offs.32 Understanding these joint kinetics during take-offs is just as important. An athlete may use compensatory patterns to accomplish the SLHT. They are also important in providing proper justification for using SLHTs as accurate representations of an athlete’s ability to return to participate. If an athlete is unable to propel himself or herself forward correctly, the entire SLHT will be affected.

**Kinetics vs. Kinematics**

Kinetics and kinematics are equated to a cause-effect relationship as kinetics causing the motion and kinematics as the product of the effects of the
forces. In joint kinetics, moments are formed around the joints in either a medial-lateral, abduction-adduction, or in a medial-lateral rotation. The product of a net joint moment and time is called a net joint moment angular impulse. By examining the angular impulses at each joint and adding them to formulate a net joint propulsion impulse, the contribution of each joint and all joints to forward propulsion in the take-off can be determined. With this net joint propulsion impulse, compensatory patterns may become evident. It is necessary to examine how tests are completed and joint kinetics help explain this. Bobbert et al tested the kinetics of different drop jumping techniques to determine how the techniques differed and concluded that the technique used greatly affected each joint and therefore it was imperative that the clinician be mindful of the differences so that incorrect technique is not used.

**Test-Retest Reliability of the SLHT**

Research has consistently demonstrated that outcome measures of SLHTs have high test-retest reliability. Reliability in the vast majority of the investigations was determined through the intraclass correlation coefficients. In a meta-analysis of SLHT reports, collegiate athletes performing a SLHT for distance were reported to have had an ICC of .92 while a single-leg crossover test had an ICC of .93. Additionally, the standard error of the measure in collegiate athletes is 4.6 in SLHT for distance and 17.7 for the single-leg crossover hop.

Specifically, Booher et al wanted to determine the reliability of closed-chain kinetic exercises including a SLHT for distance and concluded that SLHT
for time and for distance were reliable and contained a small measurement error. Similarly, SLHT were found to be significantly representative of knee instability. Risberg and Ekeland found significant differences in a study of 35 ACL-R participants between the involved limb and uninvolved limb during different functional performance tests.

When administering functional tests such as SLHTs, the clinician evaluates the outcome measures to determine success. However the clinician needs to be aware of the joint kinetics being employed to complete the SLHT. Sensitivity, specificity, validity and reliability of qualitative clinical evaluation of SLHT performance have not been examined.
Review of Literature – Additional References


14. Petschnig R, Baron R. Assessment of quadriceps strength and functional limitations determined by hop tests for distance and a newly designed


APPENDIX C: ACTIVITY LEVEL QUESTIONNAIRE
**Personal Information**

Age: _____ Date of Birth: _____/_____/_____ Sex: ______ Dominant Arm: L  R
Dominant Leg: L  R  Shoe size: ____________

---

**Emergency Information**

Do you have medical alert identification? _________ YES _______NO
If YES, where is it located?
______________________________

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**Current Medications (include ALL medications)**

<table>
<thead>
<tr>
<th>Name of Drug</th>
<th>Dosage; Times/day</th>
<th>Why are you on this drug?</th>
</tr>
</thead>
<tbody>
<tr>
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<td>_________________</td>
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</tbody>
</table>

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**Hospitalizations**

Please list the last three (3) times you have been ill (sick) enough to see a physician, been hospitalized or had surgery.

<table>
<thead>
<tr>
<th>When?</th>
<th>What was done (surgery, etc.)?</th>
<th>Why was this done?</th>
</tr>
</thead>
<tbody>
<tr>
<td>______</td>
<td>______________________________</td>
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<tr>
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<tr>
<td>______</td>
<td>______________________________</td>
<td>____________________</td>
</tr>
</tbody>
</table>
Family History

Have any members of your immediate family had, or currently have, any of the following?

<table>
<thead>
<tr>
<th></th>
<th>Heart Disease</th>
<th>Stroke</th>
<th>Diabetes</th>
<th>Sudden Death</th>
<th>Pulmonary Disease</th>
<th>Age of onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Father</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Sisters</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Brothers</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Aunts/Uncles</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Grandparents</td>
<td>______</td>
<td>______</td>
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<tr>
<td>Don’t know</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>

Personal Medical History

Do you have any known allergies? ______ YES ______ NO
If YES, please explain:______________________________________________________________________________

Do you use tobacco products? ______ YES ______ NO If YES, please describe product used (cigarettes, pipe, dip, etc.), how often per day (packs, bowls, etc.) and how long you have been a tobacco user (years):
______________________________________________________________________________
______________________________________________________________________________

What is your cholesterol level? ____________ mg/dl ____________ don’t know
What is your resting blood pressure? ____________ mm Hg ____________ don’t know

Please check the following disease conditions that you had or currently have:

____ High blood pressure  ____ Aneurysm  ____ Abnormal chest X-ray
____ High blood cholesterol  ____ Anemia  ____ Asthma
____ High blood triglycerides  ____ Diabetes  ____ Emphysema
____ Angina pectoris  ____ Jaundice  ____ Bronchitis
____ Heart attack  ____ Hepatitis  ____ Thyroid problems
____ Heart surgery (catheter, bypass)  ____ Infectious mononucleosis  ____ Hernia
____ Heart failure  ____ Phlebitis  ____ Cancer
___ Heart murmur        ___ Gout        ___ Epilepsy or seizures
___ Stroke/transient ischemia attacks  ___ Kidney stones   ___ Prostate problem
___ Rheumatic fever           ___ Urinary tract infections ___ Osteoporosis
___ Arteriosclerosis       ___ Emotional disorder (depression, etc.) ___ Eating disorder

Please provide dates and explanation to any of the above which you checked:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Have you experienced, or do you currently experience any of the following on a *recurring* basis?

<table>
<thead>
<tr>
<th></th>
<th>At rest:</th>
<th>During exertion:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortness of breath</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Dizziness, lightheadedness, fainting</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Daily coughing</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Discomfort in the chest, jaw, neck or arms (pressure, pain, heaviness, burning, numbness)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skipped heart beats or palpitations</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Rapid heart rate</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Joint soreness</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Joint swelling</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Slurring or loss of speech</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Unusually nervous or anxious</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Sudden numbness or tingling</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Loss of feeling in an extremity</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Blurring of vision</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

If YES to any of the above, please explain:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
Orthopedic/Musculoskeletal Injuries

Please check the following diseases or conditions which you had or currently have:

____ Stiff or painful muscles  ____ Muscle weakness  ____ Head injury
____ Swollen joints  ____ Amputation  ____ Shoulder injury
____ Painful feet  ____ Fractures or dislocations  ____ Ankle injury
____ Severe muscle strain  ____ Tennis elbow  ____ Whiplash or neck
____ Limited range of motion  ____ Torn ligaments  ____ Injury in any joint
____ Pinched nerve  ____ Slipped disc  ____ Bursitis
____ “Trick” knee/knee injury  ____ curvature of spine

Do any of the above limit your ability to exercise? _____ YES _____ NO  If YES to any of the above, please explain:
__________________________________________________________________________
__________________________________________________________________________

Activity History

Please list any physical or recreational activities that you currently do or have done on a regular basis.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency (days/week)</th>
<th>Time (min/session)</th>
<th>How long (years)</th>
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</tbody>
</table>
APPENDIX D: ANKLE ACTIVITY SCORE
The Biomechanics Laboratory at Georgia Southern University
ACTIVITY LEVEL QUESTIONNAIRE
(based on Tegner and Lysholm)

Today’s Date: _____/_____/_____ Study Code/Participant Number ________

Circle the number that corresponds to your current physical activity level:

0 – Sick leave or Disability
1 – Sedentary work, minimal walking
2 – Light labor
3 – Light to moderate labor
4 – Moderate to heavy labor, recreational bicycling or light jogging
5 – Heavy labor, competitive bicycling, moderate jogging (2 times a week)
6 – Recreational tennis, basketball, moderate jogging (5 times a week)
7 – Competitive sports: tennis, track (running), basketball, baseball OR Recreational: soccer, hockey
8 – Competitive sports: track (jumping),
9 – Competitive sports: soccer, football, wrestling, gymnastics
10 – Elite level: soccer, football, basketball, running

How many days per week do you participate at this activity level? ________
APPENDIX E: ANKLE SCORE SCALE
### Ankle Activity Score


<table>
<thead>
<tr>
<th>Cat</th>
<th>Sports and Activities</th>
<th>T</th>
<th>C</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>American Football</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Basketball</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Gymnastics</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Handball</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Rugby</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Soccer</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Hockey</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Martial Arts (Judo, Karate, Kungfu, Taekwando)</td>
<td>9</td>
<td>8</td>
<td>7</td>
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<tr>
<td></td>
<td>Orienteering</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Rhythmic Gymnastics</td>
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<tr>
<td></td>
<td>Volleyball</td>
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<tr>
<td>8</td>
<td>Boxing</td>
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<tr>
<td></td>
<td>Freestyle Snowboarding</td>
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<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Ice Hockey</td>
<td>8</td>
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<td>6</td>
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<td></td>
<td>Tennis</td>
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<tr>
<td></td>
<td>Wrestling</td>
<td>8</td>
<td>7</td>
<td>6</td>
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<td>7</td>
<td>Aerobics, fitness</td>
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<tr>
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<td>Badminton</td>
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<td>Baseball</td>
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<td>Cross-country running</td>
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<tr>
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<td>Modern Pentathlon</td>
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<tr>
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<td>Squash</td>
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<tr>
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<td>Surfing, windsurfing</td>
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<td>Table Tennis</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Track &amp; Field (field events)</td>
<td>7</td>
<td>6</td>
<td>5</td>
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<tr>
<td></td>
<td>Water skiing/ Wakeboarding</td>
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<td>6</td>
<td>Dancing</td>
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<td>Fencing</td>
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<td>Floorball</td>
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<td>Mountain/Hill climbing</td>
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<td>Nordic Skiing</td>
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<td>4</td>
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<td>Parachuting</td>
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<td>Softball</td>
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<td></td>
<td>Special professions</td>
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<th>T</th>
<th>C</th>
<th>R</th>
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<tbody>
<tr>
<td>5</td>
<td>Diving</td>
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<td>4</td>
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<tr>
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<td>Scuba Diving</td>
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<td>4</td>
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<tr>
<td></td>
<td>Skating/In-line skating</td>
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<td>5</td>
<td>4</td>
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<tr>
<td></td>
<td>Track &amp; Field (track events)</td>
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<td>4</td>
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<td>Triathlon</td>
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<td>Weightlifting/Bodybuilding</td>
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<td>All competitive sports of categories 4 and 3 with seasonal conditioning</td>
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<td>Heavy Physical work</td>
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<tr>
<td>4</td>
<td>Alpine skiing &amp; snowboarding</td>
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<td></td>
<td>Bowling/Curling</td>
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<td>Golf</td>
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<td>Mountain biking/BMX</td>
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<td>Power lifting</td>
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<td>Sailing</td>
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<td>Physical work</td>
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<td>Cycling</td>
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<td>Motorsports</td>
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<td>Rowing/Kayaking</td>
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<td>Shooting/Archery</td>
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<td>Water polo/ Swimming</td>
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<td></td>
<td>Able to walk on uneven ground</td>
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<tr>
<td>2</td>
<td>No sports, everyday activities not limited</td>
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<tr>
<td>1</td>
<td>Able to walk on even ground, but everyday activities limited</td>
<td>1</td>
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<tr>
<td>0</td>
<td>Unable to walk, disabled because of ankle problems</td>
<td>0</td>
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</tbody>
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T, top level (international elite, professional, national team, or first division); C, lower competitive levels; R, recreational level (participation should be considered only if it exceeds 50 hours per year).
APPENDIX F: MEDICAL QUESTIONNAIRE
**Ankle Score Scale**


I  
**Subjective Assessment of the injured ankle**

- No symptoms of any kind* 15
- Mild symptoms 10
- Moderate symptoms 5
- Severe symptoms 0

II  
**Can you walk normally?**

- Yes 15
- No 0

III  
**Can you run normally?**

- Yes 10
- No 0

IV  
**Climbing down stairs+**

- Under 18 seconds 10
- 18-20 seconds 5
- Over 20 seconds 0

V  
**Rising on heel with injured leg**

- Over 40 times 10
- 30-39 times 5
- Under 30 times 0

VI  
**Rising on toes with injured leg**

- Over 40 times 10
- 30-39 times 5
- Under 30 times 0

VII  
**Single-limbed stance with injured leg**

- Over 55 seconds 10
- 50-55 seconds 5
- Under 50 seconds 0

VIII  
**Laxity of Ankle joint (ADS)**

- Stable (≤5mm) 10
- Moderate Instability (6-10mm) 5
- Severe Instability (>10mm) 0

IX  
**Dorsiflexion range of motion, injured leg**

- ≥10° 10
- 5°-9° 5
- <5° 0

* Pain, swelling, stiffness, tenderness, or giving way during activity (mild, only 1 of these symptoms is present; moderate, 2-3 are present; severe, 4 or more are present

+ Two levels of staircase (length, 12m) with 44 steps (height, 18 cm; depth, 22 cm)

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Total: Excellent, 85-100; Good, 70-80; Fair 55-65; Poor, ≤50
APPENDIX G: IRB CONSENT TO ACT
CONSENT TO ACT AS A SUBJECT IN AN EXPERIMENTAL STUDY

Title: Comparison of Lower Extremity Propulsion Joint Kinetics during the Single Leg Hop Tests Between Healthy and Chronic Ankle Instability Recreational Athletes

Primary Investigator:
Stacy Fundenberger, ATC/L
Graduate Student, Athletic Training
Georgia Southern University
(509)939-0817

Co-Investigator:
Bryan Riemann, PhD, ATC
Assistant Professor
Georgia Southern University
(912) 681-5268

DESCRIPTION:
We are attempting to study the how recreational athletes with chronic ankle instability complete single-leg hop tests compared to healthy recreational athletes. Specifically we will be examining the movements at the ankle, knee and hip used to propel you forward during single-leg hop tests. Forty subjects will participate in this study. The results of this study will help us better understand the potential compensatory patterns developed due to an unstable ankle.

You are being asked to participate in this study because you are a physically active individual, meaning you participate in intercollegiate, intramural or club athletics and fall under one of the following two categories:

1) You have had no significant injury to your dominant leg (the leg you kick with) in the past 3 months.
2) The ankle of your dominant leg has been sprained twice (you have sought medical attention or had to modify your athletic participation) but you are healthy now.

Additionally, you have no history of any nerve, inner ear or balance injury, disease or disorder. Lastly, you have no history of head injury in the past six months.

If you agree to participate in this study, you will be asked to attend two testing sessions that will last a total of 1½ hours. During the first session (30 minutes) you will be asked to answer a brief medical health questionnaire pertaining to your injury history and physical activity level. Additionally, if you fall under the chronic ankle instability group, you will be asked measured to quantify the instability of your ankle. If for any reason you are rejected from this study, the information that you have provided will immediately be destroyed. If accepted for this study, you will be asked to perform the functional tasks listed below. Each task will be completed five times on each leg during the first session. This will establish a baseline distance that you will need to reach during the second session (data collection).

1) **Anterior Single-Leg Hop for Distance:** Each participant will stand in a single-leg stance on the forceplate and jump off straight ahead towards the predetermined mark and land on the same leg. Participants will be allowed free arm movement throughout the entire task. When the participants land, they will maintain a single-leg stance for 2 seconds. This task will be performed five times on each leg.
2) **Cross-Over Single-Leg Hop for Distance:** Each participant will stand in a single-leg stance on the forceplate and jump off diagonally towards the predetermined mark and land on the same leg. Participants will be allowed free arm movement throughout the entire task. When the participants land, they will maintain a single-leg stance for 2 seconds. This task will be performed five times on each leg.

During the second session (60 minutes), which will occur no more than one week after the first, several types of measurements concerning the coordination of your legs will be collected. The position of your hips, thighs, lower legs and feet will be made using a special computer system that uses magnetic based sensors to track your body’s motion. Eight sensors will be attached using double-sided tape and a neoprene sleeve to your feet, lower legs, upper legs, lower back, and upper back. Cables will be attached form each of these sensors to a personal computer.

**RISKS AND BENEFITS:**

The risk assumed during the testing is mild. The functional tasks are commonly used methods in our laboratory, as well as other laboratories. To minimize risk of injury, you will be instructed on the proper test procedures during a practice session prior to participation. Only trained laboratory personnel will conduct the testing and procedures. You may experience some skin irritation from the tape used to secure the sensors. This is usually minimal and using an underwrap will reduce the chances. It is possible that any experiment may have harmful effects that are not known. There are no known risks to a fetus or pregnant mother from participants in this study.

There are no direct benefits to you for participating in this study. The health and rehabilitation professions may benefit from this study by helping to reveal how one leg accomplishes these functional performance tests compared to the other leg.

**COSTS AND PAYMENTS:**

There are no costs or payments associated with participation in this study.

**COMPENSATION FOR ILLNESS OR INJURY:**

Georgia Southern University investigators and their associates recognize the importance of your voluntary participation to their research studies. These individuals and their staffs will make reasonable efforts to minimize, control and treat any injuries that may arise as a result of this research.

You understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. You also understand that you are not waiving any rights that you may have against the University for injuries resulting from negligence of the University or investigators/ If you believe that you are injured as the result of the research procedures being performed, please contact Stacy Fundenberger at (509)939-0817 (e-mail: babyberger21@hotmail.com) immediately or the Georgia Southern University Institutional Review Board Coordinator at the Office of Research Services and Sponsored Programs at (912)681-7758 (e-mail: oversight@georgiasouthern.edu). You will not receive monetary payment for, or associated with, any injury that you suffer in relation to this research.

**CONFIDENTIALITY:**

You understand that any information about you or your records will be handled in a confidential (private) manner consistent with medical records. Your identity on all records will be indicated by a case number. You will not be specifically mentioned in any publication of research results. However, in unusual cases my research records may be inspected by appropriate government agencies or released to an order from a court of law. All information and research records will be kept for a period of five years after the termination of this investigation.

**RIGHT TO WITHDRAWL:**

You understand that you are not required to take part in this research study and, if you change your mind, you can withdraw at any time. Your decision whether or not to participate in this study or to
withdraw from participation will have no affect on your status with Georgia Southern University or any other benefit to which you are entitled. You also understand that you may be removed from the research study by the investigators in the event of an inability to complete the testing procedures.

VOLUNTARY CONSENT:
I certify that I have read the preceding information, or it has been read to me, and understand its contents. Any questions I have pertaining to the research have been, and will continue to be answered by the investigators listed at the beginning of this consent form at the phone number give (509)939-0817. Any questions I have concerning my rights as a subject will be answered by the Georgia Southern University IRB Office (912)681-5465. A copy of this consent for will be given to me. My signature below means that I have freely agreed to participate in this project.

____________________________________  __________________  
Participant’s Signature                          Date

____________________________________  __________________  
Witness                          Date

INVESTIGATORS CERTIFICATION:
I certify that the nature and purpose, the potential benefits, and possible risks associated with participation in this research study have been explained to the above individual and that any questions about this information have been answered.

____________________________________  __________________  
Investigator’s Signature                          Date
APPENDIX H: SINGLE LEG HOP TEST INSTRUCTIONS
Directions for hopping given to each subject during practice and as recorded on video:

Please stand on your (right/left) foot only. Using a natural motion, hop forward as far as possible along the blue line in front of you. Make sure to land on the same foot you hop off of. You may use your arms, as you feel necessary, to complete the motion. Do not touch the ground with your other foot. Maintain the landing position until I tell you to step down. You will complete 5 hops on each leg. I will now demonstrate the motion for you.

Directions for hopping given to each subject during testing:

**Anterior Hop Test**

Using the same motion that you practiced earlier, I would like you to start at the line marked on the forceplate and hop straight off. Your toes must land within the two lines marked in front of you. You must maintain the landing position until I tell you to step away. You will complete the task 5 more times on each foot.

**Crossover Hop Test**

You will start at the line marked on the forceplate only this time, you will hop laterally off of the forceplate. Again, your toes must land within the two lines marked in front of you as well as to the outside of the tape mark to the side. You must maintain the landing position until I tell you to step away. You will complete this task 5 more times on each foot.