MUSCULAR IMBALANCE AND ACUTE LOWER EXTREMITY MUSCLE INJURIES IN SPORT

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ABSTRACT

Investigating factors associated with muscle strains highlights the multifactorial origin of the injury and the difficulty of identifying isolated or combined offending factors. Among the numerous causes reported in literature, only a few have been scientifically associated with injury occurrence even though others have been empirically suggested. Contradictions between articles dealing with the topic of strength and imbalance are frequent, probably resulting from differences in methodology and criteria for patient inclusion. Imbalance in muscle strength commonly refers to abnormal bilateral asymmetry (between homologous groups) and disruption of agonist – antagonist ratio. Some authors focusing on past history of hamstring or adductor strains have demonstrated the frequent abnormality of muscle strength and balance through isokinetic assessment. Mixed ratios combining the eccentric performance of "decelerating" muscles (as hamstrings) and concentric performance of "mobilizer" muscles (as quadriceps) are suggested and seem relevant. An increased emphasis on strengthening exercises – particularly in eccentric for hamstrings – and ratio correction on the basis of statistically selected cutoffs significantly reduces the recurrence rate and lingering complaints upon return to sports activities. In the same way, isokinetic intervention as preseason screening tool in sports causing frequent strain could detect imbalances and thus promote a preventive strategy.

Key words : strength – imbalance – muscle – injury – prevention.

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Croisier JL et al. Hamstring muscle tear with recurrent complaints : an isokinetic profile. *Isokinetics Exerc Sci* 2000 ; 8 : 175-180.

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I. INTRODUCTION

Even if muscle injury can also comprise laceration or contusion, strain is probably the most common occurrence lesion, accounting for up to 30 % of the typical sports medicine practice (1). Muscle strain represents a major cause of time lost from sport (2). Between 1992 and 1999, 83 503 player-matches were analyzed in the Australian Football League (3) for risk of muscle injuries, which showed 672 hamstring, 163 quadriceps and 140 calf muscle strains. Focusing on hamstring strains sustained in 91 English professional football clubs over two competitive seasons, Woods et al. (2) demonstrated that this injury accounted for 12 % of the total injuries and caused 2029 missed matches among 2376 players. Orchard et al. (4) mention hamstring muscle strain as the most prevalent injury in Australian Rules Football, accounting for 16 % of playing time missed as a result of injury. Garrett (1) stated that muscle strain injuries occur when the muscle is either stretched passively or activated during stretch. Activation alone would fail to entail either a partial or complete strain injury (5). So, eccentric contraction must be considered as an important factor owing to higher forces developed during lengthening (6).

Literature has postulated that muscle strain may result from several causes as inadequate flexibility, muscle weakness and strength imbalance, unsatisfactory warm-up, excessive fatigue, disturbed posture, dyssynergic contraction, polyarticular characteristic and percentage of fast-twitch fibers (7-21). Classically, extrinsic factors related to the sport activity and environment are distinguished from intrinsic factors depending on specific individual features. According to Orchard (3), intrinsic factors seem more predictive of muscle strain than extrinsic ones.

Identifying and understanding factors specifically involved in a muscle injury represents the mainstay to prevent first lesion occurrence as well as re-injury. The high rate of relapse and lingering complaints after return to the offending activity, notably for hamstrings, highlights the necessity of improving scientific knowledge and guidelines in treatment. Obviously, etiological factors may not be independent of one another. Thus, Worrell (22) submitted a theoretical model in which the combination of strength, flexibility, warm-up and fatigue abnormalities increases the likelihood of hamstring strain.

Nevertheless, we must admit that, to date, only a few factors have been scientifically associated with injury, while others just remain speculative (21). For instance, lack of flexibility is frequently suggested as being implicated, but scientific evidence for this possible offending factor appears poorly established. A recent prospective study on soccer players (23) demonstrated that an increased tightness heightens the risk of developing subsequent lesion on some muscle groups (hamstrings, quadriceps), even though flexibility and injury were independent factors for other muscles (adductors, calf). This finding suggests that a given risk factor may be peculiar to specific muscle group injury and will be taken into account when tackling the influence of strength and imbalance.

That topic “role of imbalances” gives rise to various questions:

- What does imbalance really mean?
- Which muscle groups are potentially vulnerable to imbalance?
- What is the relevance of the imbalance construct?
- Does a strategy of imbalance correction prevent injury risk?

II. IMBALANCE MEANING

Investigation into the possible role of strength and imbalance as a factor of muscle injury implies the selection of an assessment method. Ordinary clinical tests commonly exhibit confounding factors (24). Isokinetic devices provide valuable information by allowing valid strength measurement of single-joint movements and the development of agonist-antagonist ratios classically calculated on reciprocal peak torques. We have to distinguish between a simple muscle weakness and an imbalance phenomenon. Strength performance of a synergistic muscle group can be compared to the contralateral side or to normative values in order to identify local deficits. Through bilateral comparison, a deficiency can be determined using statistically selected cutoffs: for instance, bilateral differences of 15 % or more are considered as abnormal for the hamstring muscle group (25). Nevertheless, the limit selected in the clinical use of isokinetics appears stricter and routinely fixed at 10 % of bilateral asymmetry. Isolated weakness is quoted as an injury factor (19), even if not related to its antagonist muscle group capacity. Imbalance commonly refers to a modification of the strength balance between agonist and antagonist muscles. Based on biomechanics, an agonist muscle group may contract concentrically to generate a limb motion, while at the same time its antagonist develops an eccentric exertion aimed to decelerate and basically protect the involved joint. In specific ranges of sports based on rapid active knee extension (sprint, track and field jump, soccer, football, rugby), the hamstring muscles have to decelerate the lower leg and thus avoid prejudicial hyperextension. Hamstrings are subjected to high forces during both open and closed kinetic chain activities, making them vulnerable to injury (26). The circumstances under which injury takes place frequently correspond to surpassing the eccentric mechanical limits tolerated by the flexor muscle unit. Logically, a correct balance between performances developed by each involved muscle group would be strictly respected in “speed athletes”.

III. MUSCLE GROUPS VULNERABLE TO IMBALANCE

The relationship between muscle injury and agonist-antagonist balance disruption has been frequently reviewed in the literature (4,27). Nonetheless, such a construct of balance in performance does not involve all of the agonist-antagonist groups, but depends on their functional task. This comment should contribute to understanding why certain muscles seem more susceptible to injury than others. Muscles such as shoulder external rotators carry out a braking action thwarting the concentric exertion of the internal rotators through different throw and overhead activities (28). Nevertheless, an agonist-antagonist imbalance would rather result in tendinous or neurological lesion (29,30) instead of true muscle strain.

The possible intervention of imbalances in muscle injuries frequently concern hamstrings. Croisier and Crielaard (31) demonstrated the high rate (70 % of cases) of knee flexor performance disorders in the context of previous hamstring strains with lingering complaints and/or recurrence upon return to activity. That profile seemed to indicate that, beside an inadequate rehabilitation, persisting problems could result from strength imbalance. Even so it remained inconclusive whether strength disorders were either a causative factor for re-injury and discomfort or simply the consequence of the initial injury. Conversely, other authors refuted the associative concept. Worrel et al. (14) found no significant strength differences between injured hamstring and non-injured athletes on any isokinetic measure evaluated. This could result from particularly efficient post-injury treatment or might more likely be due to other criteria for assignment to the injured group. In the study by Worrel et al. (14), subjects had experienced sudden or delayed muscular pain (which rather evokes delayed onset muscle soreness, DOMS) that prevented participation in sport of some of them for only one week, yet they were totally free of symptoms limiting their sport performance at the time of the isokinetic assessment.

IV. SCIENTIFIC EVIDENCE FOR IMBALANCE INVOLVEMENT

On the basis of statistically selected cutoffs of peak torque bilateral differences and knee flexor / quadriceps ratios, Croisier et al. (25) isokinetically screened a group of 26 athletes with history of hamstring strains and current complaints during practice. Eighteen cases, which represent 69 % of subjects, were considered as abnormal, confirming initial results of the author (31). Besides, 31 % of assessed athletes presented normal isokinetic data, illustrating the multifactorial origin of muscular injuries. The average value of the classical concentric ratios (Fl_{conc} / Q_{conc}) at 60°/s and 240°/s for the involved side were not significantly different from that of the uninvolved side (Figure 1). However, the analysis demonstrated an important interindividual variability after muscular injury since at 60°/s the Fl_{conc} / Q_{conc} ratio was significantly decreased in 9/26 cases. An original mixed ratio (32), combining the eccentric performance of the hamstrings and the concentric performance of the quadriceps (Fl_{ecc}/Q_{conc}) appeared significantly reduced for the injured muscles (0.73 $\pm$ 0.24) when compared with the healthy contralateral limb (0.90 $\pm$ 0.16) ($p < 0.01$). An ordinary concentric isokinetic protocol would have neglected exclusive eccentric abnormalities in 23 % of patients ! These results highlight the discriminating character of the eccentric assessment, in accordance with findings by Jönhagen et al. (8). The mixed ratio Fl_{ecc}/Q_{conc} appears closer to the functional task and the relationship between these agonist-antagonist muscles (33,34). Consequently, we draw attention to the risks of misinterpretation from a non-specific isokinetic protocol in the management of hamstring strains, even if eccentric trials require experienced therapists and adapted devices (35,36). The lack of compatibility between different brands of dynamometers (37,38) must also be taken into account when referring to normative values for agonist/antagonist ratios. Isokinetic users have to check that their referential values correspond to identical machines and evaluative protocols. The use of improper limits of ratio could lead to erroneous interpretation and increase the risk of re-injury by underestimating agonist-antagonist imbalance (21). The detected above-mentioned imbalanced athletes followed an individually adapted rehabilitative program (emphasizing hamstring eccentric training) aimed at normalizing the strength profile. Criteria for isokinetic parameter normalization were extremely severe with concentric and mixed ratios respectively up to 0.57 and 0.98 using a Cybex Norm dynamometer. This design permitted normalization in 17 of 18 subjects (Figure 2).

Prospectively followed for 12 months upon return to the offending sport activities after rehabilitation, they all reported significantly reduced intensity of discomfort, while recovering prior level of competition. None of the corrected subjects sustained a clinically diagnosed hamstring muscle re-injury. Undoubtedly, these results related to hamstring strains indicate the leading role played by strength and balance in the complex interaction between etiologic factors (21). That investigation allows us to conclude to the effectiveness of an adapted and specific rehabilitative intervention in hamstring muscle re-injury prevention. One reason for the high tendency of hamstring injury relapse could be that athletes return to sports before being fully rehabilitated (8). The use of techniques designed to rapidly return athletes to competition – as local anesthetic injections – might magnify the risk for complete rupture (39). Clanton and Coupe (40) confirm that readiness for return to competition can be assessed by isokinetic testing to confirm that muscle-strength imbalances have been corrected, the concentric hamstring – quadriceps ratio being 50 % to 60 %, and the performance of the injured leg being restored to within 10 % of that of the unaffected leg. We conclude that the concept is applicable to minor muscle strain as well. All the more so since Garrett (1) reckons that improper rest and rehabilitation of a minor strain of skeletal muscle frequently precedes a far more disabling injury. This assertion is confirmed by Orchard (3): in lower limb muscle strains, the strongest risk factor is a recent history of that same injury but a first injury, also confers risk to other muscle groups. In the same way, Hölmich et al. (41) demonstrated that an 8- to 12-week active strengthening program was more effective in treating chronic adductor strains compared to a conventional physical therapy model of massage and stretching. Thus, an increased emphasis on strengthening exercises clearly reduces the high recurrence rate for some selected muscle strains.

V. INJURY PREVENTION BY DETECTING AND CORRECTING IMBALANCE

Beyond the risk of muscle strain recurrence, possibilities for prevention in uninjured subjects have been considered for various sports related injuries (42-44). Studies analyzing the predisposing factors to muscle strain show frequent contradictions. Bennell et al. (26) asserted that isokinetic muscle strength testing was not able to directly identify Australian Rules football players at risk for hamstring muscle injury. Such a result suggests that the role of isokinetic intervention as a preseason screening tool may be limited. Other authors have found through prospective studies that muscle deficits and imbalances do contribute to muscle injury. Though working exclusively in the concentric mode, Orchard et al. (4) concluded that preseason isokinetic testing of Australian Rules professional football players could identify those at risk of sustaining subsequent hamstring strains. The best predictors were the Fl/Q ratios and hamstring-to-opposite hamstring muscles. Preseason strength was 16 % lower in the hamstring muscles that subsequently sustained an injury compared with those that were uninjured. The study also suggested that concentric isokinetic measurements at 60°/s provide greater yields in terms of strain prediction than at faster speeds, despite not being close to physiologic sprinting speeds.

A recent study (45) attempted to define the thigh muscle profile in professional soccer players and to identify preseason isokinetic strength variables as predictors of hamstring muscle strain. Seventy-seven professional players benefited from a standardized preseason isokinetic protocol including concentric and eccentric exertions. They were then followed for 9 months (throughout the subsequent competitive season) and hamstring muscle injuries were recorded. During that longitudinal follow-up, seven players sustained clinically diagnosed hamstring muscle injuries that caused them to miss more than 4 weeks of playing time. Among them, six presented isokinetic preseason abnormalities determined using statistically selected cutoffs. Hence, the risk factor of hamstring injury for one season was set at 15 % in the presence of strength imbalance (6 injuries in 41 imbalanced players), and at only 3 % in the absence of strength abnormality (1 injury in 36 normal players). Once again, the discriminating character of the eccentric trial and the specificity of the original mixed ratio (32) were confirmed. These results emphasize the importance of strength imbalances as a major risk factor, soccers with imbalances appearing 5 times more likely to sustain a hamstring strain. Further studies are needed to confirm the effects of a preventive approach aiming to correct the preseason imbalances.

Hamstring muscle group is rarely specifically trained in professional soccer players, even if players benefit from weight training sessions, notably dedicated to knee extensors. Some incorrect ideas are current about hamstrings, e.g. that strengthening systematically induces a harmful muscle shortening and then possibly increases the likelihood of injury. It is well known that the maximal strength of the mobilizer muscle groups influence sports performance and the optimization of sports related dynamic movements may require an increase in strength for specific synergistic muscle groups. Induced training modifications regularly disrupt the normal balance of strength between agonists and antagonists (i.e. knee flexor / knee extensor ratio or shoulder internal rotator / external rotator ratio). Finally, the issue of strength and balance concerns physical trainers as well as medical staff. New trends in rational training could focus more on the imbalance risk and implement antagonist (muscle group assumed to be not directly in relationship with field performance) strengthening in a preventive manner. Such an intervention would not only concern athletes recovering from injury, but also presumably healthy players.

Recently, Tyler et al. (46) conducted a prospective study to determine whether hip muscle strength plays a role in the incidence of adductor and hip flexor strains in ice hockey players. Preseason hip adduction strength was 18 % lower in players who subsequently sustained adductor muscle strain compared with that of uninjured players. Adduction strength was 95 % of abduction strength in the uninjured players, but only 78 % of abduction strength in the injured ones. The authors concluded that a player with adductor strength less than 80 % of abductor strength was 17 times more likely to sustain an adductor muscle strain. Hence, results indicate that preseason hip strength testing in professional ice hockey players can identify those players at risk of developing adductor muscle strains. The same authors recently demonstrated that a therapeutic intervention of strengthening the adductor muscle group appears to be an effective method for preventing adductor strains in these professional ice hockey players (47).

VI. CONCLUSIONS

Despite frequent contradictions in the literature review, one can reasonably assert that muscle strength and balance play a key-role in targeted acute muscle injuries. Some authors have showed that persistent muscle performance abnormalities may give rise to recurrent injuries and lingering discomfort when resuming the offending activity. A rehabilitation program emphasizing strengthening exercises based on specific deficits, until normalization of specific isokinetic parameters, contributes to a decrease in symptoms on return to sports. Some prospective studies have also demonstrated that a preseason isokinetic assessment in sports at risk is able to identify strength variables as predictors of hamstring or adductor muscle strain.

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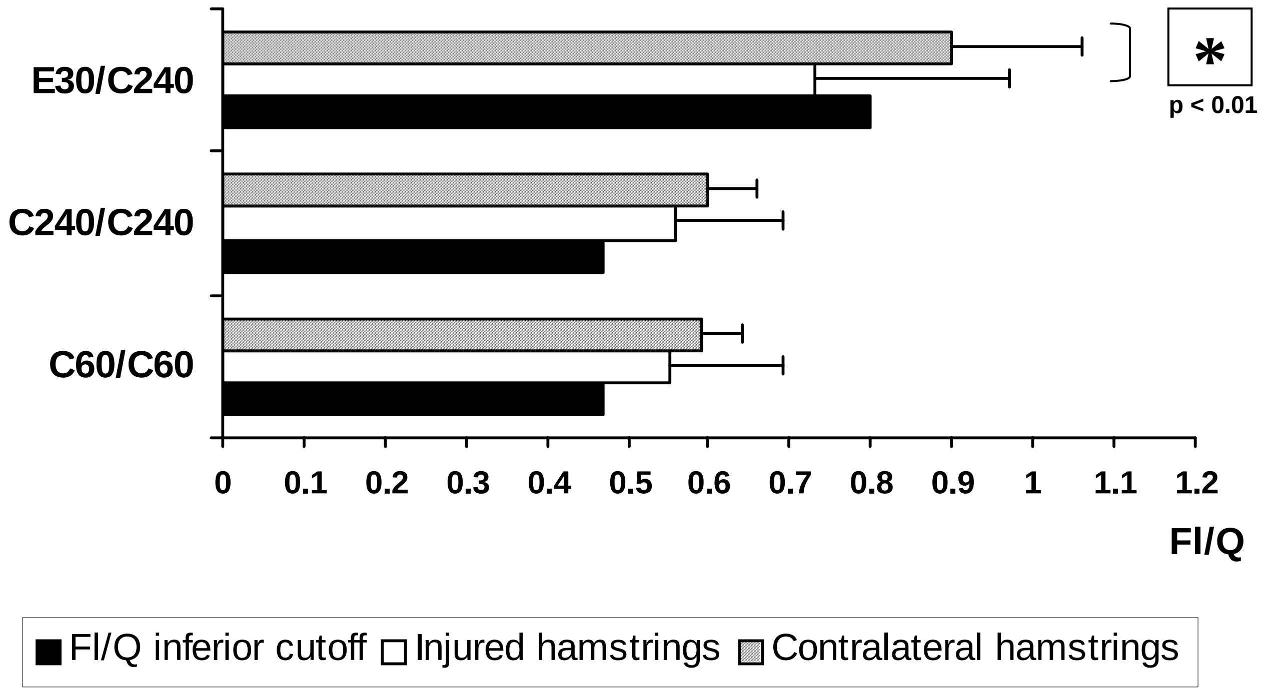

Figure 1: Comparison between an inferior cutoff, the injured and contralateral hamstrings for Fl/Q concentric and mixed ratio. Fl/Q, flexor/quadriceps; C_{60}/C_{60}, concentric flexor/quadriceps ratio at 60°/s; C_{240}/C_{240}, concentric flexor/quadriceps ratio at 240°/s; E_{30}/C_{240}, ratio of eccentric flexors at 30°/s and concentric quadriceps at 240°/s.

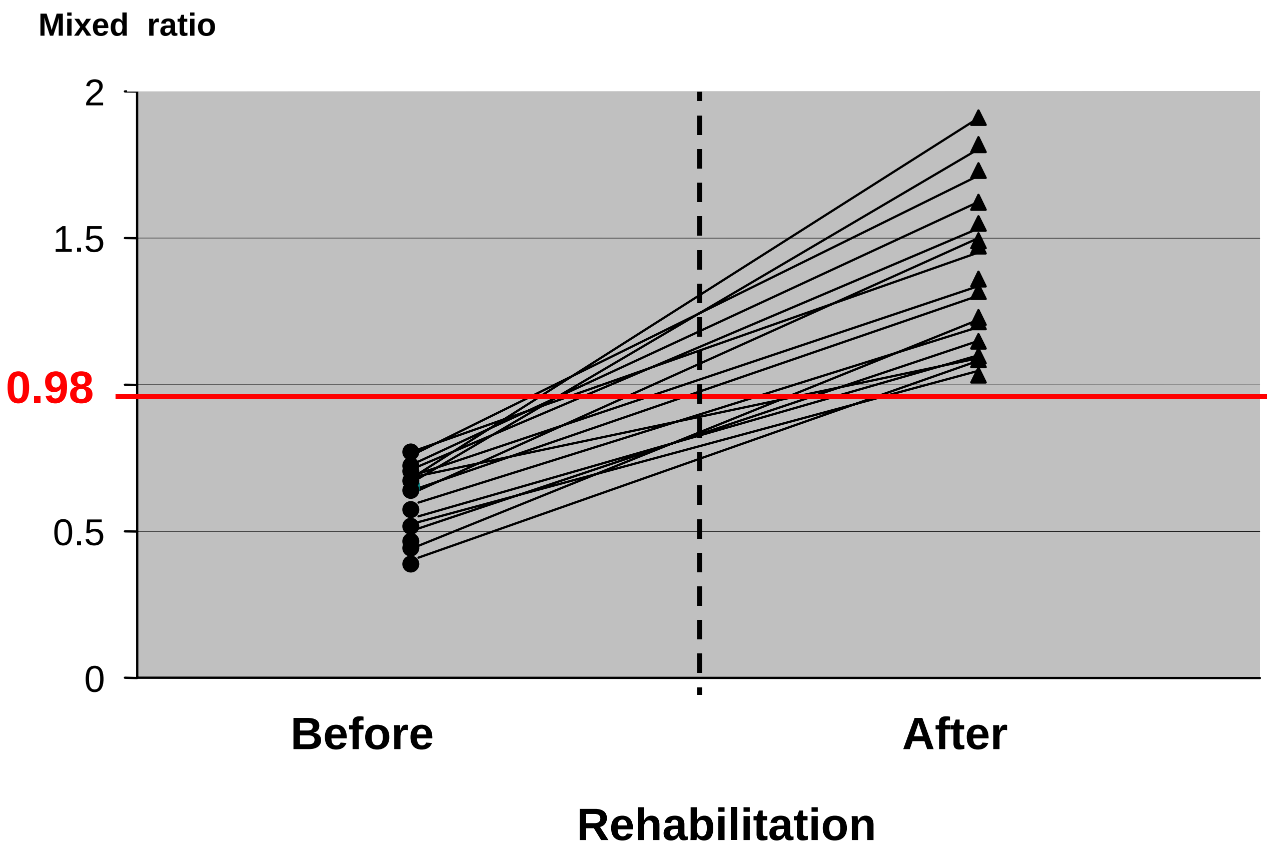

Figure 2: Values of the mixed Fl_{ecc}/Q_{conc} ratio before and after rehabilitation in the 17 normalized subjects (Mixed ratio, ratio of eccentric flexors at 30°/s and concentric quadriceps at 240°/s).