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# Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players

## A Prospective Study

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**Background:** The relationship between muscle injury and strength disorders remains a matter of controversy.

**Purpose:** Professional soccer players performed a preseason isokinetic testing aimed at determining whether (1) strength variables could be predictors of subsequent hamstring strain and (2) normalization of strength imbalances could reduce the incidence of hamstring injury.

**Study Design:** Cohort study (prognosis); Level of evidence, 1.

**Methods:** A standardized concentric and eccentric isokinetic assessment was used to identify soccer players with strength imbalances. Subjects were classified among 4 subsets according to the imbalance management content. Recording subsequent hamstring injuries allowed us to define injury frequencies and relative risks between groups.

**Results:** Of 687 players isokinetically tested in preseason, a complete follow-up was obtained in 462 players, for whom 35 hamstring injuries were recorded. The rate of muscle injury was significantly increased in subjects with untreated strength imbalances in comparison with players showing no imbalance in preseason (relative risk = 4.66; 95% confidence interval: 2.01-10.8). The risk of injury remained significantly higher in players with strength imbalances who had subsequent compensating training but no final isokinetic control test than in players without imbalances (relative risk = 2.89; 95% confidence interval: 1.00-8.32). Conversely, normalizing the isokinetic parameters reduced the risk factor for injury to that observed in players without imbalances (relative risk = 1.43; 95% confidence interval: 0.44-4.71).

**Conclusion:** The outcomes showed that isokinetic intervention gives rise to the preseason detection of strength imbalances, a factor that increases the risk of hamstring injury. Restoring a normal strength profile decreases the muscle injury incidence.

**Keywords:** strength imbalance; hamstring; injury; prevention; soccer

Hamstring strains, in addition to being very common, can be long-standing and prone to recurrence. Athletes regularly face lingering discomfort on return to athletic activities, which represents a complex issue for sports medicine clinicians as well as trainers.

Preventing injury implies the identification and understanding of the factors leading to that injury. Such an approach could allow the development of the most appropriate strategy for reducing the risk. In spite of a great number of possible causes postulated in the literature,[5,22,36] only a few factors have been scientifically associated with injury, while others have been simply suggested as being implicated. In the context of hamstring strain, intrinsic factors related to individual features seem more predictive of injury than extrinsic ones, which are principally environment-related.[27] Injury is a common occurrence through rapid, active extension of the knee, which solicits eccentric action to the hamstrings

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decelerating the lower leg in the late swing phase. It has also been suggested that the hamstring muscles are vulnerable to injury during the rapid change from their eccentric to concentric action, when they become active hip extensors.[28] At some exercise intensity, the player surpasses the mechanical limits tolerated by the muscle unit, justifying the analysis of strength imbalance as a factor leading to hamstring strain.

In spite of abundant literature dedicated to the topic, today the relationship between muscle injury and strength disorders remains controversial.[3,4,8,22,24,29] In a previous study, muscle strength performance disorders were isokinetically detected in about 70% of cases after hamstring strain, with lingering discomfort on return to the field.[7] This underlined a preferential eccentric peak torque deficit and a significant reduction of a mixed eccentric hamstring/concentric quadriceps (H/Q) ratio. It was suggested that recurrent injuries might be the consequence of inadequate rehabilitation. Nevertheless, it remained unclear whether strength imbalances were solely the consequence of the initial injury or a current causative factor for reinjury, or both.

Subsequently, athletes with muscle imbalances and lingering complaints after hamstring strain followed a rehabilitative program individually adapted from their initial strength disorder profile.[8] Normalization of isokinetic parameters, based on very strict cutoffs related to bilateral hamstring asymmetries and H/Q ratios, led to a significant reduction in the subjective intensity of discomfort and the avoidance of subsequent hamstring reinjury.

The current prospective study investigated the isokinetic intervention as a preseason screening tool in professional soccer players. We aimed to determine (1) whether isokinetic strength variables collected through a preseason assessment could be predictors of subsequent hamstring muscle strain and (2) whether normalization of strength performances and agonist/antagonist ratios in the preseason imbalanced player could significantly reduce the incidence of hamstring injury.

## METHODS

### Player Eligibility

Between 2000 and 2005, soccer players were recruited among Belgian, Brazilian, and French professional teams. Eligibility criteria included (1) being considered fit for competitive soccer activity by the team medical staff, (2) having successfully completed the previous season as a healthy player, and (3) being normally involved in training sessions through the start of the new season. From 687 players who performed accurate isokinetic testing in the preseason, 462 players (age, 26 ± 6 years) received a complete follow-up and were analyzed in this study (Figure 1). The local ethics committee approved the study, and all participants gave their informed consent. Confidentiality of information was ensured by assigning a unique code number to each player.

### Experimental Procedure

Preseason isokinetic measurements (during the first week of training beginning a new season and before any competitive activity) were performed on hamstrings and quadriceps muscles. Assessments were performed using either a Cybex Norm dynamometer (Henley Healthcare, Sugar Land, Texas) (n = 296 players with a complete follow-up) or a Biodex III dynamometer (Biodex Medical Systems, Shirley, NY) (n = 166 players with a complete follow-up). The protocol modalities were inspired from a previous study dedicated to hamstring strain.[8] All team physical therapists charged with the isokinetic assessment received instructions to strictly apply a standardized testing procedure. Measurements were preceded by a warm-up consisting of pedaling on an ergometric bicycle (75 to 100 watts) and performing stretching exercises of the hamstring and quadriceps muscles. The subject was seated on the dynamometer (with 105° of coxofemoral flexion) with the body stabilized by several straps around the thigh, waist, and chest to avoid compensation. The range of knee motion was fixed at 100° of flexion from the active maximum extension. The gravitational factor of the dynamometer's lever arm and lower leg-segment ensemble was compensated for during the measurements. An adequate familiarization with the dynamometer was provided in the form of additional warm-up isokinetic repetitions in the concentric mode at the angular speed of 120 deg/s. The testing protocol included concentric exertions of both hamstring and quadriceps muscle groups at 60 deg/s (3 repetitions) and 240 deg/s (5 repetitions) angular speeds. Afterward, hamstrings were subjected to eccentric angular speeds of 30 deg/s (3 repetitions) and 120 deg/s (4 repetitions). All sets of testing were separated by 1 minute of rest. Before assessment, 3 preliminary submaximal repetitions routinely preceded each test speed. Oral encouragement was given, but the subject did not receive any visual feedback during the test.

The analysis of results included the absolute peak torque in newton meters, and the bilateral comparison led to the determination of asymmetries expressed in percentage form. A conventional H/Q peak torque ratio was established for the same mode and speed of concentric contraction. A 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). The constructed ratio proposed in this work combines 2 extremely different velocities. Because hamstring strains usually occur during joint movements at high velocities, it would have been inviting to select the same high isokinetic angular velocity for both muscle groups to be tested. No problems in validity or accuracy of concentric measurements at 240 deg/s were documented.[10] At high eccentric velocities, the period of constant velocity, expressed as a percentage of the whole range of motion, appears drastically reduced.[19] Moreover, the eccentric peak torque occurs at the final part of the movement, corresponding to a deceleration period. These limitations may lead to erroneous results. We decided to select the 30 deg/s velocity because low speed is frequently recommended to optimize

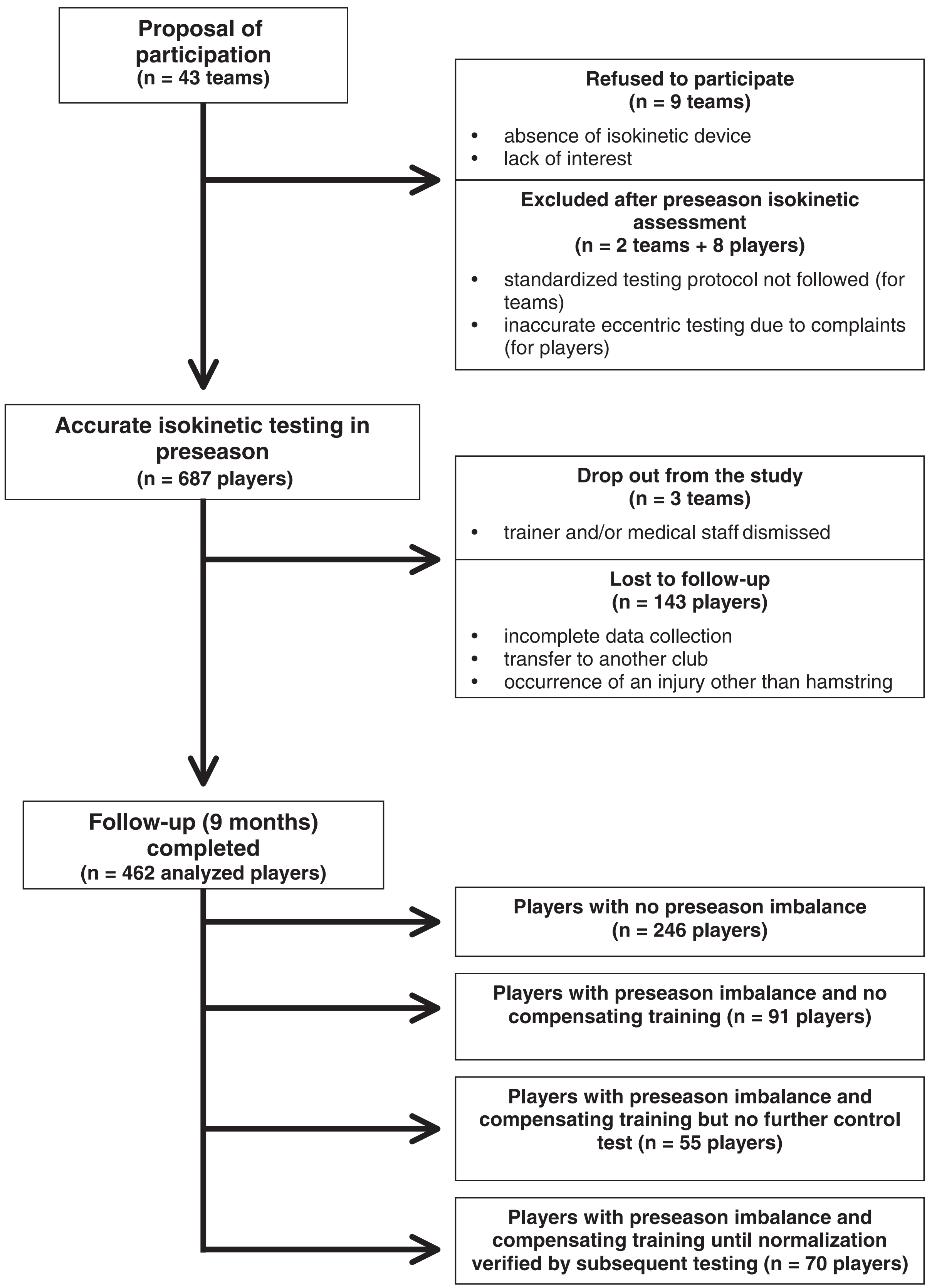


**Figure 1.** Diagram illustrating the flow of participants through the study.

TABLE 1
Criteria Description in Players With Strength Imbalances (n = 216)[a]

| | Rate of Players (%) |
|---|---|
| Bilateral difference | |
| Conc 60 deg/s | 85/216 (39) |
| Conc 240 deg/s | 69/216 (32) |
| Ecc 30 deg/s | 130/216 (60) |
| Ecc 120 deg/s | 126/216 (58) |
| H/Q ratio | |
| Conc 60/Conc 60 | 118/216 (55) |
| Conc 240/Conc 240 | 82/216 (38) |
| Mixed Ecc 30/Conc 240 | 187/216 (87) |

[a]Conc, concentric; Ecc, eccentric; H/Q, hamstring/quadriceps ratio; Mixed Ecc/Conc, mixed eccentric hamstring/concentric quadriceps ratio.

TABLE 2
Hamstring Injury Frequency in Professional Soccer Players

| Group | Players, n (n = 462) | Injuries, n (n = 35) | Injury Frequency, % |
|---|---|---|---|
| A[a] | 246 | 10 | 4.1 |
| B[b] | 91 | 15 | 16.5 |
| C[c] | 55 | 6 | 11 |
| D[d] | 70 | 4 | 5.7 |

[a]Group A had no preseason strength imbalance.
[b]Group B had preseason strength imbalances but no subsequent specific compensating training.
[c]Group C had preseason strength imbalances and subsequent compensating training, but no isokinetic control test aimed at verifying the parameter normalization.
[d]Group D had preseason strength imbalances and a subsequent compensating training until the parameter normalization was proved by repeated isokinetic control tests.

familiarization conditions with eccentric exercise. On the other hand, the isokinetic eccentric torque-velocity curve in humans appears to remain essentially constant.[10]

Through isokinetic testing, an imbalanced strength profile was determined in the preseason using statistically selected cutoffs[8] for the following parameters: bilateral differences of 15% or more in concentric and/or eccentric on the hamstrings; a concentric ratio (on at least 1 leg) of less than 0.47 or 0.45 on Cybex or Biodex, respectively; and a mixed ratio of less than 0.80 or 0.89 on Cybex or Biodex, respectively. Criteria for being allocated to the groups of players with imbalances corresponded to a significant deficiency in at least 2 of the following parameters: concentric (at 60 deg/s or 240 deg/s) bilateral asymmetry; eccentric (at 30 deg/s or 120 deg/s) bilateral asymmetry; concentric H/Q ratio (at 60 deg/s or 240 deg/s); and mixed $H_{ecc}/Q_{conc}$ ratio (Table 1).

Players without deficits in the preseason did not perform subsequent isolated hamstring strengthening. All players with imbalances were not treated alike, even if on the same team. In each team, the decision to compensate or not compensate hamstring weakness was made by the medical staff and/or trainer. When applied, the hamstring conditioning program consisted of manual, isotonic, or isokinetic strengthening under the team physical trainer or physical therapist supervision. According to a previous study,[8] the strength status of the normalized muscle corresponded to a less than 5% deficit through bilateral comparison, and the H/Q concentric and mixed ratios were more than 0.57 (Cybex), 0.55 (Biodex), and 0.98 (Cybex) or 1.05 (Biodex), respectively. Cases with imbalances in the preseason did not universally undergo further isokinetic assessment to assess their strength status.

Four subsets of players were defined according to the specific modalities of hamstring imbalance management: compensating training or the lack of it, further isokinetic control tests or the lack of it, and strength profile normalization.

After the preseason isokinetic testing, players were prospectively observed for hamstring injury for 9 months through the subsequent competitive and training season. For inclusion as hamstring injury, the following criteria had to be simultaneously completed: (1) physical examination showing pain on palpation, passive stretch, and active contraction of the involved muscle; (2) diagnosis supported by ultrasonography or magnetic resonance imaging; (3) a period of 4 weeks of missed playing time for the involved player.

From preseason to the end of the season, individual injury data on hamstrings were documented on standardized forms by the medical staff of each team. Documents detailing the specifics of data collection were sent to each medical staff before the start of the season. Therapists had the opportunity to ask questions regarding the data collection process. These injury report forms were collected every 3 months by the main investigator, and all data were processed on a personal computer by using Microsoft Excel (Version 2000; Microsoft, Redmond, Wash).

## Statistical Analysis

Results were presented as hamstring injury frequency (%) for a 9-month follow-up. Comparisons were carried out between the 4 groups using a logistic regression, and relative risks (RR) were calculated. Results were considered to be significant at the 5% critical level ($P < .05$). Statistical analyses were carried out using Statistica 7.1 (StatSoft Inc, Paris, France).

## RESULTS

Of the 462 players who received a complete follow-up, 246 (53%) had a normal preseason isokinetic profile, and 216 (47%) were characterized by significant isokinetic strength disorders. The distribution of preseason abnormalities in the 216 imbalanced players is described in Table 1, according to the predefined cutoffs. The hamstring eccentric assessment was shown to be highly specific, particularly in the form of a mixed $H_{ecc}/Q_{conc}$, which was significantly reduced in 187 of 216 (87%) of the imbalanced players.

TABLE 3
Comparison of Hamstring Injury Frequency Between the 4 Groups of Players

| Groups | Logistic Regression | Relative Risk | Confidence Interval (95%) |
|---|---|---|---|
| AB[a] | 0.0003 | 4.66 | 2.01-10.8 |
| AC[a] | 0.0493 | 2.89 | 1.00-8.32 |
| AD | 0.56 | 1.43 | 0.44-4.71 |
| BC | 0.36 | 0.62 | 0.23-1.71 |
| BD[a] | 0.044 | 0.31 | 0.10-0.97 |
| CD | 0.30 | 0.50 | 0.13-1.85 |

[a]Represents a significant ($P < .05$) difference between both groups.

Thirty-five of 462 players sustained a subsequent hamstring injury, and their apportioning to 1 of the 4 subsets (A to D) is reported in Table 2. Interestingly, no player with a mixed ratio of higher than 1.40 (whatever the dynamometer brand) sustained a hamstring injury.

The hamstring injury frequency for one season significantly differed according to the preseason isokinetic status and strengthening intervention (or lack of) aiming to correct the isokinetic parameters. Players without any preseason strength imbalance showed an injury frequency of 4.1% (Group A). The rate was significantly ($P < .05$) increased and reached 16.5% in players with untreated imbalances (Group B); the relative risk (RR) index reached 4.66 (confidence interval [CI]: 2.01-10.8), indicating that soccer activity with untreated strength imbalances increases more than 4-fold the risk of hamstring injury in comparison with a normal strength profile (Table 3). Applying a conditioning program in imbalanced players without verifying isokinetic parameter normalization did not lead to a significant reduction in injury frequency (11% in Group C) in comparison with Group B. By contrast, effective correction of imbalances, demonstrated through subsequent isokinetic control tests using precise criteria for parameter normalization, significantly ($P < .05$) reduced the injury frequency (5.7% in Group D) in comparison with Group B. No statistical difference persisted between Group A and Group D.

## DISCUSSION

During the past few years, a remarkable preoccupation has arisen in sports injury prevention, as illustrated by an abundance of scientific meetings and publications. Research on sports injury prevention is effectively emerging as a new field in medicine.[1,11-13,17,20] This field of research should have the potential to glean new knowledge and to open up new ways of managing the annoyance of injury in highly skilled as well as recreational athletes.

A rate of 5 to 6 hamstring strains per club per season has been observed in English and Australian professional soccer, resulting in 90 days and 15 to 21 matches missed per club per season on average.[25,28,35] On the other hand, the reinjury rate for hamstring injuries has been found to be 12% to 31%,[18,28,31,35] frequently resulting from early return to play and incomplete rehabilitation.[5,8] Consequently, there is a need for investigations focusing on preventive intervention in soccer and other sports involving sprinting and jumping.

Admitting the multifactorial origin of hamstring injury, some factors may be more predictive of injury than others, and it has been suggested that strength imbalances play a key role.[5,6] A recent article focusing on the evidence-based prevention of hamstring injuries in sport recommended that a study with a significant number of players be carried out to examine the potential association between concentric and eccentric strength profile and hamstring muscle strain injuries.[28]

The outcome of our study clarifies the actual influence of strength imbalance on hamstring injury. Thus, players with untreated strength imbalances were found to be 4 to 5 times more likely to sustain a hamstring injury when compared with the normal group (RR = 4.66). To our knowledge, no study has investigated the real effectiveness of correcting the individual imbalances detected in preseason on the subsequent hamstring injury rate. That point represents the most innovative finding: normalizing the strength profile significantly reduces injury frequency. No statistical difference persisted between these players who had been normalized (injury frequency of 5.7%) and those with normal isokinetic performances in preseason (injury frequency of 4.1%). Nevertheless, such a meaningful outcome requires the objectifying, through successive sessions of isokinetic testing, of the effective correction of the imbalances. Thus, the group in which strength disorders were detected, but who did not achieve control of normalization after having performed compensation exercises, still showed an injury rate of as high as 11%.

These findings clearly demonstrate the need for performing preseason isokinetic assessments in professional soccer teams and to undertake specific strengthening program for the players with imbalances. In addition to the risk of injury when playing before complete resolution of muscle strength performance, a recent paper by Verrall et al[32] investigating professional Australian soccer players has also suggested a decrease in playing performance. In recreational players, the introduction of systematic isokinetic testing would probably be too expensive and time consuming with regard to time properly allocated to training. Nevertheless, because of the high prevalence of hamstring injury, a preventive weight or manual strengthening program could be undertaken by all players.[33] On the basis of field experience with professional soccer players, we suggest implementing classic training with specific sequences aimed at hamstring strengthening, particularly in the eccentric mode. Such an approach, although not evidence-based, could be initiated in expectation of a reduction in the risk of injury.

Interestingly, in our follow-up, players with a mixed $H_{ecc}/Q_{conc}$ ratio of higher than 1.40 did not sustain any muscle injury on the hamstrings. Askling et al[2] examined the effect of preseason strength training with eccentric and concentric actions in Swedish elite soccer players. In spite of a small number of subjects, and by contrast with a control group, the number of subsequent hamstring injuries (included if it caused the player to miss at least the next game or practice session) decreased significantly in the training group. Gabbe et al[15] confirmed that a simple program of eccentric exercise could reduce the incidence of hamstring injuries in Australian soccer, yet the authors reported the difficulty in applying a widespread implementation of the program because of poor compliance.

Variations in study design compromise the comparison between published data in the literature and probably contribute to the discrepancy between authors addressing the role of isokinetic assessment in hamstring injury prevention.[3,8,9,24,29] The inconsistent manner in which injury is defined may represent a confounding factor.[16] The assessment of the severity of an injury should be based on real-time loss from participation. Fuller et al[14] have recently defined injury severity as "the number of days that have elapsed from the date of the player's return to full participation in team training and availability for match selection." Another issue relates to poor size in some prospective studies, which have, therefore, wrongly asserted that isokinetic muscle strength testing was not able to identify players at risk of hamstring muscle injury.[9]

If some authors[4,18] have believed that isokinetic testing could detect muscle imbalances requiring correction thereafter, specific criteria for recovering a "normal" strength status have remained largely variable in the literature. Surprisingly, a cutoff of 80% of the strength on the contralateral side is sometimes admitted,[10,23] while other clinicians recommend the restoration of the weakest leg strength to within 10% of that of the unaffected leg.[21,30] At the same time, statistically defined cutoffs are rarely described for the H/Q ratio, leading to subjective interpretation of this essential parameter.

Strict criteria were applied in our study, consisting of a hamstring deficit of less than 5% in side-to-side comparison and specific values in the agonist/antagonist ratio: concentric H/Q ratios superior to 0.57 or 0.55 on Cybex or Biodex, respectively, and a mixed H/Q ratio superior to 0.98 or 1.05 on Cybex or Biodex, respectively. We also draw attention to the key role played by the eccentric assessment. A significant reduction of the mixed $H_{ecc}/Q_{conc}$ ratio was observed in 87% of the players with imbalances, which highlights the discriminating character of this parameter through preseason isokinetic assessment of professional soccer players. An ordinary concentric protocol would not have revealed exclusive eccentric deficits in more than 30% of the players with an imbalance who were identified in this study. Nonspecific modalities of strength measurements could lead to erroneous interpretation and an underestimated risk of muscle injury through soccer activity.

Obviously, we do not wish to pass over the possible injury risk when performing eccentric testing because of higher torques generated in comparison with the concentric actions.[10] Eight of 687 players who were initially involved in the isokinetic testing process did not complete the eccentric trials because of complaints during the exercise. Orchard et al[26] reported an isolated hamstring strain caused by isokinetic testing in a professional rugby player. By inference, the use of isokinetic devices requires experienced clinicians as much for the athlete's safety as for measurement accuracy.

Limitations of our contribution have to be discussed. With respect to the study design, players or teams were not randomized, which is sometimes difficult in the frame of a professional sports activity. Because this point could introduce a selection flaw, we compensated by not treating all players within the same team alike; some players received different treatments and/or control isokinetic posttests.

One concern with data being collected from several teams is the many different clinicians performing isokinetic testing and observers involved in recording injury attendance.[16] Nevertheless, such a model remains unavoidable in a multicentric study aiming to include the greatest number of players. Great care was taken in our prospective investigation regarding the standardization of the isokinetic protocol as well as in terms of the criteria for injury definition. It was vital that data collection be performed in a similarly strict fashion as directed by the main investigator. As described in the Methods section, data from several clubs initially enrolled in that survey were not taken into consideration as a consequence of a lack of adherence to the predefined design and codes. Moreover, the possible issue entailed by the use of 2 different brands of dynamometer was bypassed by the selection of specific referential values for each device in identifying muscle strength disorders.

Even though the present study has generally focused on the role of muscle strength imbalances, we have to consider the 4.1% rate of injury in players with no preseason strength disorder. Such data serve to confirm the multifactorial origin of hamstring strains. Witvrouw et al[34] highlighted the role of poor flexibility as a risk factor for muscle strains. Verrall et al[33] believe that stretching can play a role in hamstring muscle strain prevention by improving force absorption for a given length of muscle, thereby making the muscle more resistant to stretch injury. A combination of abnormalities (strength, flexibility, warm-up, fatigue) has been reported as increasing the risk of hamstring strain.[36] Consequently, the tenet of hamstring injury prevention needs to address and integrate the evidence-based factors.

Furthermore, we anticipate that physical trainers, physical therapists, and sports medicine doctors will be made aware of current insights in muscle injury mechanisms through updated educational programs. A better knowledge of the consequences of strength imbalance could avoid questionable strengthening programs as well as an early return to the field without controlling muscle performance status.

## CONCLUSION

The scientific identification of risk factors related to hamstring injury represents one mainstay for developing appropriate preventive measures. The outcomes in this prospective study allow us to conclude that isokinetic intervention, as a preseason screening tool in professional soccer players, gives rise to the early detection of strength imbalances. Imbalance of muscular strength with a low H/Q ratio represents a modifiable factor. As demonstrated in this study, restoring a normal balance between agonist and antagonist muscle groups significantly decreases the risk of injury. We strongly recommend that players with significant preseason muscle imbalances undergo specific training to address the imbalance with follow-up isokinetic testing to identify a residual dysfunction in muscle performance.

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