

Hamstring to quadriceps strength ratio and noncontact leg injuries: A prospective study during one season

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Abstract. Previous studies have proposed that thigh muscle imbalance is a critical risk factor for the athletic non-contact knee injuries. However, there is a little consensus among prospective studies with regard to the correlation between isokinetic hamstring to quadriceps strength ratio (HQR) and the non-contact knee injury rates. Most of athletic movements at risk are closed kinetic chain movements, and compensatory effect among ankle, knee, and hip joints during the closed kinetic chain movement was observed in the previous literatures. Therefore, it is assumed that hamstrings and quadriceps (H:Q) imbalance can cause non-contact lower extremity injuries without necessarily causing knee injuries. The purpose of this study was to prospectively investigate the relationship between H:Q strength imbalance and overall non-contact lower extremity injuries. A prospective cohort study was conducted on NCAA division III basketball and soccer players during one season. A total of eighty two NCAA Division III athletes (41 female [19.56 ± 1.34 yrs, 68.2 ± 10.84 kg, 166.3 ± 6.78 cm] and 40 male [19.97 ± 1.43 yrs, 75.45 ± 8.23 kg, 173.21 ± 7.65 cm]) volunteered to participate in this study which tested Q and H strength at 60°/s. A trend ($p < 0.05$) indicating that lower than 60% of HQR was associated with non-contact leg injuries was apparent. This suggests that the H:Q imbalance may be of significance in athletic non-contact leg injuries.

Keywords: Kinetic integration, isokinetic strength, neuromuscular, co-contraction, plyometrics, prophylactic

1. Introduction

Co-contraction of agonist and antagonist muscles is important for joint stabilization during the dynamic movement [8,15,24]. Researchers have consistently proposed that balance of these opposing muscles is imperative in maintaining ideal joint position, therefore it is a critical factor for avoiding injuries during the athletic movements such as jumping, pivoting, and cross-cutting [5,8,28].

The National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) has collected injury data from various sport activities over a 16-year time period (1988 through 2004). According to

its report, more than 50% of all injuries were to the lower extremity and most of them were non-contact injuries [17]. Researchers in clinical and exercise sciences field have focused on developing prevention strategies of these injuries in an effort to reduce injury rates and related medical costs over time [10,12,13,22].

One of the most important goals of currently used prophylactic training programs is to enhance neuromuscular balance of hamstring and quadriceps muscles [14,16,23]. While researchers have reported that preventative conditioning program such as plyometrics and balance exercises not only decreased knee injury rates but also improved balance of hamstring and quadriceps [12–14], surprisingly, there is little consensus with regard to whether strength ratio of hamstring to quadriceps (H:Q) can be used as a predictor of non-contact knee or surrounding tissue injuries [2,9,22].

One explanation of the unclear correlation between H:Q strength ratio (HQR) and injuries is that imbalance

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of strength between hamstrings and quadriceps have been retrospectively associated with the injuries in most of the previous literatures [6,30]. These retrospective studies compared HQR of normal and deficient legs [6, 19,20], however, it is unclear if any of the strength imbalance were present before the injury. Therefore, it was suggested that thoroughly designed prospective investigations could clarify the association between HQR and injuries in knee and surrounding tissues [30].

Currently, few prospective studies are available, but these studies also reported contradicting results [2,9, 27]. While the role of HQR playing in knee and surrounding tissue injuries remain as an enigma, we cannot ignore the current emphasis of prophylactic approach on improving H:Q strength balance. Previous studies on HQR and susceptibility to injuries have focused on examining only the knee related injuries. However, trying to find the direct relationship between a risk factor and the injuries at corresponding anatomical region may not be the feasible method because non-contact athletic leg injuries are multi-factorial. Although hamstring and quadriceps muscles are directly related to knee joint stabilization, H:Q strength imbalance may not necessarily cause knee injuries. Most of the non-contact athletic lower extremity injuries happen during the closed kinetic movement such as running, landing from jumping, pivoting, or cross-cutting. It is well known that forces acting upon one joint inevitably affect forces exerting on other linked joints during the closed kinetic movement [31]. Van Ryssegem discussed that instability at the knee joint can cause dysfunction at ankle, hip, and eventually upper body joints through the kinetic chain because the person would use compensatory movement strategies in order to avoid pain and injuries [29].

In this context, it is inferred that even if an athlete with low HQR can successfully avoid knee injury, the strength imbalance still has a considerable potential to impose undesirable stress on ankle or hip joint, which can cause non-contact lower extremity injuries. Therefore, the purpose of this study was to investigate the relationship between H:Q strength imbalance with overall non-contact lower extremity injuries. It was our hypothesis that lower HQR would have an effect on lower leg injuries of Division III male and female basketball and soccer players.

2. Method

2.1. Participants

Men and women intercollegiate basketball and soccer players were recruited as the participants of the

Table 1
Subject's demographics

	Male	Female
Number of participants	40	42
Age (yrs)	19.97 ± 1.55	19.56 ± 1.34
Height (cm)	178.21 ± 8.42	169.3 ± 6.78
Weight (kg)	75.45 ± 8.2	68.2 ± 10.84

study because lower extremity injuries accounted for approximately one quarter of all injuries in these sports [17]. In addition, basketball and soccer mainly involves movements which are at risk of non-contact leg injuries such as jumping, pivoting and cross-cutting. A total of eighty two NCAA Division III intercollegiate basketball and soccer players volunteered to participate in this study (Table 1). Before the commencement of the testing, all participants read and signed an informed consent form. This study was approved by the Institutional Review Board.

2.2. Procedure

A Biodex isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Shirley, NY) was used to assess Q and H strength. Tests were carried out at 60°/s [11] and along a range of motion of at 90°, using a knee common protocol (sitting, axes alignment, stabilization). Gravity correction was performed for each limb before testing. Once the participants seated and secured, they performed 3 repetitions of extension and flexion as a warm-up. A single set of 3 maximal exertions was performed bilaterally.

In this study, an injury was defined as such providing 1) it occurred as a result of participation in an organized practice and competition; 2) it prevented the injured athletes from participating in practices and competition at least for two weeks; and 3) it required the injured athletes seek medical attention from either athletic trainers or team doctors [26]. Among the total lower extremity injuries, we validated only the injuries which were non-contact in nature. Strain, sprain, and overuse injuries were included, and contusions were excluded for data analysis. We also collected the history of ligamentous injuries.

2.3. Statistical analysis

A statistical analysis was performed using SPSS 17 software (SPSS, Inc., Chicago, IL). The chi-square test was used to examine the likelihood ratio that legs with H:Q strength imbalance get injured. An HQR of 0.60 and above was defined as "balance", while an HQR

Table 2
Pre-season hamstring: Quadriceps (H: Q) ratio, in-season lower extremity injuries, and the pearson chi-square value

HQR		Lower extremity injuries		Asymp. Sig.	
Right	Left	Right	Left	Right	Left
55.65 ± 9.57	54.02 ± 8.79	35	32	0.058	0.046*

*Indicates significant dependence (Asymp. Sig. < 0.05).

Table 2 represents the pre-season mean values ± standard deviation (SD) for the hamstrings to quadriceps (H:Q) ratios, the number of lower extremity injuries occurred during the season, and the pearson chi-square value.

Table 3
HQR and injury cross tabulation

Criteria	Number of legs		Number of injuries		% within total IP ¹ injuries	
	Right	Left	Right	Left	Right	Left
HQR < 60%	52	55	29	28	63.4%	67.1%
HQR ≥ 60%	30	27	6	4	36.6%	32.9%

¹ IP = Ipsilateral.

Table 3 shows the distribution of H:Q strength ratio among total legs and injured legs.

below 0.60 was defined as “imbalance”. Pearson chi-square value below 0.05 indicates H:Q strength ratio and rate of lower extremity injuries are dependent.

3. Results

The mean (SD) of the HQ ratio of total 82 athletes were 0.55 ± 0.09 for the right leg and 0.54 ± 0.08 for the left leg. During season, there were a total of 35 non-contact lower extremity injuries on right legs and 32 on left leg (Table 2).

Out of 35 right leg injuries, 12 were game-related and 23 were practice-related. For the left leg, out of 32 injuries, the respective injuries were 8 and 24. The mean number of practices per season for men and women’s basketball team was 75.5, and the number of games played for both teams was 19. For the soccer players, the average number of practices was 47.5 and the average number of games played per season was 19.5. In recording the number of injury, if athletes had a history of injury on the same body parts, the injury was not included. The results of the analysis showed that 63.4% of the injured right legs and 67.1% of the injured left legs had an HQR of less than 0.6 (Table 3, Fig. 1). The difference in the number of left leg injuries between the athletes with an HQR < 0.6 and those with a ratio > 0.6 was statistically significant ($p = 0.046$). Although there was a notable difference in the number of right leg injuries between the athletes with less or more than 0.6, the p value didn’t reveal a significant difference ($p = 0.058$). However, the chi-square test demonstrated sig-

nificant likelihood ratio in the relationship between the number of right leg injuries and the right HQR ($p = 0.041$).

4. Discussion

The question addressed by the present study was whether the quadriceps and hamstrings isokinetic strength imbalance was associated with susceptibility to lower leg injuries. The main finding of the study is a trend according to which injured athletes had pre-season HQ ratio of less than 0.6 ($p < 0.05$). For the left leg injuries, the result revealed the statistically significant relationship between the lower pre-season HQ ratio (< 0.6) and the number of the lower leg injuries. For the right leg injuries, the result showed no statistically significant relationship but revealed statistically significant likelihood through the Chi Square test ($p = 0.03$). This noticeable difference between muscle imbalance and injuries is consistent with previous reports [2,9,11]. Considering that most of the injuries from the study were the knee joint injuries, a possible explanation for this demonstrable relationship may arise from the knee joint mechanism. It has been suggested that the role of the hamstring muscles during leg extension is to assist the anterior musculotendinous structures in preventing anterior tibial force, by pulling the knee joint posteriorly, increasing joint stiffness and reducing anterior laxity force during quadriceps loading [2].

In previous studies, the effects of muscle imbalance have been reported specifically regarding the suscep-

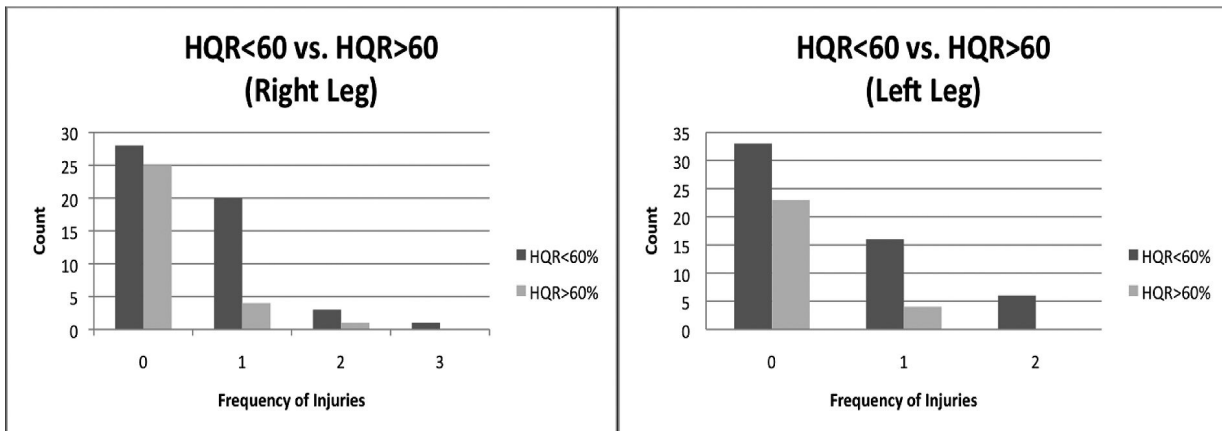


Fig. 1. Distribution of HQR within legs (preseason).

tibility of the knee injury; however, in this study, we included other lower limb injuries to elucidate possible connections between the thigh muscle imbalance and other common lower leg injuries among basketball and soccer players. The relationship between low HQR and overall lower leg injuries shown in our study may ascribe to bi-articulate nature of leg muscles and neuromuscular compensation among lower extremity joints in joint stabilization. Dontigny [3] suggested that the opposing force of hamstring muscles and psoas muscles act as a force couple in stabilizing a pelvis during the normal gait. Previous literature revealed that a combination of weak hamstring and strong anterior muscles could cause anterior pelvic tilt, which would demand muscles and soft tissues around hip and trunk to work harder in order to stabilize the lumbopelvic complex. This may explain the result of our study that more than a quarter of the total leg injuries were to the muscle and tendons around the hip and knee joints (Table 4). Stabilization of knee and protection of ligaments throughout the whole flexion angle require simultaneous contraction of quadriceps, hamstring, and gastrocnemius [25]. Nyland et al. suggested that increased ankle dorsiflexion and eversion moment is due to the compensatory movement of the ankle joint in order to decelerate the anterior translation and internal rotation of tibia during the closed kinetic flexion at the knee joint [24].

The trend describing the dependency between strength imbalance and the non-contact injury observed in our study suggests that intervention strategies of correcting strength imbalance are urgently required for the athletes who have participated in this study, because approximately 63% of the group demonstrated muscular imbalance. Previous literatures hinted that quadriceps-related strength imbalance was likely caused by ha-

bitual quadriceps dominant movement strategies [16, 18, 21]. Van Ryssegem emphasized that athletes must unlearn compensatory movement pattern and learn the proper movement technique as they train for strength of the musculature [29]. Therefore, correct movement training plays an important role in correcting strength imbalance and preventing athletic non-contact injuries. For example, traditional jump training suggested for preventing non-contact injuries should focus more on proper landing techniques than jumping height in order to unlearn quadriceps dominant movement strategies and learn to properly use hamstrings for knee joint stabilization during the landing.

4.1. Limitation and suggestion

The speed chosen for the isokinetic strength testing in the study was 60°/s. One limitation is not using other speeds for the isokinetic test. Another limitation relates to the strength ratio used in the present study. HQR in the study was only expressed in a conventional manner, which compares concentric quadriceps muscle actions to concentric hamstring muscle actions. Recently more functionally relevant protocol (known as Dynamic Control Ratio or Functional Ratio of HQ) been suggested as more common parameter in examining HQ imbalance [1, 4, 7]. Evaluation of this Dynamic Control Ratio, which eccentric hamstring muscle actions are compared to concentric quadriceps actions (Hecc:Qcon) could have provided more functionally relevant insights.

5. Clinical implication

To our knowledge, this is the first prospective study to demonstrate the relationship between H:Q strength

imbalance and overall non-contact lower extremity injury rates. The result of our study indicates that an HQR < 0.6 may be a risk factor for non-contact lower extremity injuries. In Division III setting, athletes rely on unsupervised self-conditioning until the official practice season begins. Considering the importance of HQR in preventing lower leg injuries the feasibility of correcting H:Q strength imbalance through unsupervised training is low. Therefore, thoroughly planned and supervised conditioning is necessary for division III athletes. NCAA division III athletes are occupying more than 40% of the total NCAA athletes [32]. Even though the rationale of limiting practice seasons in division III athletes is to protect their academic activities from excessive practices, it should not be ignored that radical limitation of supervised conditioning may lead to engagement in intense athletic activities with “untrained legs” which may cause more injuries.

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