The influence of soccer-specific fatigue on hip range of motion and peak isokinetic hip flexor torque in male soccer players

by

Timothy W. Robinson

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Program of Study Committee:
Ann Smiley-Oyen, Major Professor
Timothy Derrick
Warren Franke

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ABSTRACT

INTRODUCTION: Limited range of motion (ROM), muscular strength deficits and fatigue have been found to be epidemiological risk factors for muscular injuries to the hip. The purpose of this study was to observe the changes in hip isokinetic peak isokinetic torque and ROM during a soccer-specific fatigue test.

METHODS: Fourteen male high school soccer players (mean age, 17.4 ± 1.2 years; body mass, 77.8 ± 8.8 kg; height, 181.9 ± 8.0 cm) completed an intermittent treadmill protocol designed to replicate the fatigue experienced during a soccer match. At five intervals (before exercise and at 20 minute intervals throughout the treadmill test), hip ROM and hip flexor torque were measured. Isokinetic hip flexor strength was recorded at speeds of 60, 180, and 300 deg/s for three repetitions at each speed using a Biodex dynamometer. Hip flexor ROM was measured using a long armed goniometer during active and passive hip extension.

RESULTS: Peak concentric isokinetic hip flexor torque was maintained throughout the exercise duration, regardless of speed. Passive and Active ROM significantly decreased between pre and post tests (p= 0.01) and (p= 0.0001), respectively.

CONCLUSION: Active ROM decreased across the exercise protocol. This suggests increased susceptibility to injury, especially towards the later stages of a soccer match.
Chapter I

INTRODUCTION

With more than 256 million players in 2006, soccer is the most widely played sport in the world and is rapidly gaining popularity within the United States (Yard, Schroeder, Fields, Collins & Comstock, 2008; Federation Internationale de Football Association [FIFA], 2007). Soccer is a contact sport resulting in numerous injuries, most of which occur in the lower extremities. Hip flexor injury is one of the most frequent types of injury sustained by soccer players (Bradley & Portas, 2007). Hip flexor injuries can be categorized as thigh/upper leg muscle strains or groin pain resulting from non-contact injury. Most hip flexor injuries are a result of overuse where, over time, repetitive micro-trauma to the tendons, bones and joints occur. In a 2005-2007 study of U.S. high school soccer injuries, 13.1% of all injuries occurred in the thigh/upper leg region with boys sustaining a larger proportion of these injuries (Yard et al., 2008).

Previous literature suggests that a lack of muscular flexibility is an important intrinsic risk factor for the development of muscle strain injuries in sport (Bradley & Portas, 2007; Ekstrand & Gillquist; 1982; Krivickas & Feinberg, 1996). Limited hip range of motion (ROM) in athletes has been associated with chronic groin pain, conjoined tendon attenuation (Caudil, Nyland, Smith, Yerasimides & Lach 2008; Harmon, 2007; Verrall, Hamilton & Slavotinek, 2005; Verrall, Slavotinek & Barnes, 2007) and low back pain (Van Dillen, Bloom, Gombatto & Susco, 2008).

Muscle strength is necessary to execute many soccer-related tasks such as kicking, jumping and changing pace (Rahnama, Reilly, Lees & Graham-Smith, 2003). The
asymmetrical demands of sprinting, cutting and kicking put high amounts of stress on the hip and surrounding muscles. Poor muscular strength, strength deficits and ipsilateral muscular strength imbalances are etiological risk factors for muscular strains (Greig, 2008; Nicholas, Nuttall & Williams, 2000) including those occurring in the hip flexor muscle group (i.e. iliacus, psoas major and rectus femoris).

Fatigue is another suggested factor in the causation of injury during soccer play (Greig, 2008) and has been associated with a decrease in hip ROM (Bradley et al., 2007) and thigh muscle strength (Rahnama et al., 2003). Muscular fatigue is often evident during soccer, especially towards the end of play (Rahnama, Reilly & Lee 2003). Hip ROM has been shown to decrease immediately during soccer training and up to 24 hours post training (Bradley et al., 2007; Moller, Oberg & Gillquist, 1985) due in part to muscle fatigue. An exercise simulating soccer study by Rahnama et al., (2003) exhibited a proportionate decline in thigh strength related to fatigue. Though both hip ROM and thigh muscle strength have been individually studied for their ability to predict injury occurrence, they have not been evaluated concurrently to see if there is an association between them.

One important area of inquiry, therefore, is to examine the influence a soccer-specific fatiguing protocol has on hip flexor strength and ROM, thus providing more insight into fatigue related injuries. The purpose of this study was to determine if hip flexor ROM and torque are reduced in male high school soccer players after completing a fatiguing exercise protocol that simulates a high school soccer match. It was hypothesized that hip flexor torque would decrease as a result of the exercise protocol when comparing pre and post test measurements. Similarly, it was hypothesized that a decrease in passive and active hip ROM would occur when comparing ROM prior to and after the exercise protocol.
Chapter II

REVIEW OF LITERATURE

This literature review addresses hip injuries in relation to hip ROM and hip strength when fatigued, within the male soccer population. The aim is to explore previous research in more detail to identify associations between fatigue, hip ROM and hip strength. The epidemiology of soccer injuries will be examined first followed by the correlation of hip ROM and injury when fatigued. Next, research on leg strength and fatigue using similar exercise protocols to the one used in this study will be reviewed. Finally, the need for determining if an association exists between hip ROM, hip flexor strength and fatigue will be discussed.

For this study the term “hip flexor injuries” will be used when referring to all upper leg muscle strain and groin pain as they are interchangeably used throughout previous studies when dealing with non-contact hip injuries.

Soccer and Injury Epidemiology

The increasing popularity of soccer has made it the premier youth participation sport in the U.S. During the 2009-2010 school year, there were 11,375 sanctioned boys’ high school soccer programs with 391,839 participants; a more than 25 percent participation increase than just ten years ago (National Federation of State High School Associations. 2007). The number of high school soccer programs in the U.S. has nearly doubled in the past 20 years (NFHS, 2007). After football and wrestling, soccer reported the highest number of injuries in the U.S. (Centers for Disease Control and Prevention, 2006).
Many injuries classified as “overuse injuries” occur around the hip joint. Ten to 18 percent of male soccer players are diagnosed with chronic groin pain each year (Caudill et al., 2008). This was similarly noted in a study conducted by Drawer and Fuller (2001) who found that nine percent of English professional soccer players retire early due to chronic hip pain. U.S. high school soccer players incur an estimated 400,000 injuries each year (Yard et al., 2008). Lower extremity injuries represent 60 to 85 percent of total injuries sustained by soccer players (Rahnama, Reilly & Lees, 2002). During the peak growth stages of puberty, both the tibia and femur grow at faster rates, this offsets center of mass and makes core/trunk control more difficult (Myer, Brent, Ford & Hewett, 2008), which may contribute to the higher rate of lower extremity injuries experienced by high school athletes. This is quite relevant to soccer as the game is primarily comprised of activities which require an athlete to use their legs to complete skilled tasks.

**Hip ROM and Injury**

Soccer requires various types of kicking; for example; running kick, volley and push pass (Pronk, 1991). Reilly & Williams (2005) divide kicking into four phases. The first phase is priming the thigh (backswing), phase two is rotation of the thigh and leg laterally and flexion of the hip, phase three is deceleration of the thigh and acceleration of the leg and the fourth phase is the follow through. During phase one, the hip of the kicking leg is rapidly extended by the gluteal muscle (hip extension). However, the range of extension is limited by the hip flexor muscles. During phase two the hip flexor muscles contract to pull the thigh forward. The amount of strain placed on the hip flexors is directly related to the amount of
force used to kick the ball. Therefore, types of kicks such as shooting and long passes place a high amount of strain on the hip flexor muscles.

Heading the ball is another soccer action that has a significant effect on the hip flexor muscles. Heading occurs approximately 80 times throughout a soccer match (Bangsbo, 1994). This action is completed by rapid contractions of the erector spinae, gluteals, hamstrings, quadriceps and plantar flexors of the ankles. During this movement the spine extends and severe stretch may be placed on the abdominals and hip flexors which may result in injury to these muscle groups (Reilly & Williams, 2005).

Currently, only a few studies have addressed hip ROM and injury in soccer players. Bradley & Portas (2007) sampled 36 elite male soccer players from an English premiere team and measured their preseason maximum hip ROM for six movements: hip flexion, hip extension, knee flexion, knee extension, ankle plantarflexion and ankle dorsiflexion, for the dominant and non-dominant kicking leg, using a goniometer. Throughout the competitive season all injuries occurring in the lower extremities were recorded and evaluated. Thirty-two of the 36 players sustained clinically diagnosed muscle strains; 29 percent knee flexors, 24 percent hip flexors, 18 percent knee extensors, 15 percent ankle plantarflexion, 12 percent hip extensors and 2 percent ankle dorsiflexion. A significant difference was observed in the hip and knee flexors ROM (p = 0.03) between injured and uninjured. In the injured subjects, a reduction in ROM was observed in each muscle group. A multivariate stepwise logistic regression identified a low ROM of the knee flexors (p < 0.01) and hip flexors (p < 0.05) as a significant contributing factor for a subsequent muscle strain injury. The players who incurred hip flexor injuries had, on average, three degrees less ROM than the uninjured players. There was no observed correlation in players sustaining muscle strain injuries to the
hip extensors, ankle plantar-flexors and dorsiflexors in ROM compared with uninjured players. This study showed that players with less range of motion in the hip have a higher susceptibility to hip flexor muscle strain injury.

Manning and Hudson (2008) studied the relationship of hip joint ROM in youth soccer players, ages 16-18, with professional soccer players who had played at the professional level for at least two years. A relationship between the youth and professional soccer players showed their hip ROM to be significantly different (p< 0.001) from the control. They suggested that this difference in ROM may represent early stages of hip degeneration that older soccer players are more prone to experience. These studies give merit to developing specific hip flexibility techniques for soccer players.

Research of lower extremity injuries across all sports in collegiate athletes by Krivickas and Feinberg (1996) found that tight ligaments and muscles are related to injury in men. Of the 131 male participants in the study, 51 percent had muscle tightness of the hip flexors. In soccer, the hip flexor muscle group is often taken to maximal ROM while accelerating/decelerating or kicking, thus putting high amounts of stress on the hip. Lack of flexibility may produce early muscle fatigue or alter normal movement patterns (Krivickas et al., 1996). This study gives some insight into a relationship between strength and ROM, in that subjects with poor flexibility exhibited a faster rate of muscle fatigue.

In sprinting, high knee lift is associated with increased stride length and therefore considerable attention is given to exercising the hip flexors. However, they are usually not exercised against resistance and consequently there is unlikely to be any appreciable strength increase. Kicking a ball is a complex coordinated action involving simultaneous knee extension and hip flexion, so developing a more powerful kick requires exercises applicable
to these muscle groups. Overlooking this important muscle group may be a factor in numerous groin injuries and thigh strains.

Poorly designed off-season training regimens focused on leg strength and power helps to create an imbalance of strength between the leg and core muscles, which can result in chronic groin pain. When an imbalance occurs, the hip flexors may over compensate to bring stability to the leg during rotation. The principal muscles involved in hip flexion are the psoas and the iliacus, collectively known as the iliopsoas. These muscles work together to help flex the hip, and to provide stability for the lower extremity. Commonly, the rectus femoris is added to the hip flexor muscle group because the knee is routinely extended when hip flexion occurs; as it is in soccer when kicking a ball.

**Strength and Fatigue**

Fatigue can be classified as a reduction of maximal force or power that is associated with sustained exercise and reflected in a decline in performance (Rahnama et al., 2003; Reilly, 1994; Taylor, Bulter, & Gandevia, 2000). The total distance covered during a match is estimated to be 10.8 km for the top-class players, which is five percent more than moderate players 10.3 km (Bangsbo, 1994). Rahnama et al., (2003) conducted a study examining the isokinetic knee flexor strength in 13 male amateur soccer players using a soccer-specific intermittent exercise procedure. The participants performed a 90 minute soccer-related simulation exercise on a treadmill with their muscle strength being assessed before exercise, at half-time, and after exercise completion. The speeds for each activity were: walking - 6 km/hr; jogging - 12km/hr; cruising - 15km/hr; and sprinting - 21km/hr. This protocol was determined to be reliable and repeatable with a reported coefficient of variation of 4.8
percent and 95 percent ratio limits of agreement (Drust, 1997). During each strength trial, subjects performed three maximal voluntary knee extension and flexion movements in a seated position using a dynamometer. Both the dominant and non-dominant legs were tested with ROM preset at 0° (flexed) and 90° (full extension). The researchers concluded that the ability of the knee extensor and flexor muscles to develop force during the soccer-specific protocol declined with fatigue.

One reason Rahnama et al., (2003) may have observed a decrease in range of motion was that his subjects performed 10 minutes of static stretching before each trial. In recent years static stretching has been shown to decrease strength and power performance (Yamaguchi, Yamanaka, Ishii & Yasuda, 2006). Dynamic stretching is now accepted as the most effective preparation for subsequent high-speed performance.

A comparable study by Gleeson, Mercer, and Cambell (1995) examining the effects of fatigue on isokinetic leg torque in female collegiate soccer players, revealed a reduction in the knee extensors ability to generate force after a fatigue task. The decline in strength and ROM infers that a soccer player’s ability to execute soccer-specific tasks when fatigued may lead to more errors and susceptibility to injury (Rahnama et al., 2003).

Similarly, Greig (2008) studied peak isokinetic torque production of knee flexor and extensor muscles in 10 male professional soccer players. Using a comparable intermittent treadmill protocol to the Rahnama et al. (2003) study, each subject completed isokinetic protocols on a Biodex isokinetic dynamometer. Five maximal repetitions of knee extension and flexion were performed using the dominant kicking leg only. Each trial of five repetitions was recorded at 15 minute intervals throughout the exercise protocol. ROM was also preset at 0° (flexed) and 90° (full extension). The results, however, contradicted those
previously observed by Gleeson et al. (1995) and Rahnama et al. (2007). This study did not show a decrease in knee flexor and extensor torque throughout the exercise protocol. However, there was a trend for reduced torque near the end of each half of soccer. Hawkins and Fuller (1996) conducted a risk assessment of accidents and incidents at the last World Cup held in the United States and found that the final quarter of each half of soccer had a higher rate of injury.

Though there is considerable research on muscle strength and injury, the general consensus on the relationship between muscle strength and injury is mixed (Bennell, Waseiner & Lew, 1998; Crosier, Ganteaume, Binet, Genty & Ferret, 2008; Proske, Morgan, Brockett & Percival, 2004). However, research does point to a relationship between hip flexor strength and injury when hip ROM and fatigue are considered.

Summary

Most studies demonstrate that strength deficits and a limited range of motion are associated with injury frequency in soccer. Yet the relationship between hip flexor strength, ROM and fatigue are unclear. Research suggests that when fatigued, passive hip ROM decreases yet active hip ROM has not been considered. Finding a proportional relationship between hip ROM, strength and fatigue could help clarify preventative measures for injuries to the hip. This could also give credibility for introducing hip flexor strength training protocols, which is highly overlooked in high school training regimens.

Hip-flexor injuries in high schools athletes may prevent them from reaching a performance level required to be competitive for post-high school athletics. Moreover, injuries at this age can predispose these young men to repeated injuries during their student
athlete careers as well as limit hip ROM as they get older. Prevention of these injuries may improve health and activity throughout their life.
Chapter III

METHODS

Participants

Fourteen male soccer players (mean ± standard deviation; age 17.4 ± 1.2 yrs, body weight 77.8 ± 8.8 kg, height 181.9 ± 8.0 cm, BMI 23.7 ± 3.5) volunteered for this study. Participants were recruited from a nearby high school using flyers and word of mouth. Anyone with a history of lower extremity or low back pain, or who had cardiovascular or systemic conditions that limited physical activity, was excluded from this study. All subjects had participated in at least one season of high school soccer. Informed consent, and parental consent if participant was younger than 18 years of age, was obtained before data collection in accordance with departmental and university ethical procedures. There was no extrinsic reward offered for participation in this study while a time commitment of approximately four hours was required for the protocol.

Instruments

Biodex System 3. A dynamometer used to measure concentric isokinetic hip strength. This machine was used to measure both dominant and non-dominant leg hip flexor peak isokinetic torque at speeds of 60, 180 and 300 degrees per second.

Monark 818 ergo medic stationary cycle. The cycle was used during the warm-up phase. The subject was instructed to pedal for five minutes keeping their speed at approximately 60 revolutions per minute.
Quiniton Instrument Co. Q55 Series 90. A programmable motorized treadmill used as the apparatus for the fatigue test. The treadmill was preset to change between six speeds, 99 times during each 20 minute exercise bout (Table 1).

Universal Goniometer (Lafayette Instrument Co., Inc). A long armed goniometer was used to measure hip angle of both the dominant and non-dominant legs during the active and passive hip extension movements.

Experimental Design

Participants came to the research lab and exercise clinic for all testing. All trials were performed in the afternoon between 12 noon and eight o’clock in accord with regular competition time and to eliminate circadian variation. Each participant attended the laboratory on two separate occasions. The first occasion consisted of observing trials with the dynamometer, goniometer and treadmill exercise protocol. On the second visit, the participants underwent the testing protocol.

Participants 18 and older read and signed an informed consent document. Participants under the age of 18 signed an assent form and submitted a signed parental consent form. Subject age and anthropometric data were then collected. Next the subject was instructed to pedal on a stationary cycle for five minutes at 60 revolutions per minute. After completing the five minute warm-up, the subject was given another five minutes to stretch. During this time they were not instructed on how stretch. The pretest consisting of the peak torque and hip extension measurements were then administered. This was followed by the soccer-specific intermittent exercise protocol. The exercise protocol was divided into four bouts of 20 minutes. Peak hip flexor torque and hip ROM were taken after each interval for a total of
five times (including pretest). A ten minute break (simulating halftime in a soccer match) followed the third measurement of peak torque and ROM. At this time the subject remained seated and stationary. They were allowed to eat bananas and drink PowerAde during this halftime break.

**Isokinetic Strength Protocol**

The subject stepped onto the Biodex dynamometer that measured the concentric isokinetic peak hip flexor torque. He then stood next to the dynamometer with his trunk perpendicular to the floor. The subject was instructed to rest one arm on the dynamometer (right arm during right leg flexion and left arm during left leg flexion) and their other hand rested on their hip. The axis of rotation of the dynamometer was set slightly superior and anterior to the greater trochranter. The dynamometer knee attachment was placed just proximal to the popliteal fossa of the leg being tested. Once the participant’s leg was secured to the machine they were instructed to raise their knee towards their chest to an angle of approximately 90 degrees to ensure they were moving through a full range of motion. The range of motion was reset for each trial to ensure the safety of the subject in case they were unable to continually lift their leg to a 90 degree angle. The subject was instructed to keep their feet flat on the floor to avoid going into plantar flexion during the movement. They were also advised not to push using the arm resting on the dynamometer nor were they to flex or extend their trunk in any way. Peak hip flexor torque was recorded at isokinetic speeds of 180, 300 and 60 deg/s. This order was recommended by Greig (2008). Three repetitions were performed with the dominant and non-dominant kicking leg with a 30 second rest period between each set. The dominant leg was defined as the preferred kicking
leg of the subject. The subject was instructed that each repetition should be at maximal
contraction. This was performed at each of the five intervals throughout the test.

**Hip ROM Protocol**

After recording the isokinetic concentric hip torque, the subject’s hip flexor ROM
was measured. The subject was situated in the prone position on a treatment table with their
pelvis secured using a treatment table belt. Bilateral measurements of active and passive hip
extension were recorded for each subject. Hip extension was recorded as the maximal
upward movement of the femur from the neutral position. A universal goniometer was used
to record the data. A goniometer is an instrument that measures an axis and ROM.
Goniometry is the most common technique for measuring single joint systems and because it
entails direct measurement of the joint angle, it can be used to produce normative values and
is therefore useful for intersubject comparisons (Maud & Foster, 2006, p. 228). To position
the goniometer, the fulcrum of the instrument was centered over the greater trochanter of the
femur, the proximal arm aligned with lateral midline of the pelvis, and the distal arm aligned
with the lateral midline of the femur using the lateral epicondyle as a reference. The
participant was situated on a treatment table in the prone position with the hip in the neutral
adduction and abduction position and the pelvis stabilized with a treatment table belt. The leg
not being tested was held in a full extended position.

For the active ROM the subject lifted their leg as high as possible while keeping the
leg straight (at the knee). They were instructed not to twist or push using their arms and/or
trunk to assist in increasing ROM. The end of active ROM was demonstrated when the
subject could no longer increase the ROM of the extension (without pain). At that point the
angle was measured. The extension was repeated three times. For passive ROM, the investigator raised the subject’s leg into hip extension until a firm end-feel was attained. The firm end-feel can be described as tension in the anterior joint capsule and the iliofemoral ligament. An assistant was used to align the goniometer so the investigator could properly observe the end ROM. When the end-feel was attained the investigator instructed the assistant to record the measurement and the movement was repeated three times. Both active and passive hip flexor ROM measurements were measured at each of the five intervals.

Test-retest reliability was tested on a sub-sample of six participants. To determine the consistency of the ROM measurements, the test-retest reliability of active and passive ROM for both the dominant and non-dominant leg was determined during pilot testing. The intraclass correlation coefficients for each measure are shown in Table 1.

Table 1. Intraclass Correlation Coefficients (ICC) for active and passive hip extension ROM of the dominant and non-dominant leg.

<table>
<thead>
<tr>
<th></th>
<th>ICC Dominant</th>
<th>ICC Non-dominant</th>
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</thead>
<tbody>
<tr>
<td>Active ROM</td>
<td>0.83</td>
<td>0.74</td>
</tr>
<tr>
<td>Passive ROM</td>
<td>0.81</td>
<td>0.79</td>
</tr>
</tbody>
</table>

**Fatigue Protocol**

After recording the preliminary measurements the subject began the fatigue protocol. A Polar Cardio Sport heart monitor was used to obtain the subject’s heart rate to ensure they stayed below 90 percent of their maximal heart rate. If at any time heart rate exceeded 90
percent, the test was stopped. A rating of perceived exertion chart (RPE) was also explained to each subject and used to ensure safety. If at any time the subject felt they reached a level of 18 on the RPE scale, the test was stopped. Each subject was given water at anytime during the test and two fans were used to cool the subject if he requested. All subjects completed the testing protocol.

The soccer-specific intermittent exercise protocol was developed to provide fatiguing exercise estimated to be equivalent to playing a game of soccer. The velocity by time profile is shown in Figure 1. The protocol consisted of six modes of activity inherent to soccer match play that were performed on a programmable motorized treadmill similar to research conducted by Bangsbo (1994) and Greig (2008). The different exercise intensities ranged from a walking speed at 1.4km/hr to a sprint speed at 17.9km/hr (Table 2). Consecutive modes of high speed sprints and low speed walking were excluded. The intermittent fatigue protocol was split into four exercise bouts of 20 minutes. Each 20 minute bout equaled a distance of 2.8km resulting in a total distance of 11.2km. The 80 min. duration was suggested to equal that of a high school soccer match. The treadmill was set at a two percent incline to represent the ergogenic cost of running on an outdoor field (Greig, 2008). The average velocity was 8.40km/hr. The amount of energy expended during this exercise protocol was predicted using the American College of Sports Medicine (ACSM) prediction model which resulted in 907.7ml/kg.

The activity profile for the 20 minute exercise bout (Figure 1) was replicated and adjusted from a previous study that examined the influence of fatigue on peak isokinetic torque of the knee flexors and extensors in male professional soccer players (Greig, 2008). Certain aspects of the former fatigue protocol were adjusted to suite high school athletes for
this study. The maximum speed was adjusted from 25km/hr to 17.9km/hr. This speed was found to be attainable by all subjects during pilot testing. The acceleration and deceleration velocities between the six speed settings are shown in the Appendix A (Figures 1 & 2).

![Activity Profile of Twenty Minute Intermittent Treadmill Protocol](image)

Figure 1. The activity profile of the twenty minute intermittent treadmill protocol.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of Occurrences</th>
<th>Mean Duration (s)</th>
</tr>
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<tbody>
<tr>
<td>Walking (1.5km/h)</td>
<td>11</td>
<td>10.4</td>
</tr>
<tr>
<td>Fast Walk (4km/h)</td>
<td>26</td>
<td>11.7</td>
</tr>
<tr>
<td>Low Speed Jog (8km/h)</td>
<td>24</td>
<td>5.2</td>
</tr>
<tr>
<td>Moderate Jog (12km/h)</td>
<td>21</td>
<td>5.1</td>
</tr>
<tr>
<td>Run (14.5km/hr)</td>
<td>11</td>
<td>13.4</td>
</tr>
<tr>
<td>Sprint (17.9km/h)</td>
<td>6</td>
<td>8.4</td>
</tr>
</tbody>
</table>
Design and Analysis

The dependent variables used in this analysis were peak hip flexor concentric isokinetic torque of the dominant leg and the active and passive hip flexor ROM of the dominant leg. Each was averaged over three repetitions. Torque data were only used during the concentric phase of the movement. Values prior to and after the intermittent treadmill protocol were compared using one-way repeated measures ANOVA to test each hypothesis. The assumption of sphericity was controlled for all variables. All results are reported as the means ± standard deviation and significance was accepted at p < .05.
Chapter IV

RESULTS

Values for the non-dominant leg were not analyzed because the data from this study showed no statistical difference between the dominant and non-dominant leg. Also, previous literature suggests that the dominant leg is more pertinent to changes in strength when fatigued (Rahnama et al., 2003; Greig, 2008). Thus, only values for the dominant leg are included in the following analyses.

Strength

Strength was assessed using three speeds: 60, 180 and 300 degrees per second. Figure 2 shows the change in peak concentric torque of the hip flexors at each speed during the exercise protocol. The analysis of variance showed no significant effect (see Table 3 for means and standard deviations). Hip flexor strength was maintained throughout the protocol, irrespective of speed.
Figure 2. Time history of dominant leg peak concentric isokinetic hip flexor torque during the intermittent fatigue protocol. The data are means (SD).

Table 3. Pre and post averages (standard deviations) of peak hip flexor torque of the dominant leg at three speeds.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
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<tr>
<td>60°/s</td>
<td>171.4 (43.3)</td>
<td>166.8 (57.0)</td>
<td>159.0 (31.9)</td>
<td>162.0 (28.5)</td>
<td>176.6 (30.8)</td>
<td>184.1 (34.9)</td>
</tr>
<tr>
<td>180°/s</td>
<td>171.4 (43.3)</td>
<td>166.8 (57.0)</td>
<td>159.0 (31.9)</td>
<td>162.0 (28.5)</td>
<td>176.6 (30.8)</td>
<td>184.1 (34.9)</td>
</tr>
<tr>
<td>300°/s</td>
<td>171.4 (43.3)</td>
<td>166.8 (57.0)</td>
<td>159.0 (31.9)</td>
<td>162.0 (28.5)</td>
<td>176.6 (30.8)</td>
<td>184.1 (34.9)</td>
</tr>
</tbody>
</table>

**Hip ROM**

Subjects showed a 7% reduction in passive ROM throughout the test; 4% of which was observed between the fourth and fifth measurements, 60 and 80 minutes, respectively. Passive ROM of the dominant leg significantly decreased between the pre and post tests (p =
.010). Between trials, a one-way repeated measures ANOVA test showed that there was no main effect for time.

Subjects lost approximately 32 percent of their active ROM throughout the duration of the protocol. Active ROM decreased only 4 percent during the first half of exercise; a 12 percent decrease was observed between the third and fourth measurement (40 and 60 minutes), and 14 percent between the fourth and fifth measurement (60 and 80 minutes). On average, the subjects lost 3.57 degrees of active ROM throughout the analysis. The average active ROM at the beginning was 11.29 degrees. Eight subjects began with higher and six began with lower than the average ROM; those above lost an average of 3.63 degrees and those below lost 3.50 degrees, or approximately 25 and 49 percent of their beginning ROM, respectively. Figure 3 shows the average hip ROM during the soccer-specific fatigue test. The active ROM of the dominant leg was found to have a significant difference (p < 0.0001) between the pre and post tests (see Table 4 for means and standard deviations).
Figure 3. Time history of passive (A) and active (B) hip flexor ROM for the dominant leg, during the soccer-specific intermittent fatigue protocol. The data are means (SD).
Table 4. Pre and post averages (standard deviations) of active and passive hip flexor ROM of the dominant leg.

<table>
<thead>
<tr>
<th></th>
<th>Passive</th>
<th></th>
<th>Active</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Hip ROM</td>
<td>23.86</td>
<td>22.29</td>
<td>11.29</td>
<td>7.71</td>
</tr>
<tr>
<td></td>
<td>(3.88)</td>
<td>(4.78)</td>
<td>(4.10)</td>
<td>(4.70)</td>
</tr>
</tbody>
</table>
Chapter V

DISCUSSION

The objective for this study was to analyze the effect fatigue has on hip flexor strength and ROM. The first hypothesis that strength would decrease throughout the exercise protocol was not supported as strength was maintained at all speeds. These findings were similar to the study on concentric quadriceps and hamstring strength in elite soccer players (Greig, 2008) from which this study’s fatigue protocol was adapted. This was in contrast to other studies that have shown a decline in strength over time when introducing a fatiguing protocol (Gleeson et al., 1995; Rahnama et al., 2003.) However, these studies used extensive and intense exercise bouts that are not normally observed in match play. This alone would increase the probability for a decrease in strength.

Though it is very difficult to replicate the activity profile of a soccer match, many measures were taken to increase the validity of this study. First, the intermittent treadmill protocol was pilot tested and adapted to accommodate the lower level of fitness exemplified by the high school age participants (maximum speed and duration of these speeds were shortened). Six different modes of movement were used in a randomized order 99 times during each 20 minute activity bout to recreate the stop and go atmosphere of match play. The distance covered during this study was 11.2km which is within a kilometer of the distance that is associated with moderate level soccer matches (Bangsbo, 1994). Cutting, kicking and back pedaling however, were not included because of the obvious difficulty that would arise during the protocol. As of this time, this is the only study that has implemented a soccer-specific intermittent treadmill protocol for non-elite athletes.
A unique finding in this study was that active ROM decreased across the exercise protocol. Previous literature on ROM in soccer athletes addresses passive ROM whereas the investigator is responsible for taking the subject’s leg through hip extension ROM. Active ROM, in which the subject is moving their own leg through hip extension ROM, may be a more reliable measure of ROM in relation to soccer-specific activity. While kicking, the player’s leg is brought back into hip extension (backswing) using the gluteal muscles (and hamstrings to a certain degree). Therefore, the fatigue of these muscles could play a role in the ROM available during match play and could be an important factor to include. When measuring active ROM during hip extension these muscles must contract to move the leg into extension. During passive ROM they remain relaxed, therefore testing only the laxity of the hip flexor muscles which is unlike the actual requirement of the kicking movement. Passive ROM also decreased during the protocol. This is similar to previous literature on ROM and fatigue (Bradley & Portas, 2007). The decline in ROM has implications that the ability of the player to perform the necessary tasks such as kicking, sprinting, jumping and tackling would diminish towards the latter stages of a match. This might also lead to more errors resulting in a less effective player.

There were certain limitations to this study. First, this investigation looked only at peak concentric torque. Research focused on the angle at which peak torque is obtained may also be beneficial. In this study, when measuring hip flexor torque, the ROM at which the subject’s leg moved through was reset for each trial. This was done to ensure safety in case the subject was no longer able to move through their previously set ROM. However, if peak torque consistently occurred near the end of the movement altering that end would affect the measurement. Fluid intake was another variable that was not taken into account during the
protocol. Decline in strength is reflected in dehydration and consequently the depletion of glycogen stores within muscle tissue (Bangsbo, 1994). During rigorous exercise the sweat glands can produce from 12 to 30 grams of sweat per minute depending on intensity and environmental conditions, which can lead to a decrease in exercise performance (McGregor et al., 1999). In this study, hydration was not monitored as participants were allowed to intake fluids at any time which was not regulated.

**Conclusion**

Previous studies have linked hip extension ROM with injury prevalence of the hip flexor muscles. The result of this investigation suggests that the ROM decreases similarly regardless of how much initial ROM an athlete begins an exercise period with. In this study the subjects lost three and half degrees of active ROM throughout the protocol. This amount could be very limiting if an athlete began match play with an already reduced amount of ROM, as it was with nearly half of the participants in this study. As ROM decreases during match play the ability to execute the necessary tasks (e.g., kicking, heading, tackling…) are diminished even though the occurrence of these movements may not be. In later stages of match play injury prevalence rises sharply. The functions of the hip flexors musculature is such that the player may become more susceptible to both muscular strain injury and impaired joint stability when ROM is reduced. Therefore increasing pre match hip ROM becomes important. If soccer players are destined to lose approximately the same amount of ROM regardless of their start point, increasing their pre match ROM would be of great benefit. Dynamic and static stretching should be implemented in all soccer training regimens with considerable time given to the hip flexor muscle group.
Hip flexor injury will continue to be a major topic in soccer as it is the most injured area of the body relating to non-contact incidents. Further examination directed toward specific soccer activities such as shooting and heading in relation to the hip flexor muscle group may help us better understand the stress applied to these muscles during soccer.
REFERENCES


Figure 4. Velocity profile of the time spent in 1 km/h intervals during the soccer-specific intermittent treadmill protocol. Each interval runs from i-0.5 to i+0.49, where I is the interval number.
Figure 5. Velocity profile of the distance covered in 1 km/h intervals during the soccer-specific intermittent treadmill protocol. Each interval runs from \( i-0.5 \) to \( i+0.49 \), where \( i \) is the interval number.
Figure 6. Distance traveled by time during one 20-minute bout of exercise during the soccer-specific intermittent treadmill protocol.
Figure 7. Acceleration vs. velocity plot of the intermittent treadmill protocol when moving from slow to high speeds.

\[ y = -0.0257x^3 + 0.1692x^2 - 0.1653x + 0.3564 \]

\[ R^2 = 0.9889 \]
Figure 8. Acceleration by velocity plot of the intermittent treadmill protocol when moving from high to slow speeds.

\[ y = -0.0215x^3 + 0.2236x^2 - 0.5531x - 0.4555 \]

\[ R^2 = 0.9357 \]
Figure 9. Non-dominant leg peak concentric isokinetic hip flexor torque during the soccer-specific intermittent treadmill protocol.
APPENDIX B: MATERIALS FROM DATA COLLECTION

Test Subject Record Sheet

<table>
<thead>
<tr>
<th>Subject #</th>
<th>Date</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Max HR</th>
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### HIP ROM

<table>
<thead>
<tr>
<th></th>
<th>Right Leg</th>
<th>Left Leg</th>
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<tbody>
<tr>
<td></td>
<td>Flexion</td>
<td>Extension</td>
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<tr>
<td>Pre-exercise</td>
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<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Interval</td>
<td></td>
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<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-exercise</td>
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<td></td>
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</table>

### HIP FLEXION

<table>
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<tr>
<th>Peak Torque (Nm)</th>
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<th>60</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>L</td>
<td>R</td>
</tr>
<tr>
<td>Pre-exercise</td>
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<td>1&lt;sup&gt;st&lt;/sup&gt; Interval</td>
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<td>3&lt;sup&gt;rd&lt;/sup&gt; Interval</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Speed (deg/sec)
INFORMED CONSENT DOCUMENT

Title of Study: Correlation of hip range of motion and hip flexor strength using a soccer-specific fatigue test in male soccer players

Investigators: Ann Smiley-Oyen, PhD; Timothy Robinson, BA

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to better understand the relationship between hip flexor strength and hip range of motion during fatigue. Hip flexor strength is the power with which a person can lift their leg moving their knee towards their chest. This is similar to the motion used to kick a soccer ball. Hip range of motion can be defined as the flexibility that the hip joint possesses. Both hip flexor strength and hip range of motion decrease when fatigued but it has not yet been researched if they decrease independently or as a result of one or the other. The study entails performing an intermittent treadmill protocol designed to simulate the activities during a soccer match. The intermittent treadmill protocol is an 80 minute treadmill test where the participants move at different speeds just as they would on a soccer field (standing, walking, jogging and sprinting). This is broken up into four 20-minute periods. The intention is to learn more about the hip flexor muscles and to advance knowledge in athletic performance and injury prevention. You are being invited to participate in this study because this research is specifically looking at high school male soccer players.

DESCRIPTION OF PROCEDURES

If you agree to participate, you will be asked to stand, walk, jog and sprint on a treadmill for a period of 80 minutes. You will wear a heart rate monitor to ensure that you do not reach 90% of your maximal heart rate. At five intervals throughout the treadmill protocol your hip range of motion (flexibility) and hip flexor strength will be tested. To collect hip range of motion data, you will lie on your back on a treatment table with a stabilizing belt around your waist. Your leg will be raised towards your chest to determine hip flexion range of motion. A similar procedure will be done with you on your stomach to measure hip extension range of motion (lifting your leg towards your back). A handheld instrument (inclinometer) that measures the angle created by the table and your leg will be used to determine hip angle. Both legs will be measured. Hip flexor strength data will be collected using a dynamometer. A dynamometer is a tool used to measure force (or power) and in this study will be used to measure the amount of power you use to contract your hip flexor muscles. You will lie on your back on the dynamometer with both legs laid flat. You will be asked to flex your hip (pulling your knee towards your chest) as fast as you can for three repetitions. Both legs will be measured.

You will be asked to visit the Forker Building lab at Iowa State University on two separate occasions. The first session is to familiarize you with the research equipment (treadmill, heart rate monitor, inclinometer and dynamometers) and should last approximately 20 to 30 minutes. The second visit will require approximately 2½ hours. You will complete the 90 minute
treadmill soccer simulation along with the five intermittent hip range of motion and hip flexor strength tests. Each measurement of hip range of motion and hip flexor strength will take approximately 10 minutes.

RISKS
While participating in this study you may experience the following risks: physical fatigue and muscle soreness. The following precautions will be taken to assure the safety of all participants.

Precautions:
- You will be allowed to stretch during the half time rest period of the intermittent treadmill protocol.
- You will have access to water at all times during the testing.
- A fan will be placed near the treadmill during the fatigue test to ensure that you do not become overheated.
- You will wear a heart rate monitor during the treadmill test. If at any time you reach 90% of your maximal heart rate the test will be stopped.
- If at any time you do not want to continue the test you will be encouraged to stop.

BENEFITS
If you decide to participate in this study there may be no direct benefit to you. It is hoped that the information gained in this study will benefit society by advancing knowledge in the areas of soccer performance and injury prevention. Understanding more about the relationship between hip range of motion and hip flexor strength during fatigue can help us develop better training regimens.

COSTS AND COMPENSATION
You will not have any costs from participating in this study. You will not be compensated for participating in this study.

PARTICIPANT RIGHTS
Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

CONFIDENTIALITY
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.
To ensure confidentiality to the extent permitted by law, the following measures will be taken:
Subjects will be assigned a unique code and will be used on forms instead of their name. Only the research investigator and supervising professor will have access to the study records. These forms are kept in the Motor Control and Learning Laboratory, which is locked with limited access, and the forms are kept in a locked file cabinet. All records will be kept in password protected computer files. Data will be kept on file until data are published or for a period of 24 months before erasure. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study.

- For further information about the study contact Timothy Robinson at 563-340-2599 or email me at timothyrv@iastate.edu. You may also contact Dr. Smiley-Opyn at 515-294-8261.
- If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

*********************************************************************************************************************************************

PARTICIPANT SIGNATURE

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant's Name (printed)

Participant's Signature (Date)

Signature of Witness (Date)
PARENTAL CONSENT DOCUMENT

Title of Study: Correlation of hip range of motion and hip flexor strength using a soccer-specific fatigue test in male soccer players

Investigators: Ann Smiley-Oyen, PhD; Timothy Robinson, BA

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

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The purpose of this study is to better understand the relationship between hip flexor strength and hip range of motion during fatigue. Hip flexor strength is the power with which a person can lift their leg moving their knee towards their chest. This is similar to the motion used to kick a soccer ball. Hip range of motion can be defined as the flexibility that the hip joint possesses.

Both hip flexor strength and hip range of motion decrease when fatigued but it has not yet been researched if they decrease independently or as a result of one or the other. The study entails performing an intermittent treadmill protocol designed to simulate the activities during a soccer match. The intermittent treadmill protocol is an 80 minute treadmill test where the participants move at different speeds just as they would on a soccer field (standing, walking, jogging and sprinting). This is broken up into four 20-minute periods. The intention is to learn more about hip flexor muscles and to advance knowledge in athletic performance and injury prevention.

Your child is being invited to participate in this study because this research is specifically looking at high school male soccer players.

DESCRIPTION OF PROCEDURES

If you agree to allow your child to participate, he will be asked to stand, walk, jog and sprint on a treadmill for a period of 80 minutes. Your child will wear a heart rate monitor to ensure that he does not reach 90% of his maximal heart rate. At five intervals throughout the treadmill protocol his hip range of motion (flexibility) and hip flexor strength will be tested. To collect hip range of motion data, he will lie on his back on a treatment table with a stabilizing belt around his waist. Your child’s leg will be raised towards his chest to determine hip flexion range of motion. A similar procedure will be done with your child on his stomach to measure hip extension range of motion (lifting your leg towards your back). A handheld instrument (inclinometer) that measures the angle created by the table and your child’s leg will be used to determine hip angle. Both legs will be measured. Hip flexor strength data will be collected using a dynamometer. A dynamometer is a tool used to measure force (or power) and in this study will be used to measure the amount of power your child uses to contract his hip flexor muscles. He will lie on his back on the dynamometer with both legs flat. He will be asked to flex his hip (pulling his knee towards his chest) as far as he can for three repetitions. Both legs will be measured.

Your child will be asked to visit the Forker Building lab at Iowa State University on two separate occasions. The first session is to familiarize him with the research equipment (treadmill, heart rate monitor, inclinometer and dynamometers) and should last approximately 20 to 30 minutes. The second visit will require approximately 2 1/2 hours. Your child will complete the 90 minute
treadmill soccer simulation along with the five intermittent hip range of motion and hip flexor strength tests. Each measurement of hip range of motion and hip flexor strength will take approximately 10 minutes.

RISKS

While participating in this study your child may experience the following risks: physical fatigue and muscle soreness. The following precautions will be taken to assure the safety of all participants.

Precautions:
- Your child will be allowed to stretch during the half time rest period of the intermittent treadmill protocol.
- Your child will have access to water at all times during the testing.
- A fan will be placed near the treadmill during the fatigue test to ensure that your child does not become overheated.
- Your child will wear a heart rate monitor during the treadmill test. If at any time your child reaches 90% of his maximal heart rate the test will be stopped.
- If at any time your child does not want to continue the test he will be encouraged to stop.

BENEFITS

If you decide to allow your child to participate in this study there may be no direct benefit to him. It is hoped that the information gained in this study will benefit society by advancing knowledge in the areas of soccer performance and injury prevention. Understanding more about the relationship between hip range of motion and hip flexor strength during fatigue can help us develop better training regimens.

COSTS AND COMPENSATION

Your child will not have any costs from participating in this study. Your child will not be compensated for participating in this study.

PARTICIPANT RIGHTS

Your child’s participation in this study is completely voluntary and he may refuse to participate or leave the study at any time. If he decides to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which your child is otherwise entitled.

CONFIDENTIALITY

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your child’s records for quality assurance and data analysis. These records may contain private information.
To ensure confidentiality to the extent permitted by law, the following measures will be taken. Subjects will be assigned a unique code and will be used on forms instead of their name. Only the research investigator and supervising professor will have access to the study records. These forms are kept in the Motor Control and Learning Laboratory, which is locked with limited access, and the forms are kept in a locked file cabinet. All records will be kept in password protected computer files. Data will be kept on file until data are published or for a period of 24 months before erasure. If the results are published, your child’s identity will remain confidential.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study.

- For further information about the study contact Timothy Robinson at 515-340-2599 or email me at timothy7@iastate.edu. You may also contact Dr. Smiley-Oyen at 515-294-8261.
- If you have any questions about the rights of research subjects or research related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

******************************************************************************

PARTICIPANT SIGNATURE
Your signature indicates that you voluntarily agree to allow your child to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant's Name (printed)

Parent or Authorized Legal Guardian Signature (Date)

Signature of Witness (Date)
Assent Form
(For Minors aged 14-17)

Your Parents have identified you as someone who may help us with a project, and we want to make sure you want to help us. Therefore, we want to explain the project to you. Please ask any questions you may have after reading this form.

What will happen during the study?
If you agree to participate, you will be asked to perform some activities, like standing, walking, jogging and sprinting on a treadmill for 80 minutes. This will be broken up into four 20-minute periods. Other tasks you will be asked to perform will be hip flexion/extension movements on a dynamometer. Hip flexion is simply lifting your leg up towards your chest and hip extension is lifting your leg behind you (towards your back). A dynamometer is a tool used to measure force (or power) and in this study will be used to measure the amount of power you use to contract your hip flexor muscles which are located at the top of your thigh. Your hip range of motion (or flexibility) will also be recorded. This will require you to lie on a table and have the researcher measure your hip flexion and extension using an instrument that measures the angle of the table and your leg. We will take these measurements five times through the treadmill exercise periods.

You will be asked to visit the Parker Building, at the Iowa State campus, on two separate occasions. The information we collect will not be kept with your name, and will instead be given a number. This will keep people from knowing the information is about you, and only the research investigator and supervising professor will have access to the study records.

How will my results be used?
The information collected in this study will be used to better understand the relationship between hip range of motion and hip flexor strength during fatigue. This could lead towards better training routines designed to promote a higher level of performance and a better understanding of injury prevention. We will use the results to write a paper, but no one will know the information is about you. The data are kept in the Motor Control and Learning Laboratory, which is locked with limited access, and the forms are kept in a locked file cabinet. All records will be kept in password protected computer files.

RISKS
While participating in this study you may experience the following risks: physical fatigue and muscle soreness. The following precautions will be taken to ensure the safety of all participants.

Precautions:
- You will be allowed to stretch during the half time rest period of the intermittent treadmill protocol.
- You will have access to water at all times during the testing.
- A fan will be placed near the treadmill during the fatigue test to ensure that you do not become overheated.
- You will wear a heart rate monitor during the treadmill test. If at any time you reach 90% of your maximal heart rate the test will be stopped.
- If at any time you do not want to continue the test you will be encouraged to stop.

**Do I have to agree?**
You do not have to agree to participate in this study. And, even if you do, if at any time during the study you no longer wish to participate you may leave the study.

**Offer to answer questions**
If you have any questions about this study, please contact Timothy Robinson at 563-340-2599 or timrobinson@iastate.edu. You may also contact Dr. Ann Smiley-Oyen at 515-294-8261 or asmiley@iastate.edu.

If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office of Research Assurances, 1138 Pearson Hall, Iowa State University, Ames, Iowa 50011.

<table>
<thead>
<tr>
<th>Subject's name (PRINT)</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
</table>

Witness' Signature

Investigator's Signature
Correlation of hip range of motion and hip flexor strength using a soccer-specific fatigue test in male soccer players

Layperson description

Investigators
- Timothy Robinson
- Dr. Ann Smiley-Oyen

The research we would like to conduct at Iowa State examines hip flexor strength and hip range of motion in high school male soccer players. What we would like to examine is the relationship between hip flexor strength and hip range of motion during fatigue to see if one decreases as a result of the other. In other words, does hip range of motion only begin to decrease after hip flexor strength decreases, or vice versa? Our goal is to establish a correlation between them so we can better understand how injuries occur and therefore how better to prevent them. If the decrease in hip range of motion was found to be dependent of the decrease in hip flexor strength it would give credibility to establishing hip flexor strength training exercises for soccer players in order to prevent injury.

For this study the participants will complete an eighty minute treadmill test which will be split into four periods of twenty minutes. Hip flexor strength and hip range of motion tests will be conducted at five intervals throughout the exercise protocol, before exercise and after each of the four twenty minute bouts of exercise. To collect hip range of motion data, subjects will lie on their back on a treatment table with a stabilizing belt secured around their pelvis. Their leg will be raised towards their chest to determine hip flexion range of motion. This same procedure will be done with the subject on their stomach to measure hip extension. A handheld instrument that measures the angle created by the table and the subject’s leg will be used to determine hip angle. Both the dominant and non-dominant leg will be measured. Hip flexor strength data will be collected using a dynamometer. A dynamometer is tool used to measure force (or power) and in this study will be used to measure the amount of power the participants use to contract their hip flexor muscles. Subjects will lie on their back on the dynamometer with both legs laid flat. They will be asked to flex their hip (pull their knee towards their chest) as fast as possible for three repetitions. Both the dominant and non-dominant leg will be measured.
June 22, 2010

Institutional Review Board
1138 Pearson Hall
Iowa State University
Ames, IA 50011

Dear Director:

This letter will serve as verification that Tim Robinson and Dr. Ann Smiley-Oyen have contacted me about Mr. Robinson’s proposed research project involving male soccer student-athletes at Gilbert High School and has my approval to conduct such research. Specifically, I have granted the following permissions:

- Mr. Robinson has permission to place a flyer about his study in the school.
- He has permission to contact interested students about his research.
- Mr. Robinson will verify, through school records, that all students have a valid physical form on file prior to their participation in the study.

Please contact me if you have any questions.

Sincerely,

John Kinley, Superintendent
Participants for Soccer studies.
All Gilbert male athletes who have played at least one season of high school soccer and have a current medical examination on file.

Purpose:
To research how hip flexor strength and hip range of motion affect soccer performance.

Tasks:
• Walking, jogging and running on a treadmill for 80 minutes
• Having your hip flexion and extension range of motion measured
• Having your hip flexor strength measured

Time:  
First visit 30 minutes  
Second visit 2½ hours

Location:  
Forker Building on Iowa State Campus, Ames  
Dept. of Kinesiology  
Parking will be provided.

For information contact Tim Robinson at (563) 340-2599 or at timothyr@iastate.edu
ACKNOWLEDGEMENTS

I thank Charles Everson for his time and effort in the adaptation of the intermittent treadmill protocol and overall analysis for this research project.