Hamstring Strength Measurements in Collegiate Athletes With a History of Hamstring Injury

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ABSTRACT
Eccentric hamstring strength and 2 types of hamstring to quadriceps ratios (conventional, functional) at 2 velocities were examined for 42 athletes with a history of hamstring injury. The authors used the Biodex System 3 for eccentric/concentric knee flexion and extension at 1.05 and 3.14 rad·s⁻¹ and knee flexion endurance of 30 reps at 3.14 rad·s⁻¹. The authors assessed the differences between side (injured or uninjured) and division (Division I or III) for the peak torque per body weight and ratio variables and included repetitions (1-5 and 26-30) for the endurance measurement. The authors found division differences for peak torque per body weight at 1.05 rad·s⁻¹ (Division I was higher) and for division for functional hamstring to quadriceps ratios (Division III was higher at 3.14 rad·s⁻¹ only) and repetition changes (repetitions 1-5 were higher than repetitions 26-30) for total work. The injured side is comparable with the uninjured side when examining values at approximately 9 months from injury; however, differences should be examined immediately on return to play.

Hamstring injuries are one of the most commonly occurring injuries in sports participation.¹⁻⁷ The National Collegiate Athletic Association Injury Surveillance System (2000-2001 through 2003-2004) reported that lower extremity muscle strains were one of the leading athletic-related injuries.² In addition, incidence of hamstring injury was second to knee injuries in a 10-year study of all National Football League training camps³ and accounted for 12% to 47% of all injuries sustained during a season from major league soccer teams to Gaelic football players.¹⁻⁵,⁸ The frequency of hamstring injury is further compounded by the fact that individuals who incur a hamstring strain have a reinjury rate as high as 34%,¹ and many of these injuries occur within 1 year of return to play. The most common mechanisms of injury involve eccentric contraction of the hamstring muscle group during the latter part of the swing phase of gait or running in which the hamstring muscles reach their maximal length.⁹,¹⁰ Previous studies have identified multifactorial risks associated with hamstring injuries. These factors include muscle attachment site and anatomy of the muscle,¹⁶⁻¹⁸ history of injury,¹²,¹⁴,¹⁵ age,¹⁹,²⁰ flexibility,²¹⁻²⁴ fatigue,²³ poor lumbar and core strength,²⁵⁻²⁷ insufficient warm-up,²⁸⁻³¹ muscle imbalance,¹³,¹⁶,³² hamstring and quadriceps strength comparisons,¹⁰,³³,³⁴ scar tissue,¹,³⁵⁻³⁸ and overall strength weakness.⁶,²¹,²²,²³,³³,³⁹⁻⁴²

Although there are many risk factors associated with individuals predisposed to hamstring injury, eccentric hamstring strength deficits appear to be one of the leading factors related to recurrent hamstring injury.¹⁰,¹⁵,³⁹,⁴³ Many hamstring rehabilitation protocols include eccentric strength components; however, return-to-play criteria often do not include specific assessment of eccentric strength. This may be due to the availability of equipment or because functional or sports-specific tests that target eccentric strength are limited and not used.¹²,⁴⁴,⁴⁵ There also may be differ-
ences in eccentric strength deficits based on the level of competition; however, this comparison has not been addressed within collegiate athletics. Eccentric strength comparisons between hamstring and quadriceps muscle strength are depicted as hamstring-to-quadriceps ratios (H:Q) and have been shown as a strength factor that contributes to injury.21,33,46 In addition, bilateral deficits between H:Q ratios exceeding 10% are linked to a predisposition to injury.33 Often, various types of H:Q ratios (conventional and functional) at various speeds and calculations have been used to determine the imbalance34,46-48; however, there is little information related to the ratios following return to play.

The purpose of this study was to investigate eccentric hamstring strength peak torque, total work, and H:Q ratios for collegiate athletes at Division I and III schools with a history of unilateral hamstring injury. We hypothesized that the previously injured hamstring limb would present with deficits, depending on the measurement calculated.

METHODS

The participants included a convenience sample of 42 collegiate athletes from Division I and III schools (mean age, 20.64±1.51 years; mean height, 175.93±10.94 cm; mean mass, 81.77±18.33 kg) with a previous hamstring injury (occurring in the past 24 months) (Tables 1 and 2). Each participant was currently active with a collegiate athletic team. Individuals were included if they met the following conditions: a history of unilateral grade I or II hamstring strain within the past 24 months, completion of some type of rehabilitation process following initial injury, and cleared for athletic participation at the time of the study. Participants were excluded for any documented history of bilateral hamstring strain, grade III hamstring strain, and anterior cruciate ligament surgery within the past year. This study was approved by the university’s institutional review board, and all participants gave their informed consent prior to data collection.

Participants were instructed to refrain from physical activity 24 hours prior to the study and from eccentric strength training 1 week prior to testing. Participants reported to either the university athletic training clinic or rehabilitation clinic for a single test session. The Biodex System 3 (Biodex Medical System, Inc, Shirley, New York) was used to complete a total composite of tests: (1) seated knee flexion eccentric/concentric at 1.05 rad·s⁻¹ (60° per sec) and 3.14 rad·s⁻¹ (180° per sec); (2) seated knee extension eccentric/concentric at 1.05 and 3.14 rad·s⁻¹; and (3) seated knee flexion endurance measurement of 30 repetitions at 3.14 rad·s⁻¹. Calculated values were determined for the measures of conventional H:Q ratios, which consisted of concentric comparisons (concentric hamstring peak torque per body weight ÷ concentric quadriceps peak torque per body weight), whereas functional H:Q ratios consisted of eccentric hamstring and concentric quadriceps comparisons (eccentric hamstring peak torque per body weight ÷ concentric quadriceps peak torque per body weight). Measurements were preceded by a warm-up consisting of pedaling on a bike at preferred speed for 5 minutes. All participants performed 1 submaximal and 1 maximal contraction for familiarization prior to data collection. Three maximal test contractions were performed at 1.05 rad·s⁻¹, followed by 3 maximal contractions at 3.14 rad·s⁻¹. Manufacturer’s guidelines for test setup were followed, and standardized directions and uniform encouragement prompts were given throughout the test session. We counterbalanced the order of testing for limb (injured and uninjured) and contraction (flexion and extension), and the session was concluded with the total work measurement.

Separate repeated measures analysis of variance (ANOVA) were conducted for side (injured or uninjured) by division (Division I or III) for peak torque per body weight and H:Q ratios at 1.05 and 3.14 rad·s⁻¹. A 2X2X2 repeated measures ANOVA was used for endurance comparisons between side (injured and un-

| TABLE 1: Participant Sport Demographics (N = 42) |
|-----------------|-----------------|
| SPORT           | NO. OF PARTICIPANTS |
| Baseball        | 6               |
| Field hockey    | 8               |
| Football        | 11              |
| Lacrosse        | 1               |
| Rowing          | 1               |
| Sailing         | 1               |
| Soccer          | 8               |
| Tennis          | 1               |
| Track           | 4               |
| Wrestling       | 1               |

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injured), repetition (1-5 or 26-30), and division (Division I or III). We assessed the relationships between time since injury and the various strength measures with a Pearson correlation coefficient. Significance was set a priori at $P < .05$. Results were imported into SPSS 16.0 for Windows (SPSS, Inc, Chicago, Illinois) for statistical analysis.

RESULTS

Peak Torque per Body Weight and H:Q Ratios

There was a main effect for division ($F_{1,40} = 4.38, P = .043$) (Division I, 1.67±0.006 standard error; Division III, 1.46±0.01 standard error), but there were no main effects for side ($F_{1,40} = .70, P = .41$) or interactions between side and division ($F_{1,40} = 1.48, P = .23$) for peak torque per body weight eccentric hamstring strength at 1.05 rad·s$^{-1}$. There were no significant main effects for side ($F_{1,40} = .66, P = .430$) or division ($F_{1,40} = 2.22, P = .141$) or for interactions between side and division ($F_{1,40} = .04, P = .852$) for peak torque per body weight eccentric hamstring strength at 3.14 rad·s$^{-1}$ (Table 3).

There were no main effects for side ($F_{1,40} = 1.26, P = .269$) or division ($F_{1,40} = .95, P = .335$), and there were no interactions for side by Division ($F_{1,40} = .56, P = .459$) for conventional H:Q at 1.05 rad·s$^{-1}$. There were no main effects for side ($F_{1,40} = .000, P = .993$) or division ($F_{1,40} = 1.46, P = .234$), and there were no interactions for side by division ($F_{1,40} = .503, P = .954$) for conventional H:Q at 3.14 rad·s$^{-1}$. There were no main effects for side ($F_{1,40} = .014, P = .906$) or division ($F_{1,40} = 1.18, P = .297$), and no interactions for side by division ($F_{1,40} = .217, P = .644$) for functional H:Q at 1.05 rad·s$^{-1}$. There were no main effects for side ($F_{1,40} = .145, P = .705$), however, there were differences for division ($F_{1,40} = 1.26, P = .037$), with Division III having greater values for functional H:Q at 3.14 rad·s$^{-1}$ (Table 3). There were no correlations between time since injury (months) and strength measures (range, −0.088 to 0.248).

Endurance

There were no main effects for side ($F_{1,40} = 2.41, P = .130$) or division ($F_{1,40} = 1.14, P = .291$); however, there was a main effect for repetition ($F_{1,40} = 64.71, P = .001$),
with 1-5 repetitions having greater total work than 26-30 repetitions. There were no interactions between side by division by repetition ($F_{1,40} = .46$, $P = .503$) for 3.14 rad·s$^{-1}$ (Table 4).

**DISCUSSION**

The relative high frequency of hamstring reinjury prompted our investigation related to isokinetic dynamometry assessment of strength components in active individuals with a history of previous hamstring injury. Our findings have demonstrated that there are no differences in select hamstring strength measures when comparing the injured extremity to the healthy contralateral side following clearance to participate in full activity, but there are some differences when comparing athletic division. We hypothesized that there would be deficits in eccentric hamstring peak torque per body weight and ratios on the injured side versus the uninjured side at 1.05 and 3.14 rad·s$^{-1}$; however, we found no significant differences at either velocity, but did see division differences for peak torque per body weight at 1.05 rad·s$^{-1}$ and at functional H:Q ratios. Worrell et al.$^{22}$ was one of the few studies that examined individuals ($N = 16$) with like characteristics (previous injury) and found no differences in eccentric peak torque per body weight at 1.05 rad·s$^{-1}$ and at functional H:Q ratios. Worrell et al.$^{22}$ was one of the few studies that examined individuals ($N = 16$) with like characteristics (previous injury) and found no differences in eccentric peak torque per body weight at 1.05 rad·s$^{-1}$ and at functional H:Q ratios.

We were able to investigate additional information about our sample by examining divisional differences and eccentric endurance of the hamstrings and factors related to time since injury. The divisional differences revealed a difference between Division I and III for peak torque per body weight at a lower speed, indicating that comparisons of isokinetic strength should be examined within similar participant characteristics. The differences in functional H:Q ratios between divisions should also prompt clinicians to examine the values that are computed for these ratios. Functional H:Q ratios are determined by hamstring eccentrics and quadriceps concentrics; therefore, the weakness could be evident due to isolated values. Division I athletes demonstrated 40% lower functional H:Q ratios at 3.14 rad·s$^{-1}$ than did Division III athletes, and this was due to lower quadriceps concentric values. Eccentric values were similar at this velocity; therefore, clinicians should examine these ratios closely when applying them.

We also theorized that there would be a significant decrease in eccentric hamstring total work on the injured side versus the uninjured side at 3.14 rad·s$^{-1}$ for 30 repetitions based on previous studies$^{49-53}$ reporting the effect fatigue has on hamstring injury. These studies have identified that hamstring injuries commonly occur during the latter stages of competitions and practices. We were interested in identifying the ability of injured hamstrings to produce equal force comparable to uninjured hamstrings over a period of continuous repetitions. The majority of previous studies that used an endurance protocol for the hamstrings and quadriceps examined concentric activity at 3.14 rad·s$^{-1}$ and used a variety of repetitions, ranging from 25 to 50.$^{52-56}$ In addition, individuals with hamstring injuries were not examined.

Sauret et al.$^{57}$ examined eccentric hamstring endurance over 50 repetitions (1.56 rad·s$^{-1}$) in a reliability study and found that individuals had decreased total work ranging from 29% to 40%. Our sample population also decreased in total work over the course of the repetitions (16% to 28.2%), but there were was only a small difference between sides (a 3.5% to 5.2% decline). Little is known about the eccentric endurance of the hamstrings over various repetitions within a
previously injured population, and it would be of interest to examine additional protocols with increased repetitions throughout various speeds to determine whether this measure of strength provides clinicians with needed information.

We examined our athletes within a 2-year window from the initial injury episode, with returning to play as criteria for inclusion. As is known, muscle has 3 basic physiologic stages of healing. During the first stage, which lasts approximately 5 days, the immune system is stimulated, the body fights off infection, damaged tissue is removed, and disorganized production of fibroblasts (scar tissue) occurs. During the second stage, which can last from 4 weeks to several months, cells, proliferate to replace damaged muscle cells and physical activity organizes and eliminates unnecessary scar tissue. The last stage of muscle healing can occur beginning at 6 months. During this time, repaired tissue remolds itself and tissue is restored to its previous preinjury state.

Based on this information, most of our participants were within the remodeling phase (8.6±6.4 months from injury), but some of them were most likely within the second stage of the healing process (4 weeks to several months following injury). Correlational analysis of time since injury and strength measures were not demonstrated; however, our sample was chosen with a wide range of months since injury (up to 24 months) and this may not be the ideal time frame to conduct examinations. Most athletes return to play within several weeks of initial injury depending on the severity, and reinjury is highest within 1 year of return to play, specifically within the first month of return to play. These facts and our findings suggest that examination of strength factors may need to be examined at a closer interval to return to play.

LIMITATIONS
Each athlete underwent a rehabilitation protocol by a health care provider not under direct supervision of the study; therefore, additional information that could have been useful for analysis purposes (length of time from rehabilitation to return to play, type of rehabilitation specific to lower extremity strengthening) was not available. This missing information could provide additional knowledge beneficial for clinicians to use for determination of return-to-play criteria. The length of time since the injury and date of testing also varied from 1 to 24 months. The additional time of healing that some athletes had may have played a role in their strength gain over time; therefore, assessment of individuals at return to play must be completed.

CONCLUSIONS
We found no strength differences between injured and uninjured side for peak torque per body weight, total work, and both H:Qs when examining speeds of 1.05 and 3.14 rad·s⁻¹; however, some differences were found when examining division. We believe that strength measurements should be taken immediately at return to play to determine eccentric deficits due to the fact that most hamstring muscle groups are reinjured within a smaller window following return-to-play. It is evident that we need evidence of hamstring eccentric strength and endurance markers through the time course of recovery for injured athletes to understand more about the factors associated with the high recurrence rate. Further research should be conducted to determine whether the total work measures can provide additional information about the function of the hamstrings following continuous isolated activity. Further research may also need to be conducted to identify functional tests that can be used on return to play that are reliable and valid at determining hamstring strength deficits.

IMPLICATIONS FOR CLINICAL PRACTICE
Hamstring injuries are commonplace within clinical practice; therefore, it is necessary to understand as much as possible about the condition to make effective return-to-play decisions for an athletic population. Variations within divisional setting exist and should be considered when making these decisions, with particular attention given to type of contraction within ratio calculations. Although overall values for hamstring strength should be considered, one should contemplate the threshold needed for a limb symmetry index for hamstring injured individuals because the reinjury rate is highest within the first month of returning to play.

REFERENCES


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