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FUNCTIONAL HAMSTRING: QUADRICEPS RATIO AND HAMSTRING INJURY INCIDENCE IN TRACK AND FIELD ATHLETES

Taryn Cadez-Schmidt

Taryn Cadez-Schmidt
Candidate

College of Education – Health Exercise & Sport Science
Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

Annie Clement Ph.D., J.D. , Chairperson

Christine Mermier Ph.D. , Co-Chairperson

Mary Virginia Wilmerding Ph.D.

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by

TARYN CADEZ-SCHMIDT

B.S., COLORADO MESA UNIVERSITY, 2010

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FUNCTIONAL HAMSTRING: QUADRICEPS RATIO AND HAMSTRING INJURY INCIDENCE IN TRACK AND FIELD ATHLETES

By Taryn Cadez-Schmidt

B.S., Athletic Training, Colorado Mesa University, 2010

M.S., Physical Education, University of New Mexico, 2013

Abstract

Twenty-one percent of hurdlers and sprinters (22 of 106 athletes) from a Division 1 University Track and Field team sustained hamstring strains in the 2010 season preventing practice and competition. Functional hamstring to quadriceps strength ratio was measured to study muscular imbalances in these athletes. The hypotheses were: 1) Athletes with previous hamstring injuries have a greater chance of subsequent hamstring injury whether or not they have a functional ratio deficit than those who don't have a history of hamstring injuries; 2) Athletes with a functional hamstring to quadriceps ratio deficit at pretest will have a higher occurrence rate of hamstring injury during the study than those without a deficit. A sample size of fifteen (8 females and 7 males; 18 years +) volunteered. No athlete had a recent history (within 12 weeks) of lower extremity injury. The PrimusRS isokinetic testing produced the eccentric hamstring (30 deg/s) and the concentric quadriceps (240 deg/s) muscle contractions for functional ratio. A Pearson correlation analyses found a moderate correlation between the pretest functional ratio deficit of the right/left leg and previous hamstring injuries and low correlation between the pretest functional ratio deficit of the right/ left leg and injuries sustained during the study. Majority of athletes with a previous history of hamstring injury had a functional ratio deficit.

Key Words: hamstring, quadriceps, track and field athletes.

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Chapter I

Introduction

Competitive athletes are required to execute explosive and powerful movements during many sporting events including football games, soccer tournaments and track and field competitions. Athletes are able to do this by engaging in specific training so their strength and power becomes highly developed. They risk injury on a daily basis in order to attempt to reach the pinnacle of success. One of the injuries that plague many athletes is the hamstring strain. Health professionals and the athletes spend substantial amounts of treatment and rehabilitation time dealing with this injury. "Hamstring strains, in addition to being very common, can be long-standing and prone to recurrence" (Croisier J.-L. , Ganteaume, Binet, Genty, & Ferret, 2008, p. 1469). There are ongoing debates on the topic of how and why the hamstring muscle group "is the most frequently injured, representing approximately 12 to 24% of all athletic injuries" (Ebben W. , 2009, p. 84). "Reports suggest possible causes such as: muscle weakness, strength imbalance, lack of flexibility, fatigue, inadequate warm-up, and dyssynergic contraction" (Croisier J.-L. , Forthomme, Namurois, Vanderthommen, & Crielaard, 2002, p. 199). Wright, Ball & Wood (2009) report, "A muscular imbalance of the hamstrings and quadriceps is to be a predisposing factor in hamstring strains" (p. 161). Muscular weakness and strength imbalances play an interdependent role where one muscle is weaker than another muscle creating a disparity in biomedical function at the knee.

A brief description of these two muscle groups follows: "The quadriceps muscle group is the anterior portion of the thigh. It is made up of four muscles: rectus femoris, vastus lateralis, vastus medialis and vastus intermedius. The hamstring muscle group is the posterior portion of the thigh. It is made up of three muscles: biceps femoris, semitendinosus, semimembranosus" (Prentice, 2011, p. 608).

There are several types of muscular resistance testing and training methods including isometric, isotonic and isokinetic techniques. "Isometric training is the muscle contracting statically without changing its length…isotonic training is the shortening and lengthening of muscle through a complete range of motion…isokinetic training is a fixed velocity of movement without accommodating resistance" (Prentice, 2011, p. 99 - 103). Isotonic testing is of interest in this study because of the concentric and eccentric contractions with velocity replicating lower leg movement. "A concentric contraction is the muscle shortening while contracting against a resistance and accelerates movements. An eccentric contraction is the muscle lengthening while contracting against a resistance and decelerates movements. The eccentric contraction generates greater amounts of force against resistance when compared with a concentric contraction due to a much lower level of motor unit activity to achieve to a certain force. For example, while running the hamstrings must contract eccentrically to decelerate the lower leg as the quadriceps is contracting concentrically to accelerate the lower leg" (Prentice, 2011, p. 98-99). Due to the deceleration forces involved with eccentric hamstring contractions and the powerful acceleration of the quadriceps, injury to the hamstring muscles is common. This situation is only exacerbated further if the quadriceps is stronger than the hamstring muscle.

In the current literature, two ratios have been used to find the strength comparison of the hamstring and quadriceps. The conventional ratio uses a concentric contraction of both the hamstring and quadriceps muscle predicting injury with value of >0.6 as abnormal (Wright et al., 2009). The limitation to the conventional ratio is that the athletes move in an isotonic manner. Croisier (2004) explains, "Based on biomechanics of running the quadriceps contract concentrically to generate limb movement while at the same time the hamstring contracts eccentrically to decelerate the limb movement thus preventing injury of the knee" (p. 170). This research project focused on the use of the functional ratio to determine the imbalance of the hamstring eccentrically and quadriceps concentrically. The functional ratio more realistically replicates the movement of an athlete and is reported to be normal at 1:1 (Holcomb W. , Rubley, Lee, & Guadagnoli, 2007) however it has been studied much less compared to the conventional ratio.

Discrepancies between the hamstring and quadriceps using the functional ratio pre and/or post injury could help explain why many hamstring injuries occur. A reason for the discrepancy between the muscle groups, according to Ebben (2009), is "training the quadriceps disproportionately to the hamstrings, inhibiting hamstring co-activation creating more risk for a hamstring injury" (p. 85). "It has also been suggested recurrent injuries might be the consequence of inadequate rehabilitation" (Croisier et al., 2008, p. 1470). Both reasons concern health professionals working with athletes because these situations can be potentially controlled and prevented.

"Clinicians often associate hamstring injuries with sports emphasizing explosive activities, such as sprinting and jumping, as well as rapid acceleration and deceleration…the clinicians found in both men and women, the incidence of hamstring strains was greatest among student athletes playing soccer, a sport requiring repeated sprinting…supporting the anecdotal evidence suggesting that explosive activities increase the risk of hamstring strains" (Cross, Gurka, Conaway, & Ingersoll, 2010, pp. 124,128). Track and field athletes perform explosive movements in sprints, hurdles, the pole-vault, multi events and mid-distances similar to soccer and football, however research involving hamstring is more limited in track a field.

The population chosen for this study was a group of male and female Division 1 university track and field athletes including hurdlers, sprinters, pole-vaulters, multiple event athletes and mid-distance athletes, in part because they had a high incidence of hamstring injuries. In the track season of 2010, 22 sprint and/or jump athletes from the team sustained a hamstring injury ranging from a mild to moderate strain or recurrent strain based on clinical diagnosis from a health professional. This accounted for 21% of the track and field team (22/106 athletes). Each athlete missed practice time and competition events from the injuries.

Statement of the Problem

The purpose of this study was to identify muscle deficits in the hamstring muscles of track athletes using the hamstring: quadriceps functional ratio during the preseason. Additionally, these athletes were monitored for hamstring injuries throughout the 2012-2013 indoor and outdoor seasons to discover any correlation between the functional ratio and injury incidence.

Hypotheses

The following hypotheses were tested with this investigation:

1) Athletes with previous hamstring injuries have a greater chance of subsequent hamstring injury whether or not they have a functional ratio deficit than those who don't have a history of hamstring injuries.
2) Athletes with a functional hamstring to quadriceps ratio deficit at pretest will have a higher occurrence rate of hamstring injury during the study than those without a deficit.

Basic Assumptions

The following were basic assumptions of this investigation:

Subjects carefully followed directions during the isokinetic testing procedures.

The measurements made by the primary investigator were accurate.

The administration of the isokinetic functional ratio followed standardized procedures.

All measuring devices were accurately calibrated.

Limitations

The following were limitations of this investigation:

Only male and female athletes between the ages of 18 and 30 years participated.

Only athletes without current lower body injuries preventing him/her from performing maximally participated.

Delimitations

The following were delimitations of this study:

Only track and field athletes at the university who volunteered for the study participated.

All track and field athletes who participated in the study had competed within the last year.

Significance of the Study

Track and field athletes were tested for functional ratio deficits and monitored for a full season for hamstring injuries to find a relationship between hamstring injury rate and functional ratio. This work is novel because it is the first study to investigate the relationship between functional ratio and hamstring injury using track and field athletes.

<u>Definition of Terms</u>

Concentric Contraction – Dynamic activity in which the muscle shortens.

Eccentric Contraction – Dynamic activity in which the muscle lengthens.

Agonist Muscle – A muscle acting as a prime mover to produce a motion.

Antagonist Muscle – A muscle that opposes the motion of another muscle.

Synergist(ic) – A muscle that assists an agonist muscle.

Co-activation – Muscles working together to achieve movement.

Conventional Ratio – Concentric hamstrings: Concentric quadriceps

Functional Ratio – Eccentric hamstrings: Concentric quadriceps

Chapter II

Literature Review

This chapter contains the literature review and is divided into the following sections: a) conventional, functional/dynamic control ratio and b) recurrence rate of hamstring strains.

Conventional and Functional/Dynamic Control Ratio

The meaning of muscle imbalance is important in understanding muscle ratios. In Croisier J.L. , *Review Article: Muscular imbalance and acute lower extremity muscle injuries in sport* (2004) explained “an imbalance in a muscle commonly refers to a modification of the strength balance between the agonist muscle and antagonist muscles…the agonist muscle contracts concentrically to create a movement while the antagonist protects the knee by eccentrically contracting slowing down the movement” (p. 170). For example, during the later phase of a squat when an individual is moving up the quadriceps is shortening concentrically and the hamstring is lengthening eccentrically to provide stability at the knee.

Croisier, Ganteaume, Binet, Genty, & Ferret’s (2008) study defined conventional and mixed ratios. “A conventional hamstring to quadriceps peak torque ratio was established for the same mode and speed of concentric contraction. The mixed ratio associated the eccentric performance of the hamstrings (at 30 deg/s) and the concentric action of the quadriceps muscles (at 240 deg/s)” (p. 1470).

Another ratio is the Dynamic Control Ratio (DCR). The DCR is used for the detection of anterior cruciate ligament (ACL) injury associated with strength imbalances between the hamstring and quadriceps, which is also used to detect previous hamstring muscle injury

(Houweling, Head, & Hamzeh, 2009). The main purpose of the ACL is to "oppose anterior shear forces in the normal knee" (Hole, Smith, Hammond, Kumar, Saxton, & Cochrane, 2000, p. 1604). Hole et al., (2000) explained "the anterior shear forces created by the resistance of the attachment site of the limb to the lever arm in relation to the rotatory force of the maximally contracting quadriceps is thought to be counteracted by the eccentric contraction of the hamstrings… suggesting the hamstring muscle induces an increased braking effect on motion as the knee becomes more extended" (p. 1604). They tested the DCR on ten subjects with complete ACL ruptures to find differences between peak torque for dominant and non-dominant legs. The study "revealed no differences as being statistically significant ($p > .05$) for any of the peak torque ratio values between the dominant and non-dominant legs" (Hole et al, 2000, p. 1606).

Wright, Ball & Wood (2009) explained that the DCR ratio is the ratio of peak torque of the eccentrically contracting hamstring and the concentrically contracting quadriceps during the extension of the knee. The main objective in their study was "to assess the effect of fatigue on the conventional ratio and the DCR as well as the co-activation of hamstring and quadriceps during knee flexion and extension" (p. 162). The effect of fatigue on the DCR and conventional ratio "increased significantly following the fatigue protocol ($p = 0.024$ and $p = 0.003$) and both ratios increased above a ratio of 1:1 following fatigue…the hamstring co-activation during concentric quadriceps muscle action increased following fatigue showing a significant difference in hamstring co-activation pre and post fatigue ($p = 0.017$)… during concentric hamstring muscle actions the quadriceps co-activation decreased showing no significant difference for quadriceps co-activation…this showed that an increase in hamstring co-activation following fatigue in this study may increase the stability of the joint and act as a natural safety mechanism during knee extension" (p. 164-166). Wright et al., (2009) recommended that "future studies examine whether reductions in the DCR following fatigue will correspond to injury incidence and aid in the future development of the H:Q ratio for injury prevention and rehabilitation strategies" (p. 166).

Another way the DCR ratio has been explained was as an "indicator of the braking function of the hamstrings during an extension of maximal quadriceps strength" (Tourny-Challet & Leroy, 2002, p. 183). With this explanation, the DCR ratio illustrates how the hamstrings undergo an eccentric phase to slow down the quadriceps from moving further into knee hyperextension causing injury. Sprinting is a good example of this movement. As knee extension increases in the stride pattern of a sprinter, the hamstring eccentrically contracts as the quadriceps maximally concentrically contracts to allow the running motion to occur (Hole et al., 2000).

Hole et al., (2000) referred to the "combination of these dynamic control ratios, conventional Hamstrings:Quadriceps (H:Q) strength ratios and measures of absolute strength can serve to provide a more complete picture of the strength balances for dynamic and static muscle actions, giving a clear outline of functional implications" (p. 1604). The conventional ratio has traditionally been calculated from the hamstrings and quadriceps peak or mean torque while contracting concentrically. Many clinicians use this ratio as a means of predicting injury with a value of less than 0.6 as being predictive for most athletes. Olmo, Lopez-Illescas, Martin,& Rodriguez (2009) stated in their research on track and field athletes that the "H/Q concentric ratio at 60 degrees/sec was not sport specific and as a result was not effective as a differentiator of muscular adaptations in athlete" (p. 287). "Due to the function of these muscles during movement it has been suggested that the Dynamic Control Ratio…should be used (instead of the conventional ratio)… this ratio has also been described as a functional or mixed ratio" (Wright et al., 2009, p. 161).

Bennell, Wajswelner, Lew, Schall-Riaucour, Leslie, Plant, Cirone's (1998) prospective study found that when assessing muscle strength using the functional ratio, the results do not support an association between preseason muscle weakness or imbalance and subsequent occurrence of hamstring muscle strain on 102 male Australian Rules footballers.

Recurrence Rate of Hamstring Strain

O'Sullivan, O'Ceallaigh, O'Connell, & Shafat (2008) found evidence that the cause of hamstring injury may be multifaceted, one potential contributing factor being muscle weakness. Further reports have suggested hamstring muscle injury can be caused by muscle weakness, strength imbalance, lack of flexibility, fatigue, inadequate warm-up and dyssynergic contraction (Croisier J.L. , Forthomme, Namurois, Vanderthommen, & Crielaard, 2002). Croisier et al. (2002) referred to the rehabilitation process or lack of a rehabilitation plan as the cause of recurring hamstring injury because muscle weakness and strength imbalance are not addressed after injury.

Croisier et al., (2008) research analyzed whether professional soccer players "isokinetic strength variables collected through preseason assessment could be predictors of subsequent hamstring muscle strains and whether normalization of strength performances and agonist/antagonist ratios in the preseason imbalanced player could significantly reduce the incidence of hamstring injury" (p. 1470-1473). They studied 462 soccer players, and found 216 athletes had significant isokinetic strength disorders. "The players were divided into four groups based on injury frequency. Group A (n=246) had no preseason strength imbalance and sustained

10 hamstring injuries (4.1%); Group B (n=91) had preseason strength imbalances but no formal training and sustained 15 injuries (16.5%); Group C (n=55) had imbalances and training but no isokinetic control test aimed at verifying the parameter normalization and sustained 6 hamstring injuries; in Group D, 70 of the athletes had subsequent compensating training until the parameter normalization was proved by repeated isokinetic control tests of which 4 sustained a hamstring injury (5.7% injury frequency). The information represents an innovative finding: normalizing the strength profile significantly ($p < .05$) reduced injury frequency" (Croisier et al., 2008, p. 1472-1473).

Croisier et al., (2002) constructed a functional ratio with two different velocities to replicate the biomechanical conditions involved in sprinting to find the muscle weakness explained in the previous article. "The mixed ratio showed a disequilibrium, suggesting an insufficient eccentric braking capacity of the hamstring muscles compared with the concentric motor action of the quadriceps muscles accounting for a recurrence of injury due to surpassing of eccentric performance mixed ratio (eccentric flexors/concentric quadriceps) for the injured muscles appeared significantly reduced (0.73 +/- 0.24) when compared with the healthy contralateral limb (0.90 +/- 0.16) ($P< 0.01$)" (p. 200-202). O' Sullivan et al. (2008) found similar results in Irish-Gaelic footballers. He found "unilaterally injured hamstrings tended to be weaker, rather than stronger, when compared within subjects…the comparison of hamstrings-to-opposite hamstrings ratios between the unilaterally injured (n=11) and the uninjured subjects (n = 29) at 60 degrees/sec and 180 degrees/sec was significant… also in the relationship between strength and previous injury, researchers found a reduced HQ ratio at 60 degrees/sec when all injured limbs were compared to all healthy limbs" (O'Sullivan et al., 2008, p. 1473-1476).

From the review, the functional hamstring to quadriceps ratio was found to be most beneficial for this study to assess the previous hamstring injuries and any future hamstring injuries in the upcoming track and field indoor and outdoor season. Sprint, hurdle, pole-vaulters, multi event and mid-distance athletes move in a functional manner with the eccentric hamstring slowing down the concentric quadriceps muscle during the swing phase in sprinting.

Chapter III

Methods

The purpose of this study was to identify muscle deficits in the hamstring and quadriceps muscles of track and field athletes including sprinters, hurdlers, pole-vaulters, multi event and mid-distance athletes using the functional ratio during the preseason. Additionally, the athletes were monitored for hamstring injuries throughout the 2012-2013 indoor and outdoor seasons to discover any correlation between the functional ratio and injury incidence.

The methods chapter was organized into the following sections: a) Participants, b) Procedures and c) Statistical Analysis.

Participants

Fifteen male and female track and field athletes from a National Collegiate Athletic Association Division One University volunteered for the study. All volunteers were eighteen years or older. Criteria to be eligible for the study required a physical examination from the university's sports medicine clinic concluding that the athlete was cleared for testing and training. All females required testing to rule out pregnancy due to the maximal effort involved in testing. In addition, the athlete was to have no lower body injuries preventing him/her from performing maximally. All athletes were required to fill out a previous history of hamstring injury questionnaire for the data collection. Athletes were informed of the potential risks of the study and signed a written informed consent approved by the university's Human Research Protections Office (HRPO).

Procedures

Approval for all procedures to conduct this study was obtained from the university's Human Research Protections Office. Preseason functional isokinetic measurements (during the first week of pre-season training) were performed on the hamstrings and quadriceps muscles of each athlete that volunteered. Assessments were performed using the PrimusRS dynamometer (BTE Technologies, Hanover, Maryland). "The PrimusRS dynamometer is a piece of equipment used for multi-joint testing, orthopedic rehab, neuromuscular reeducation, and advanced musculoskeletal athletic training of the upper and lower extremities and the core. It is used to evaluate, rehab, and track the progress with isotonic, isometric, isokinetic and CPM resistance modes" (PrimusRS System Overview, 2012).

Two days prior to testing, athletes received familiarization with the equipment by performing the procedures explained below. Two days were allowed for adequate muscular recovery. Athletes were tested on both legs. The researcher strictly adhere to standardized testing procedures explained below. The athletes reported to the university's athletic training facility for the isokinetic testing twice in their pre-season; the pretest was in September and the posttest was in December. Before testing began, athletes performed a monitored fifteen minute warm up on a stationary bike, keeping the cadence between 95 and 100 rpms. Monitored stretching of the hamstrings and quadriceps muscles followed, holding each stretch for 30 seconds with 3 repetitions. The athletes became familiar with the stretching techniques two days before the testing began. The subjects were seated on the PrimusRS chair with the body stabilized by several straps around the thigh, torso, and lower leg. The thigh and torso straps stabilized the hips and core from assisting with the functional movements of the hamstrings and quadriceps. The lower leg strap stabilized and prevented any extra movement of the lower leg during the flexion and extension of the knee. The lower leg strap stabilization was placed above the ankle with the lever arm axis at the joint line of the knee (Appendix A). The lever arm was set to the nearest ½ inch. The testing protocol included concentric and eccentric exertions of both hamstring and quadriceps muscle groups at 30 degrees per second and 240 degrees per second (5 repetitions) as demonstrated in Croisier, Ganteaume, Binet, Genty, & Ferret (2008). The athletes received a one minute break between each set. The athletes did not have visual feedback but did receive oral feedback.

The athletes had two starting points through the testing cycle (Table 1).

Degree of Movement for Pre-Testing

Table 1

Degrees of Movement for Pre-Testing

1st Starting Point: (Isokinetic – Knee Extension)	**2nd Starting Point: (Isokinetic – Knee Flexion)**
90 Degrees of Knee Flexion	170 Degrees of Knee Extension
170 Degrees of Knee Extension	80 to 85 Degrees of Knee Flexion
80 to 85 Degrees of Knee Flexion	170 Degrees of Knee Extension

The first starting point represented the performance of quadriceps concentric contractions and hamstring concentric contractions. The second starting point represented the performance of the quadriceps eccentric movement and the hamstring eccentric movement of the muscle. The hamstring: quadriceps functional ratio was calculated with the hamstring eccentric contraction at 30 deg/s divided by the quadriceps concentric contraction at 240 deg/s as defined by Croisier, Ganteaume, Binet, Genty, & Ferret (2008). This provided the hamstring to quadriceps ratio, and percentage of strength deficits (if applicable) for each athlete.

An adequate familiarization with the dynamometer was provided in the form of the same testing cycle two days before the experimental trial.

Throughout the duration of the testing and the current season demands each athlete was assessed for hamstring injury. When a hamstring injury occurred, the athlete was seen by the team physician for definitive diagnosis. He determined the nature of the injury and the ability of the athlete to resume training or be removed. The criteria for the hamstring injury were as follows: a clear history of how the injury occurred, pain upon palpation of select areas effected on the muscle, pain with manual resistance of knee flexion and/or hip extension, and if any deviations were present. Documentation was recorded for individual injuries by the medical staff on the team.

The data from the PrimusRS was collected by the researchers and downloaded into a computer using Microsoft Excel for the pretest and any injuries that occurred while the study was in session. This computer was locked in the university's athletic training room #4. The computer had a password only known by the P.I. and associate investigators.

Statistical Analysis

The pretest functional ratio deficits and injuries sustained in the 2012-2013 track and field indoor and outdoor season were recorded and used in the data analysis. Pearson correlation analyses were conducted to see if there were significant relationships between the pretest right and left leg and previous hamstring injury. Pearson correlation analyses were conducted to see if there was significant relationships between the pretest right and left leg and current injuries sustained during the study.

Chapter IV

Results

The purpose of this study was to identify muscle deficits in the hamstring and quadriceps muscles in track and field athletes using the functional ratio during the preseason. Additionally, these athletes were monitored for hamstring injuries throughout the 2012-2013 indoor and outdoor seasons to discover relationships between the functional ratio and injury incidence.

This results chapter includes: a) hypotheses b) group demographics, c) preseason functional ratios, d) statistical analysis, and e) injury case reports.

Hypotheses

The following hypotheses were tested with this investigation:

1) Athletes with previous hamstring injuries have a greater chance of subsequent hamstring injury whether or not they have a functional ratio deficit than those who don't have a history of hamstring injuries.
2) Athletes with a functional hamstring to quadriceps ratio deficit at pretest will have a higher occurrence rate of hamstring injury during the study than those without a deficit.

Group Demographics

Table 2

Group Demographics 2012 – 2013

ID #	Gender	Ht (inches)	Wt (lbs)	Event	Pregnancy Test
25	F	66	115	Middistance	(-)
26	F	69	128	PoleVault	(-)
27	F	63	142	Hurdler	(-)
28	F	66	147	Heptathlete	(-)
29	F	66	112	Sprinter	(-)
31	F	66	136	Sprinter	(-)
32	M	68	153	PoleVault	
33	M	67	148	Sprinter	
34	M	77	167	Middistance	
35	M	69	169	Sprinter	
37	M	70	200	Hurdler	
38	M	70	171	Sprinter	
39	F	63	138	Sprinter	(-)
40	M	67	158	Sprinter	
41	F	63	129	Distance	(-)
Mean		67.3	147.5		
SD		3.6	23.3		

Mid-distance 800M
Sprinter - 60M, 100M, 200M, 400M
Pole-vault - 100 to 60M
Distance - 5K
Hurdlers - 110M or 60M
Heptathlete - 100M hurdles

Pretest Hamstring:Quadriceps Functional Ratio

Table 3

Pretest H:Q Functional Ratios

ID #	Pre-test Ratio Right Leg	Left Leg	P.H.I	I
25	0.98	0.69*†	1	0
26	0.96	0.74*†	2	0
27	0.62*†	0.59*†	1	0
28	1.75	0.96	0	0
29	0.73*†	0.67*†	1	1
31	1.03	1.34	0	1
32	0.77*†	0.54*†	1	0
33	0.61*†	0.54*†	1	1
34	0.94	0.76*	0	0
35	0.81*	0.80*	0	0
37	0.51*†	0.50*†	2	0
38	0.66*†	0.64*†	2	0
39	1.00	0.92	1	0
40	1.47	1.09	1	0
41	1.03	3.27	0	0
Mean	0.92	0.94		
SD	0.33	0.68		

Note: P.H.I. = Previous hamstring injury
I = Current Injury
(*) = Functional Ratio Deficit Defined by (<0.85)
(†) = Functional Ratio Deficit with P.H.I.

Statistical Analysis

Hypothesis 1 addresses the relationship between athletes with previous hamstring injuries and the chance of subsequent injury compared to those without previous injury. The purpose of hypothesis was to find the relationship whether the athlete had or did not have a measured functional ratio deficit. The Pearson correlation conducted prior to the pre-season using the functional ratio on the left (Figure 1; $r = .47$) and right (Figure 2; $r = .46$) legs and previous hamstring injuries showed moderate relationship.

Figure 1

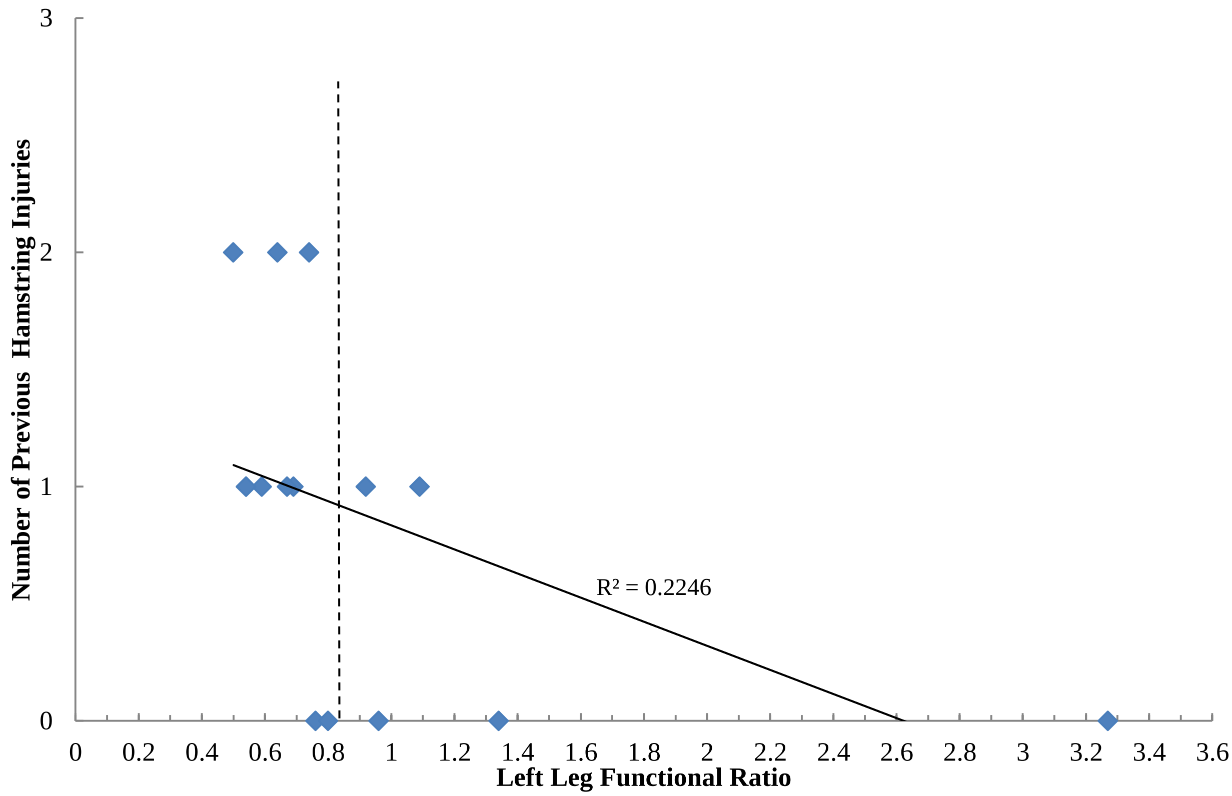

Figure 1. The black dashed line = .85 shows the cutoff used to define functional ratio deficit. Refer to Table 3 for marked functional ratio deficits. The data shows that 80% of athletes who had any previous hamstring injury had a deficit in the functional ratio on the left leg while only 20% of athletes with a previous hamstring injury had a normal functional ratio on the left leg.

Figure 2

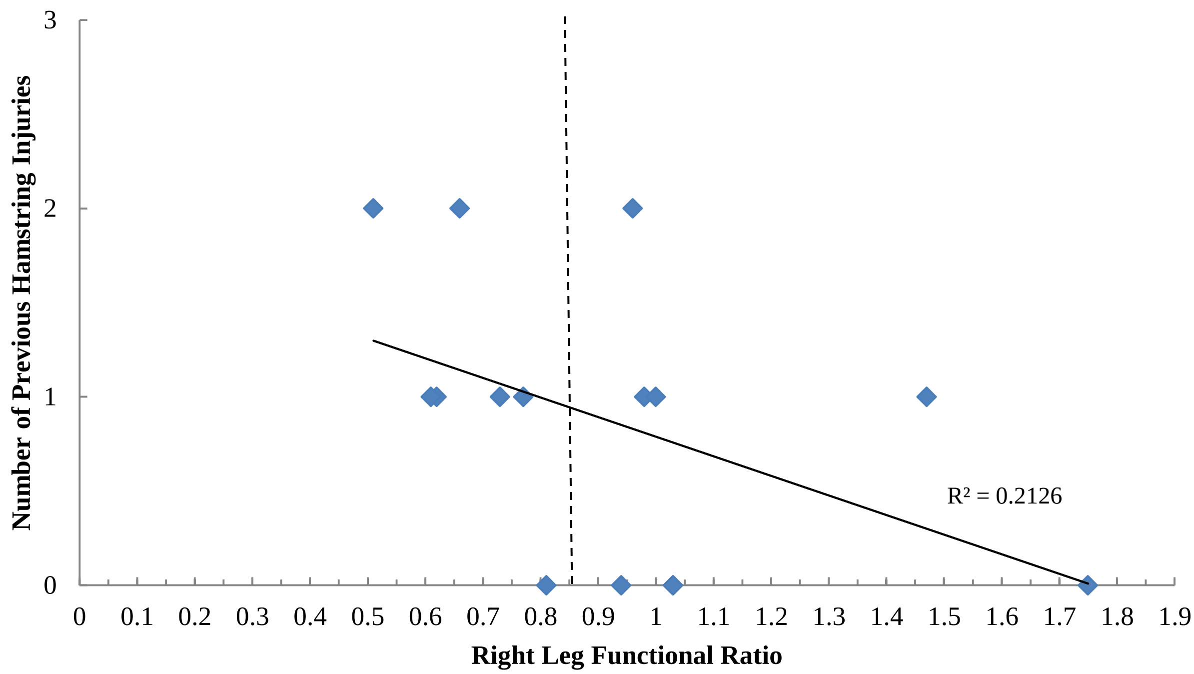

Figure 2. The black dashed line = .85 shows the cutoff used to define functional ratio deficit. Refer to Table 3 for marked functional ratio deficits. The data shows that 60% of athletes who had any previous hamstring injury had a deficit in the functional ratio on the right leg while only 40% of athletes with a previous hamstring injury had a normal functional ratio on the right leg.

Hypotheses 2 asked if athletes with a functional hamstring quadriceps ratio deficit at pretest will have a higher occurrence rate of hamstring injury during the study than those without a deficit. Pearson correlation showed no relationship between pretest functional ratio for the left (Figure 3; r =.07) and right leg (Figure 4; r = .21) and hamstring injuries that occurred during the study.

Figure 3

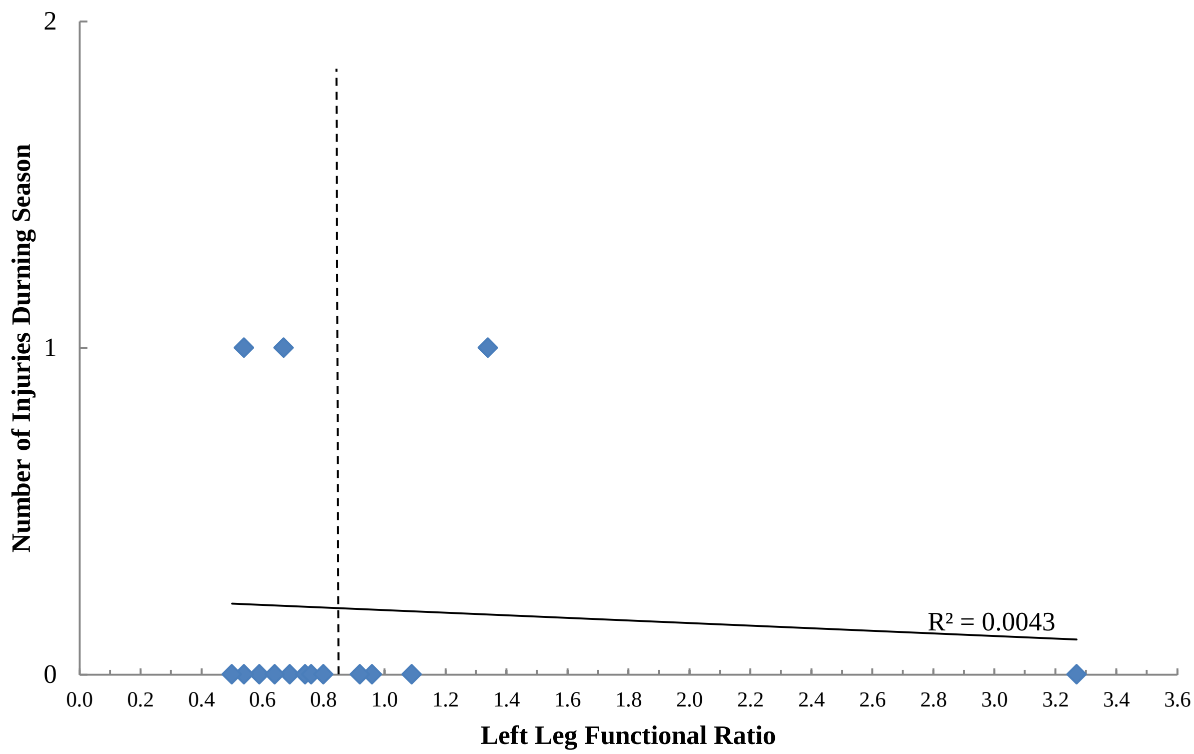

Figure 3. The black dashed line (.85) represents the cutoff used for the functional ratio deficit. Refer to Table 3 for marked functional ratio deficits. The data shows that 67% of athletes who had an in-season hamstring injury had a deficit in the functional ratio on the left leg while only 33% of athletes who had an in-season hamstring injury had a normal functional ratio on the left leg.

Figure 4

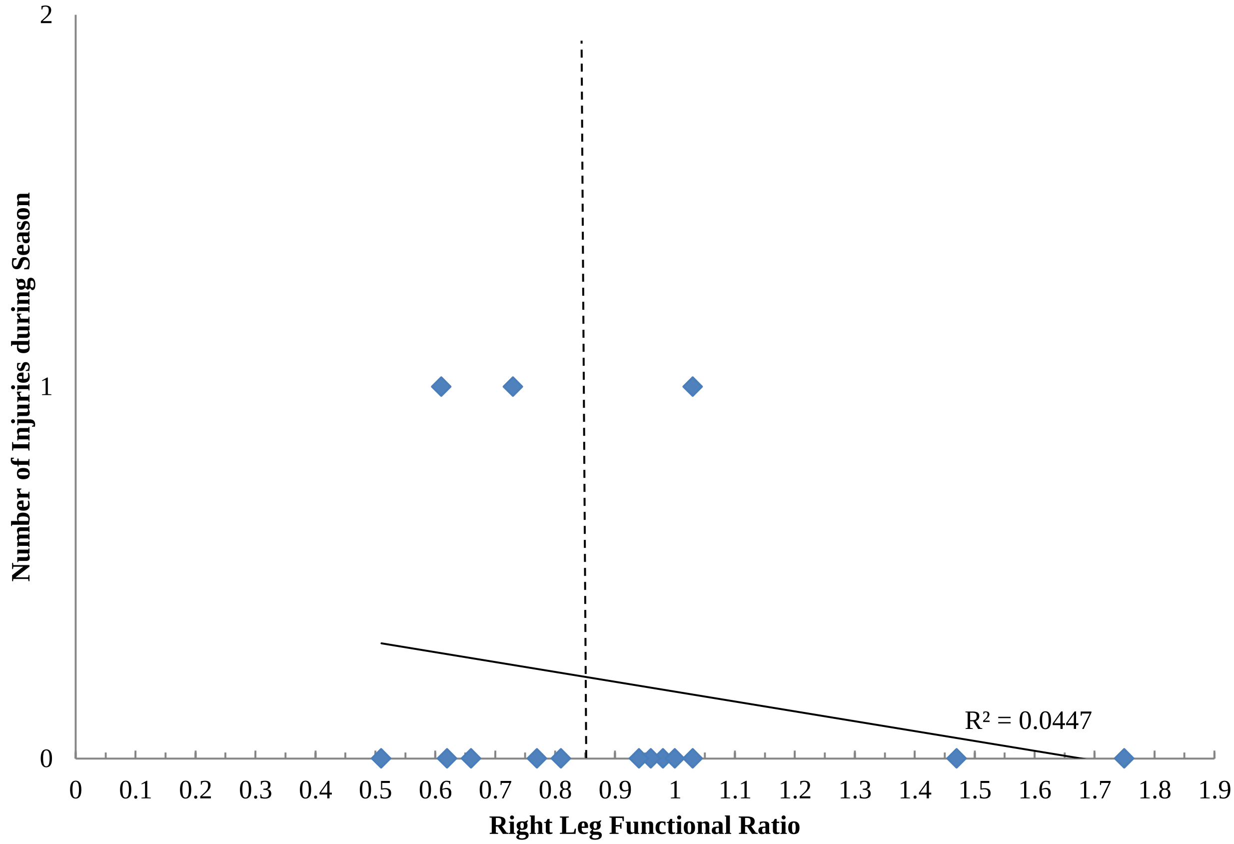

Figure 4. The black dashed line (.85) represents the cutoff used to define the functional ratio deficit. Refer to Table 3 for marked functional ratio deficits. The data shows that 67% of athletes who had an in-season hamstring injury had a deficit in the functional ratio on the right leg while only 33% of athletes who had an in-season hamstring injury had a normal functional ratio on the right leg.

Injury Case Reports

Case 1: 12-351-29

A 19 year old female sprinter (200m/400m) with a previous hamstring injury in high school sustained a hamstring injury during practice. The athlete's subjective history claims she did not perform the dynamic warm up prior to practice leading to the injury. She was performing repetition activities around the curve and began to feel soreness in the hamstring and pushed through. During the second to last repetition the athlete felt a sharp pain in the hamstring and immediately stopped running. The athlete limped into the athletic training room and was diagnosed by the team physician with a mild hamstring strain. She presented with point tenderness at the mid-belly of the biceps femoris with decreased range of motion at the knee and hip. She was restricted and limited by pain for several weeks to perform at practice and weight lifting. She was placed on a hamstring strengthening rehabilitation program with the team's athletic trainer. One athlete presented with pain-free range of motion, equal strength when compared bilaterally and the ability to perform functionally, she was cleared by physician to resume full practice. The athlete was monitored and competed throughout the indoor and outdoor track season without any recurrence of hamstring injuries.

The athlete's previous history of the hamstring injury in high school was discovered to have not been rehabilitated properly – as the injury occurred at the state meet, the last competition of the season. She allowed the hamstring to heal during the summer but did not strengthen or functionally rehabilitate the muscles due to the unavailability of a health professional. She was found to have bilateral hamstring weakness (R=0.73;L=0.67) through pre-season testing with the Primus.

Case 2: 12-531-31

A 21 year old female mid-distance (400m/800m) runner with no previous history of hamstring injury sustained a hamstring injury during this study. The athlete claims she did not perform the dynamic warm up properly and felt previous soreness in the hamstring before the practice began. The athlete performed repetitions on the track while ignoring the sharp pain in her hamstring and completed the workout. The athlete cooled down and was limping due to pain and stiffness in the hamstring. She walked to the athletic training room and was diagnosed with a mild hamstring strain by the team physician due to point tenderness. The athlete had full range of motion at the knee and hip with slight weakness with knee resistance. The athlete was limited based on her tolerance of the hamstring soreness and when the team athletic trainer assessed fully functional hamstring strength and capabilities, the athlete returned to play. She did not miss a practice and was placed on a rehabilitation program for strengthening and functionality for two weeks. The athlete was monitored for the duration of the indoor and outdoor season without recurrence of injury. The data collection showed the proper strength ratio in bilateral hamstrings (R=1.03;L=1.34).

Case 3: 12-351-33

A 20 year old male sprinter/jumper (100m/200m/long jump) with previous history of hamstring injury sustained a hamstring injury during competition in the indoor season. He was running a 60m sprint when at 40m he felt sharp pain and did not complete the race. He limped back to his gear and was immediately placed on ice after assessment of the hamstring. Upon assessment, pain with range of motion at the knee and hip and point tenderness at the insertion of the semitendinosus was found. The athlete was diagnosed later by MRI from team orthopedic surgeons with a moderate hamstring strain with the insertion site being compromised. He wasn't able to compete the duration of the indoor track season and the outdoor season due to lingering pain and weakness. The athlete was placed on a treatment and rehabilitation plan based on pain for the duration of the track season. The data collection showed bilateral functional ratio deficit (R=.61;L=.54).

Chapter V

Discussion

Throughout the literature hamstring injuries and the reasons for their causes has continually been a needle in a haystack scenario. In Croisier (2004) review article *Factors Associated with Recurrent Hamstring Injuries*, he goes over several extrinsic and intrinsic factors that could cause hamstring injury including: warm-up, fatigue, fitness level and training modalities, eccentric deficits, flexibility, age-related factors, joint dysfunction and hormonal status. The functional ratio is only one part of a large issue.

The results of this study only encourage more research regarding functional ratio deficits. It is shown in this study (Figure 1 and 2) that subjects with a previous history of hamstring strains had a moderate correlation to a functional ratio deficit with the left leg at 80% injury frequency and the right leg at 60% injury frequency. In Croisier J. , Ganteaume, Binet, Genty, & Ferret's (2008) study, they found similar results with the soccer players discovering that the rate was significantly ($p<.05$) increased and reached 16.5% injury frequency when the imbalance was untreated. Even those soccer athletes in the same study who didn't have a deficit showed an injury frequency of 4.1%. However, in the current study, there was low correlation between the functional ratio deficit and hamstring injury with both the left and right leg at 67% as seen in Figure 3 and 4. Again in Croisier et al (2008), athletes who found a functional ratio deficit who had a conditioning program without verifying isokinetic normalization did not lead to significant reduction in injury frequency at 11%. Keeping in mind during this current study the athletes were performing weight lifting two times a week and training six times a week for the preseason.

Fifteen subjects completed pretest isokinetic testing and were monitored throughout the indoor and outdoor track season. Three of the athletes were diagnosed with hamstring injury by the team physician. Six other athletes had subsequent hamstring complaints such as tightness, soreness and mild point tenderness. These athletes were treated by the team's athletic trainer throughout the indoor and outdoor track season but did not consult the team physician (Table 4). 67% of these athletes had a previous history of hamstring injuries with the majority of them having a functional deficit in one or both left and right leg.

Subject with Hamstring Complaints

Table 4

Subjects with Hamstring Complaints

ID #	Pre-test Ratio Right Leg	Left Leg	P.H.I	**I**
25	0.98	0.69	1	0
26	**0.96**	**0.74**	**2**	**0**
27	**0.62**	**0.59**	**1**	**0**
28	**1.75**	**0.96**	**0**	**0**
29	0.73	0.67	1	1
31	1.03	1.34	0	1
32	0.77	0.54	1	0
33	0.61	0.54	1	1
34	0.94	0.76	0	0
35	**0.81**	**0.80**	**0**	**0**
37	**0.51**	**0.50**	**2**	**0**
38	**0.66**	**0.64**	**2**	**0**
39	1.00	0.92	1	0
40	1.47	1.09	1	0
41	1.03	3.27	0	0
Mean	0.92	0.94		
SD	0.33	0.68		

Note: P.H.I. = Previous hamstring injury
I = Current Injury.

Ultimately, the results of our study were limited due to the population size, but there are still lessons to be learned from the data. Fifteen subjects were used; several of those subjects showed signs of deficit determined by the isokinetic measurement criteria developed by Croisier J.-L. , Forthomme, Namurois, Vanderthommen, & Crielaard (2002). The criteria is explicit and includes: 15 % bilateral differences when each limb was compared bilaterally, a concentric ratio less than 0.47 and a mixed ratio less than 0.80. These critiera are clearly stated in this research, however the diagnosis of hamstring injury throughout the literature review was not consistent. In this current study, a hamstring injury was diagnosed by a medical physician using several factors including: a clear history of how the injury occurred, pain upon palpation of select areas affected on the muscle, pain with manual resistance of knee flexion and/or hip extension, and if any deviations were present. Only one of the participants received an MRI, and that test showed injury to the insertion of the hamsting muscle after several weeks of rehabiliation and treatment. In Croisier, Ganteaume, Binet, Genty, & Ferret (2008) study, the authors found an "inconsistent manner in which injury is defined may represent a confounding factor" (p. 1474). They recommend that the assessment of injury should be based on the amount of time an athlete is out of competition and practice times (Croisier J.-L. , Ganteaume, Binet, Genty, & Ferret, 2008). In the Croisier et al. (2008) study, the researchers list the inclusion criteria for a hamstring injury being: physical examination showing pain on palpation, passive stretch, and active contraction of the involved muscle, diagnosis supported by ultrasonography or magnietic resonance imaging and a period of 4 weeks of missed playing time for the involved player (p. 1472). Bennell, et al. (1998) found if an injury was severe enough to cause the player to miss an official match, it was also a diagnosis of the hamstring strain. They also included:1) sudden onset of pain in the hamstring muscle, 2) pain with contraction of the muscle and stretching and 3) tenderness during palpation. Bennell, et al. (1998) highly encouraged ultrasound examination for confirmation of the injury. In the Croisier J.-L. , Forthomme, Namurois, Vanderthommen, & Crielaard (2002) study on *Hamstring Muscle Strain Recurrence and Strength Performance Disorders*, they presented 26 male athletes with prolonged hamstring pain syndrome injuries confirmed by ultrasound examination. For subsequent studies for our research team, one recommendation is to find a consistent hamstring injury definition. The most complete is described by Croisier et al (2008) *Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players* with the addition of an magnetic resonance imaging to confirm diagnosis.

Only three of the 15 subjects in the study sustained a hamstring injury diagnosed by the team physician. Future studies by research groups will not be limited to track and field athleties. It is proposed that multiple varsity sports involving sprinting at the university including: men's and women's soccer, baseball, softball, track and field and football. The multiple disciplines will be mulifacted and novel because there is no known study in the literature looking at funcational hamstring to quadriceps ratio and hamstring injury rate. One difficulty could be a decreased compliance from participants. To solve this issue, each athletic trainer or physicial therapist can choose to correct the H:Q ratio imbalance or not, this same practice is seen in Croisier et al (2008) study involving professional soccer players on several different soccer teams. It would be highly encouraged to correct the H:Q ratio imbalance by altering the athletes training until normalization of the functional ratio is gained. Croisier et al (2008) found this to be the best practice for the prevention of hamstring injuries with this group of participants.

Dominant and non-dominant legs are discussed in several studies to discover if the dominant leg or non-dominant leg had a higher risk of hamstring injury than its contralateral side. Bennell, et al. (1998) found no significant ($p > 0.05$) differences between the legs when looking at the Australian Rules football athletes (p. 311). Holcomb W. R., Rubley, Lee, & Guadagnoli (2007) found differences with women soccer players; "comparison of dominant and nondominant legs revealed a significant main effect (p = 0.013), with mean being 0.94 +/-0.06 and 1.11 +/- 0.09 for the dominant and nondominant legs, respectively (p. 44). Each article defined the dominant leg by the "kicking leg". Due to the variety of participants and sports that could be tested, the dominant leg could be determined by what foot catches their body when leaning forward in a standing position. In future studies, the researchers would be looking for a relationship between the injury and the dominant or non-dominant limb.

Chapter VI

Summary, Conclusions and Recommendations

Summary

Competitive athletes are observed executing explosive and powerful movements during sprint, hurdle, pole-vault, multi events and mid-distance events in track and field. The sprint and hurdle specialty events sustained 21% of the track and field hamstring injuries in the 2010 season at this university. Each athlete missed practice times and competition events. The intent of the research study was to discover whether a relationship could be found between previous hamstring injury and the functional hamstring to quadriceps ratio deficits. We were also looking to interpret an increased hamstring injury frequency during the season with those athletes would had a functional ratio deficit.

After receiving permission from the university's Human Research Protections Office, one hundred athletes were asked to participate. The criteria to be eligible for the study required a physical examination from the university's sports clinic, a previous history of hamstring injury but not within twelve weeks and no current lower body injury. Fifteen athletes volunteered after signing an informed consent and each participated in the pre-isokinetic testing procedures. Each athlete was then monitored throughout the track and field indoor and outdoor season of 2012-2013 for any subsequent hamstring injuries.

A Pearson correlation was used for the relationships between the pretest left (Figure 1; $r = .47$) and right (Figure 2; $r = .46$) legs and previous hamstring injuries finding a moderate relationship. Another Pearson correlation was performed showing low correlation between pretest left (Figure 3; $r = .07$) and right leg (Figure 4; $r = .21$) and hamstring injuries that occurred during the study. It was discovered that athletes with a previous history of hamstring injuries had a functional ratio deficit on the left leg (80%) and right leg (60%). And the 67% of athletes who were not diagnosed with a hamstring injury but complained of other aliments in the hamstring i.e. muscle tightness, soreness and mild point tenderness without losing time of play had a previous history of hamstring injury with the majority of legs having a functional deficit in either left or right legs.

It was concluded that athletes with a previous hamstring injury have an increased chance of a functional ratio deficit than their counterparts who have not sustained a hamstring injury. Those athletes complaining of other hamstring aliments should be regarded and their previous history taken because they could become diagnosed with recurrent hamstring injuries in the future. Further research needs to be performed with this population to help assist in the assessment and prevention in further hamstring injuries.

Conclusions

1. There was a moderate correlation between previous history of hamstring injury and a functional ratio deficit.
2. There was a low correlation between previous history of hamstring injury and sustaining current hamstring injuries during the season
3. Athletes with previous history of hamstring injuries had functional ratio deficits on the left leg (80%) and the right leg (60%).
4. Athletes with an in-season hamstring injury had a functional ratio deficit on the left leg (67%) and right leg (67%).

Recommendations

Based on the results of this study, the following recommendations are suggested in further research:

1. Repeat this study with a larger population due to the high variability of (n=).
2. Repeat this investigation by including an exercise protocol to correct the functional ratio deficits and taking a posttest to discover any hamstring injury frequency changes with integration of exercise.

Appendix A

Starting Point 1: 90 Degrees of Knee Flexion

Starting Point 2: 170 Degrees of Knee Extension

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