Research Square

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Hamstring injury in futsal players: the effect of active range of motion (AROM) deficit on the full recovery time

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Abstract

Background

Hamstring muscle injuries are one of the most common traumas occurring in athletes and football players. Thus, the recovery time is crucial for their return to full athlete activity.

Objective

This article examines cases of hamstring injury in futsal players and finds association between the active range of motion (AROM) deficit and the full recovery time.

Methods

For this study, 200 futsal players with acute, first-time, unilateral posterior hamstring injuries were recruited, all men. All patients underwent clinical examination and ultrasonography. In 74 of 200 patients, sonography revealed no abnormalities in the musculoligamentary structures. Thereby, they were excluded from further investigation. Only 126 futsal players underwent measurement of the active range of motion with a 30-cm clear plastic inclinometer. Injured areas were compared with the normal hamstrings in all athletes and with the control group, and the AROM deficit was evaluated. The association between the full recovery time and the AROM deficit was identified. A control group (100 men) underwent examination in the same series of steps as the study group.

Results

Biceps femoris was the most commonly injured muscle, making up 80% of injuries. The musculotendinous junction, proximal and distal, was involved in 91% of injury cases. Twelve athletes had an AROM deficit of 25 to 35 degrees and reached full recovery at 2.5 months and later. Seventy or 55.5% of athletes had an AROM deficit less than 15 degrees and felt fully recovered only in a month.

Conclusions

The classification system of hamstring muscle injuries that is offered here is based on an objective clinical marker (active knee ROM deficit), is easily applicable, and is indicative of recovery duration.

Introduction

Skeletal muscles make up the largest tissue of a body, which composes almost the half of the total body weight (up to 40% according to McCall [1], Freckleton and Pizzari [2]). The specificity of active sports, in particular football, is an increased traumatic risk. From 25–50% of all sustained injuries comes for muscle injuries [3, 4, 5]. Most muscle injuries (90%) are bruises or stains and the remaining 10% are tears [6–8]. The most serious types of injuries can cause chronic post-traumatic pain, dysfunction of the ligaments, individual muscles or their groups. Almost all muscle injuries (95% according to Hallen and

Ekstrand [4]) can be divided in four groups: hamstring injury, adductor injury, quadriceps injury, and the calf muscle injury. Among the above groups, hamstring injuries are the most common, presenting a third of all cases. Overall, the number of hamstring injuries varies depending on the competition. In football, for example, their frequency is 52 per 1000 players per year [9].

The hamstrings consist of three muscles that can be found at the back of the thigh covering the hip and knee joints: Musculus semitendinosus, Musculus semimembranosus, and Musculus biceps femoris [10]. The semitendinosus muscle is located closer to the medial edge of the posterior femur. Musculus biceps femoris is situated along the lateral edge of the posterior thigh and consists of two parts, long head (caput longum) and short head (caput breve). The long head of biceps femoris has a common origin with semitendinosus as a proximal tendon from the ischial tuberosity. After an approximately 9-cm distance, this common tendon divides [11] and the Musculus semitendinosus becomes separated from the ischial tuberosity at a greater angle of inclination as compared to the biceps femoris. A recent study has shown that at this angle, the proximal part of the semitendinosus muscle is susceptible to injury [12]. Further, the semitendinosus muscle passes downwards, to a long tendon which follows a path around the medial epicondyle of the femur to the anteromedial surface of the tibia and attaches to a tibial tuberosity. At the attachment point, this tendon forms a pes anserinus superficialis with tendons of two other muscles, gracilis and sartorius. The semitendinosus muscle is frequently has a tendinous intersection in the middle and is approximately 44.3 cm in length [11]. Separated from the common tendon, the long head of the biceps femoris merges with the short head to form a strong belly, which runs down to a long narrow tendon. The latter goes posteriorly around the lateral epicondyle to the head of the fibula. The semimembranosus muscle is located at the medial edge of the posterior femur. It originates with a flat tendon on the ischial tuberosity that narrows, goes around the medial epicondyle, and inserts at the posteromedial aspect of the medial condyle of the tibia. Semimembranosus extends approximately 38.7 cm [11].

A hamstring muscle injury typically occurs during eccentric loading (stretching) when the contracting muscle fibers generate even more tension in the muscles. Considering the absorption of kinetic energy during the eccentric phase of muscle contraction as the main function of hamstrings, the posterior compartment of the thigh is susceptible to trauma from stress, especially in the region adjacent to MTJ (musculotendinous junction) [10, 13]. Recent studies have shown that hamstring injuries vary depending on the type of the training load. There are 2 types of injuries known, the high-speed running type [14] and the stretching type [15]. Hamstring injuries due to high-speed running is most frequent among football players, basketball players, tennis players or athletes engaged in similar sports (these are sports that require sprinting with sudden stops) and is closely associated with damage to the long head of the biceps femoris [14]. Hamstring injuries due to stretching occur at the extreme joint load (i.e., at hip flexion and at knee extension). Frequently, they involve more than one muscle but the most common combinations comprise the semimembranosus muscle and its free proximal tendon [15]. These types of injuries vary in prognosis regarding the time to full recovery, which is normally longer for injuries due to stretching [16]. Alongside the mechanism of injury, its exact location also affects the prognosis. Hamstring strains usually occur in the proximal parts of the muscle and are more problematic because they are located closer to their origin in the ischial tuberosity [16]. The involvement of the free proximal tendon is also associated with a longer recovery period [14].

As with other muscle injuries, hamstring strains are classified depending on a condition, which they cause [17] and which is associated directly with the degree of damage to the muscular-tendon node. In the clinical classification, three levels of severity are distinguished: mild (first degree), moderate (second degree) and severe (third degree) hamstring strains [17]. This classification system, however, is rather fuzzy and does not take into account the effect of an injury site on symptom duration and full recovery time. For instance, a small rapture in the proximal part of the biceps femoris can have more serious consequences than a severer injury located more distally [17]. Therefore, it is preferable to have a clinical classification system that is built around these factors too.

Imaging can provide detailed information about the nature and extent of damage to the hamstring muscles. Magnetic resonance imaging (MRI) and ultrasound are the common instrumental methods of choice [18, 19]. To evaluate the hamstring muscle damage based on imaging findings, the Peetrons classification [20] for ultrasound and its modification for MRI are used [21]. This classification defines four grades of muscle injury: grade 0 with no injury; grade I with a focal fiber rupture or edema, without architectural distortion (less than 5% of muscles injured); grade II with a partial focal fiber rupture, with/without fascial damage (5%, to 30% of muscles injured); and grade III with a focal fiber rupture to complete muscle rupture with retraction and fascial damage (more than 30% of muscles injured). Grades 0 to I correspond to a mild hamstring strains, grade II falls within the moderate level of severity, and grade III is associated with severe clinical cases.

Despite possible inaccuracies due to pain, the range of motion (ROM) variables can reveal a decrease in flexibility for the injured leg. An impairment in the back of the thigh is best defined by evaluating the passive and active ROM through a series of straight leg rise and knee extension tests. When the patient is lying supine, the strength of his hamstring muscles can be measured by means of a knee flexion test and a hip extension test. Testing both legs allows detecting a decrease in the strength of the injured leg but keep in mind that a ROM deficit may be implicated by the presence of pain, rather than damage to muscle fibers [16].

For this reason, a deep understanding of hamstring injury processes is required. A right treatment, a more detailed research and evidence on the most effective treatments may be useful in recovery prognosis and enable a full, effective and quick return to sport activities. This article examines cases of hamstring injury in futsal players and finds association between the active ROM deficit and the full recovery time.

Methods

Participants and acceptance criteria. A total of 200 male futsal players with first-time hamstring injuries were admitted into the study (age range, 18–23 years) between January 2010 and December 2016. Patients with the following injuries were excluded from the study: concomitant bilateral tension of hamstring (with chronic tendonitis); tearing of tendon fibers; severe hamstring injuries (tearing of one, two or three muscles, which form the hamstring); and previously registered cases of damage to muscles and tendons that could affect AROM findings.

In 74 of 200 patients, sonography revealed no abnormalities in the musculoligamentary structures (grade 0 according to Peetrons [20]). Thereby, only 126 futsal players were included in further research. The control group included 100 men of the same age who had never experienced hamstring muscle injury.

Research protocol was approved by the Ministry of Sport of the Russian Federation and all athletes signed an informed consent to participate in the study.

Clinical Assessment. All athletes underwent an examination by a sport medicine doctor. A traumatologist was only involved in the most severe cases. All athletes had the following symptoms of injury: (1) local pain on palpation, (2) pain with resisted movements (e.g. hip extension, knee flexion). Athletes were managed with the PRICE protocol (protect, rest, ice, compression, and elevation). Ice was applied for 15 minutes every hour for the first 6 hours after injury and initial evaluation, and then every 3 hours. The thigh was protected and compressed using a compressive elastic bandage and was kept elevated. No motion was allowed for the first 6 hours and isometric exercises were encouraged for all periarticular muscles of the hip and knee thereafter.

Clinical evaluation 2 days after the injury included the following: a) inspection for bruising, b) walking on level ground without pain, c) palpation of the hamstring muscle with the athletes prone and knees extended (for presence or absence of tenderness), d) provocation of pain on isometric hamstring contraction, e) provocation of pain on passive movements (hip flexion with the knee extended and athletes supine), and f) AROM measurement under the Askling protocol [14, 15]. These parameters are important for obtaining accurate data on injury severity and recovery time as well as a true prognosis for a specific injury.

Athletes enrolled in the study underwent clinical and ultrasound examinations. The study and control groups had the same AROM testing procedures for both legs, injured and uninjured.

Protocol processing. The athlete was supine with the hip and knee flexed to 90 degrees. The unaffected leg is placed flat on the couch with the knee fully extended, and maintained in this position throughout the test. The athlete is then instructed to actively extend the knee through the full available ROM until he experiences pain at the injured site and firm resistance is felt at the healthy side. Meanwhile the hip is maintained at 90° of flexion. The degree angle was measured by adouble-arm 30-cm clear plastic inclinometer. The inclinometer was aligned along the femur with the reference point at the greater trochanter of the femur. All measurements were made in triplicate by the same physician to exclude the personality factor. The results were averaged and used in further analysis. The full recovery time should be understood as an interval between the injury and a follow-up of physical characteristics showing a return to what was before the injury. The difference in ROM data between the injured and uninjured leg was expressed as an “AROM deficit.” The same measurements were performed for both knees in the control group.

Rehabilitation protocol. All injured athletes were supervised by experienced physiotherapists and traumatologists. The rehabilitation process was divided into 4 phases:

Traumatic or Acute Phase. Attempts of gait normalization, that includes using of strapping and/or crutches);

Rehabilitation or Strength Phase. Attempts of regaining pain-free ROM that includes starting of concentric training and progressing to eccentric training.

Functional Loads Phase. Applying of limited loading and return to full activities under supervision of a doctor or according to recommendations.

Full Recovery Phase. Athletes return to full sport activities, in this case – football.

Follow-up. The athletes were examined weekly in the clinic during the rehabilitation program. The clinical follow-up period lasted until the athlete returned to pain-free full sports activity. The athletes had additional remote monitoring by telephone. Telephone contacts with the athletes and their coaches were held at 3, 6, 12, 18 and 24 months after injury.

Statistical analysis. Pearson correlation was used to find correlation between a return to full athletic activity (4th phase) and clinical assessment (AROM findings). Statistical assessment was evaluated using the 1-way analysis of variance, the chisquare (x2) test and regression analysis. Significance (t-test) was set at $P < 0.05$. Statistical processing was performed with Past v. 3.0 program.

Results

Among 126 (63%) athletes with abnormalities on sonography, 101 or 80% had injuries to the biceps femoris muscle. MTJ, proximal or distal, was involved in 91% of injuries or in 115 athletes. None of the athletes had more than one injured muscle. Characteristics of muscle injuries in 126 athletes with abnormal ultrasound findings are presented in Table 1.

Table 1
Muscle Injury Characteristics in 126 Athletes with Abnormal Findings Documented by Ultrasound Imaging

Injured area, muscle and ligaments	Number of athletes (%)
Biceps femoris	80.0
Semimembranosus	11.0
Semitendinosus	13.0
Proximal or distal musculotendinous junction (MTJ)	91.0
Intramuscular tendon	40.1
Myofascial injury	9.8
Hematoma	17.8

Ultrasound scans revealed grade I injuries (according to Peetrons [20]) in almost half of the participants (62 or 49.2%), grade II injuries in 58 (46%) athletes, and grade III injuries in six (4.8%) athletes.

The mean AROM of the injured leg in the study group was 56.12 ± 6.9° (range, 11–90°; $P < 0.05$). For asymptomatic side, it was 68.9 ± 5.4° (range, 40–91°; $P < 0.05$). The mean AROM deficit in the study group was 12.8 ± 6.8 degrees. In the control group, the mean AROM indicated similarly to uninjured side of examined athletes, 67.9 ± 6.5 degrees at the range 42 to 93 degrees. There were no significant differences in the AROM values between the uninjured side and the control group ($p < 0.697$). However, there was a significant difference ($p < 0.001$) in the AROM deficit between the injured side and the controls.

The majority of athletes in the study group (70 or 55.5%) had an AROM deficit of less than 15 degrees and it took them three weeks to a month to fully recover. Forty-four athletes, or 35%, had an AROM deficit of 15 to 25 degrees and spent slightly more than a month recovering. Twelve of 126 athletes, or 9.5%, experienced an AROM deficit of 25 to 35 degrees, with the recovery time exceeding 2.5 months (Table 2). The average number of days lost from futsal training was 29 days ± 3.9 and ranged from seven up to 80 days. Hamstring strains were categorized into three grades based on the AROM deficit: grade I – less than 15°; grade II – 16° to 25°; grade III – 26° to 35°.

Table 2
Classification of hamstring stains in 126 athletes

Clinical grade	AROM deficit	Recovery days	Number of athletes	%
I	less 15°	25.9	70	55.5
II	16° to 25°	30.7	44	35.0
III	26° to 35°	75.0	12	9.5

According to our classification, sixty-two athletes had grade I injuries and eight athletes had grade II injuries (with 6–8% of muscles involved, which is close to a grade I boundary value). Those 44 athletes with an AROM deficit ranging from 15 to 25 degrees had grade II injuries and six athletes with an AROM deficit of over 25 degrees had a grade III hamstring injuries.

Athletes with grade I and II had no hematoma on ultrasound returned to futsal training 3 weeks or a month after injury. Hematoma was present in athletes with grade III injuries. During follow-up, 15% of athletes experienced a hamstring strain reinjury. Thus, injury grade directly correlates with the high likelihood of reinjury.

Discussion

The study found a connection between the AROM deficit and the full recovery time. The larger AROM deficit, the longer the recovery time. With an AROM deficit of less than 15 degrees (grade 1 according to our classification), athletes fully recovered in 3–5 weeks. Athletes with an AROM deficit of 15 to 25 degrees recovered slightly longer than a month. The recovery time for an AROM deficit of over 25 degrees was 2 months or longer. In contrast to Askling clinical classification [17], hamstring injury categories here embraced mild (grades II and I) and moderate injuries (grade III), while severe cases were excluded due to association with a complete muscle rapture and difficult, less informative evaluation of AROM deficit. AROM deficit also correlated with the percentage of muscles involved in the injury. The hamstring injury classification by ultrasound findings [20] largely coincided with the AROM deficit based classification by contrast, with differences noted only in cases with the boundary percentage of muscles involved according to the ultrasound-based classification.

Evaluation of the muscle stain severity is important in rehabilitation planning and recovery prognosis. First, the study population included only futsal players of local level and thus not reflected the injury characteristics in different sporting populations. Second, the athlete's behavior was unknown and could be the subject of future research. The classification scheme proposed here was based on objective and reproducible clinical measurements that could be easily performed in the clinic. In addition, no specialized skills and special equipment are required.

Clinical and ultrasound examination were performed 48 hours after the injury to allow partial recovery of lower severity injuries. We thought that in the acute setting, immediately after the injury, significant pain and disability are present. For this reason, attempts to accurately determine the athlete's ROM on the injured side would be unreliable [16].

We found out that the predominant portion of athletes with hamstring injuries recovered their active ROM and returned to full activity in the span of 3 to 5 weeks. Rarely (1 in 10 cases), the recovery time exceeded 10 weeks. Athletes with the worst recovery prognosis can be identified early, as their ROM deficit is over 25 degrees.

Studies using MRI [8] or ultrasound scanning [15, 22] showed that the athletes with normal imaging had a significantly faster return to competition, but there was no correlation between the presence of hematoma and recovery [22].

Other authors, however, found that fluid or hemorrhagic collections, cross-sectional involvement more than 50%, and distal musculotendinous injury were associated with longer recovery time [23].

Sonography was chosen to obtain images of the injured muscles, since it is less expensive and more accessible than MRI. Imaging of injured muscles was performed to confirm the diagnosis and to identify complete muscle or tendon ruptures that would require surgery.

The predominance of biceps femoris injuries in the study group is consistent with other reports [1, 22, 24–27].

The incidence of semitendinosus and semimembranosus muscles in our study was 11% and 13% respectively. These indicators vary in different studies [2, 22, 24, 28–30], and this may reflect the difference in the injury patterns among different sports [31–33].

As several other studies, this study shows that injuries occur mainly at the proximal or distal musculotendinous junctions [31, 34–36].

Conclusion

This study detects the correlation between the ROM deficit and sonographic findings. Therefore, the recovery period was three weeks to a month in 55.5% athletes and slightly more than a month in 35% of athletes. The presence of hematoma was a marker of severe injury but was not a consistent finding in athletes with an AROM deficit greater than 25 degrees.

Research findings proved clinical evaluation alone an adequate tool in recovery prognosis. Perhaps, imaging is good for athletes with an excessive reduction in ROM, with a hematoma or complete rupture of the muscle suspected but routine imaging in the clinical practice is not justified. This study did not use the MRI method to detect grade I and II injuries and thus made our protocol more practical and cost-effective.

In conclusion, the proposed classification system of hamstring muscle injuries is based on an objective clinical criterion (active knee ROM deficit), is easily applicable and indicative of recovery duration for athletes.

Abbreviations

AROM
active range of motion
MTJ
musculotendinous junction
MRI
Magnetic resonance imaging
ROM
range of motion

Declarations

Ethics approval and consent to participate. Research protocol was approved by the Ministry of Sport of the Russian Federation and all athletes signed an informed consent to participate in the study.

Consent for publication. All athletes signed an informed consent to participate in the study.

Availability of data and materials. Data will be available on request.

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Competing interests. The authors declare that they have no competing interests.

Authors' contributions. All authors contributed equally to the experimentation. They all wrote and edited the article, equally designed and conducted the experiment, and studied scientific literature about the topic. All authors read and approved the final manuscript.

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References

1. McCall A, Davison M, Andersen T, Beasley I, Bizzini M, Dupont G, et al. Injury prevention strategies at the FIFA 2014 World Cup: perceptions and practices of the physicians from the 32 participating national teams. Br J Sports Med 2015;49(9):603-608.
2. Freckleton G, Pizzari T. Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis. Br J Sports Med. 2013;47:351–358.

3. Feeley BT, Kennelly S, Barnes RP, Muller MS, Kelly BT, Rodeo SA, Warren RF. Epidemiology of National Football League training camp injuries from 1998 to 2007. Am J Sports Med. 2008;(8):1597–603.
4. Hallen A, Ekstrand J. Return to play following muscle injuries in professional footballers. J Sports Sci. 2014;32(13):1229–36.
5. Järvinen TAH, Järvinen TLN, Kääriäinen M, Kalimo H, Järvinen M. Muscle injuries: biology and treatment. Am J Sports Med. 2005;33(5):745 - 764.
6. Beiner JM, Jokl P. Muscle contusion injuries: current treatment options. J Am Acad Ortho Surg. 2001;9(4):227 - 237.
7. Huard J, Li Y, Fu FH. Muscle injuries and repair: current trends in research. J Bone Joint Surg Am. 2002;84(5):822 - 832.
8. Eirale C, Farooq A, Smiley FA, Tol JL, Chalabi H. Epidemiology of football injuries in Asia: a prospective study in Qatar. J Sci Med Sport. 2013;16:113–117.
9. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). Am J Sports Med. 2011;39(6):1226–32.
10. Linklater JM, Hamilton B, Carmichael J, Orchard J, Wood DG. Hamstring injuries: anatomy, imaging, and intervention. Semin Musculoskelet Radiol. 2010;14(2):131–61.
11. Van der Made AD, Wieldraaijer T, Kerkhoffs GM, Kleipool RP, Engebretsen L, van Dijk CN, Golanó P. The hamstring muscle complex. Knee Surg Sports Traumatol. Arthrosc. 2015;23(7):2115-22.
12. Battermann N, Appell HJ, Dargel J, Koebke J. An anatomical study of the proximal hamstring muscle complex to elucidate muscle strains in this region. Int J Sports Med. 2011;32:211–5.
13. Koulouris G, Connell D. Hamstring muscle complex: an imaging review. Radiographics. 2005;25(3):571–86.
14. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high speed running: a longitudinal study including clinical and MRI findings. Am J Sports Med. 2007;35:197-206.
15. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during slow speed stretching: clinical, magnetic resonance imaging, and recovery characteristics. Am J Sports Med. 2007;35:1716-1724.
16. Askling C, Saartok T, Thorstensson A. Type of acute hamstring strain affects flexibility, strength, and time back to pre-injury level. Br J Sports Med. 2006;40:40-44.
17. Askling CM. Hamstring muscle strain. Stockholm: Karolinska University; 2008.
18. Kerkhoffs GM, Van Es N, Wieldraaijer T, Sierevelt IN, Ekstrand J, van Dijk CN. Diagnosis and prognosis of acute hamstring injuries in athletes. Knee Surg Sports Traumatol Arthrosc. 2013;21(2):500–9.
19. Koulouris G, Connell D. Hamstring muscle complex: an imaging review. Radiographics. 2005;25(3):571–86.
20. Peetrons P. Ultrasound of muscles. Eur Radiol. 2002;12:35–43.

21. Ekstrand J, Healy JC, Waldén M, Lee JC, English B, Hägglund M. Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play. Br J Sports Med. 2012;46(2):112–7.
22. Connell DA, Schneider-Kolsky ME, Hoving JL, et al. Longitudinal study comparing sonographic and MRI assessment of acute and healing hamstring injuries. AJR Am J Roentgenol. 2004;183:975-984.
23. FreckletonG,CookJ,PizzariT.The predictive validity of a single leg bridge test for hamstring injuries in australian rules football players. Br J Sports Med 2014;48:713–7.
24. De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. AJR Am J Roentgenol. 2000;174(2):393-399.
25. Schut L, Wangensteen A, Maaskant J, Tol JL, Bahr R, Moen M. Can clinical evaluation predict return to sport after acute hamstring injuries? A systematic review. Sports medicine 2017;47(6):1123-1144.
26. Timmins R, Shield A, Williams M, Lorenzen C, Opar D. Architectural adaptations of muscle to training and injury: a narrative review outlining the contributions by fascicle length, pennation angle and muscle thickness. Br J Sports Med 2016; 50(23):1467-1472.
27. TimminsRG,BourneMN,ShieldAJ,et al. Biceps femoris architecture and strength in Athletes with a previous anterior cruciate ligament reconstruction. Med Sci Sports Exerc 2016;48:337–345.
28. RebellaA Prospective Study of Injury Patterns in Collegiate Pole Vaulters. Am J Sports Med 2015; 43:808–815.
29. NilstadA,AndersenTE,BahrR,et al. Risk factors for lower extremity injuries in elite female soccer players. Am J Sports Med 2014 42:940–948.
30. OparDA,SerpellBG.Is there a potential relationship between prior hamstring strain injury and increased risk for future anterior cruciate ligament injury? Arch Phys Med Rehabil 2014;95:401–405.
31. Zvijac JE, Toriscelli TA, Merrick S, et al. Isokinetic concentric quadriceps and hamstring strength variables from the NFL scouting combine are not predictive of hamstring injury in first-year professional football players. Am J Sports Med. 2013;41:1511–1518.
32. ColbergRE, AuneKT, ChoiAJ , et al. Incidence and prevalence of musculoskeletal conditions in collegiate tennis athletes. JMST 2015;20:137–144.
33. GabbettTJ.The training-injury prevention paradox: should athletes be training smarter *and* harder? Br J Sports Med 2016;50:273–280.
34. Yeung SS, Suen AMY, Yeung EW. A prospective cohort study of hamstring injuries in competitive sprinters: preseason muscle imbalance as a possible risk factor. Br J Sports Med. 2009;43:589–594.
35. BourneMN, OparDA, WilliamsMD, et al. Eccentric knee flexor strength and risk of hamstring injuries in Rugby Union: a prospective study. Am J Sports Med 2015;43:2663–2670.
36. Bianchi S, Martinoli C. Ultrasound of the Musculoskeletal System. Berlin: Springer-Verlag;2007.