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Methodology and exercises to reduce the hamstring injury risk: from literature knowledges to the field

Abstract

Injury prevention is a topic that has received greater attention in recent years: in fact, even if knowledge and research about prevention has increased, the injury incidence remains very high, especially as regards the hamstring district.

As can be seen from the scientific literature, there are many studies that have described risk factors, but above all what strategies can be used to decrease this incidence through the prevention exercises. The exercise considered the *gold standard* for the hamstring injuries prevention is the *Nordic hamstring* although the literature highlights the particular complexity of the anatomical district of hamstrings.

For these reasons, it seems simplistic and reductive to assume that one exercise is sufficient. In this study is proposed further exercises proposed in the literature that can integrate the traditional Nordic hamstring and help to activate more fully all the muscle heads that make up the hamstrings. In conclusion, in a prevention session or in a strength session, in addition to the Nordic hamstring exercise, other exercises could be included, such as the Laying Kick, the Standing Kick, the Nordic bump, the Nordic with return, the Cranes and the Cranes return.

Keywords: injury prevention, hamstring, soccer

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Performance increase and prevention strategies

Today the attempt to reduce the soccer injury risk of injury is experiencing a worrying paradox: despite the increase in knowledge and research about the effectiveness of some prevention strategies, there is a substantially unchanged scenario regarding the injuries, both at an amateur and amateur level as well as at a professional level, and especially for the hamstring district.[1–5]

Today, in fact, the technical and medical staff have the goal of increasing performance by protecting the player health.[2] It appears evident from the epidemiological data as though having had a wide sharing and a rapid diffusion, introducing the Nordic hamstring exercise alone, for years considered essential, no longer seems to guarantee an effective prevention strategy: for these reasons, in literature there is a more holistic orientation which contemplates dominant hip and dominant knee exercises, considers the appropriate training volumes based on high intensity runs, together with multiple cofactors able to include multiple preventive factors.[1,6–10]

The attention to prevention involves risk assessment to (consequent) management of the same risk. Effective surveillance systems are now implemented by major clubs to understand which injuries can be expected (and relative severity), monitoring training loads and other variables related to physiological markers.

Today, therefore, the attention is not only directed to the incidence of each individual trauma, but also and above all to the severity of the same.[11,12]

In the specific case (hamstring injuries), the literature helps identify the extent of the problem by resorting to a risk matrix (Figure 1) that integrates the two aspects mentioned.[11]

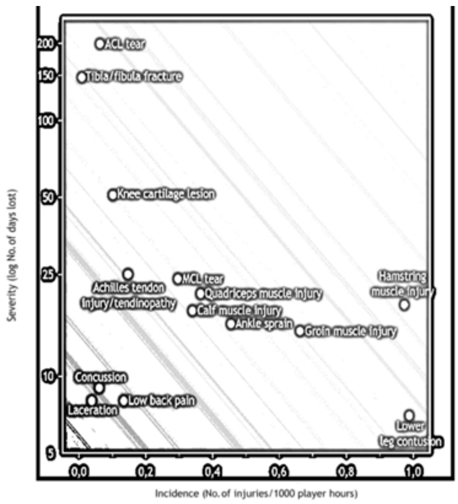

Figure 1 The incidence and severity of the main injuries in football (da Bahr et al.[11] modified).

The matrix proposed by the cited Authors highlights that hamstring accidents have a high incidence and significant severity.[11]

As can be seen from the quantitative matrix of the risk of injury adopted by UEFA, the muscle injuries to the hamstring district are located on the right side, thus highlighting a significant incidence and in the middle part, attesting an average absence of about 25 days, at the equal to other types of acute and overload trauma.[11]

Hamstring: a complex and articulated functional muscle district

If the analysis focuses on anatomical and biomechanical aspects, the muscles that make up the posterior kinetic chain of the thigh are four: the semitendinosus (ST), the semimembranous (SM) and the biceps femoris (BF), long head and short head; these muscles are divided into medial (SM and ST) and lateral (long and short head of the BF).

They are all biarticular muscles, as they control two joints (hip and knee) and have the function of flexing the knee and extending the hip, except for the short head of the hamstring which involves only the knee joint and has the function of flexor of the knee itself.

This biarticularity of the hamstring district, for some Authors, constitutes one of the factors predisposing to the injury.[13]

A few years ago the long head length of the BF was related to the predisposition to the risk of injury in the same district, especially when this variable is combined with other risk factors, such as the athlete's age, previous muscle trauma to the hamstrings and the low eccentric strength.[14]

The risk factors analysis must consider, in addition to the specific functionality of each district and muscle architecture, the innervation of the individual muscles that make up the hamstrings. Infact, ST and SM are innervated by the tibial nerve, while the BF provides a double innervation: the long head presents an innervation common to the other muscular districts that make up the hamstrings, while the short head is innervated by the common peroneal nerve.[13]

Recently, a very detailed analysis of the anatomical peculiarities of the muscle districts that make up the hamstrings has meticulously described volume, length of the muscle and proximal and distal tendons, as well as the ratio between the muscular component and the muscle-tendon junction of the same districts (Table 1) highlighting specific traits and characteristics of each.[15]

Table 1 Values related to average length, proximal free tendon length, free tendon/muscle ratio, average tendon junction length, ratio muscle/tendon junction length (From Volpi & Bisciotti, 2016, modified)[15]

Muscle district	Average muscle length (cm)	Average free tendon length (cm)	Muscle/tendon ratio(%)	Average length junction muscle-tendon (cm)	Ratio muscle/ junction muscle-tendon length (%)
Biceps femoris	42	5,0±3,4	12-15	14,6±4,1	35-45
Semitendinosus	44,3	0,2±0,7	0,4-3	12,2±3	27-28
Semimembranosus	38,7	9,4±2,6	24-25	14,9±3,9	39-48

This meticulous description helps to understand the morpho-functional heterogeneity of the hamstrings, already from their anatomical peculiarities.

To these aspects, it must be added that the mechanical behavior of the bi-articular hamstring muscle-tendon units is determined by the angular displacement of the hip and knee joints and respective moment arms.[16]

Consequently, it can be deduced that hamstrings constitute a very complex muscular district, both for the synergies, both for the muscular architecture, and for the different innervations, both for the anatomical details and for the actions they carry out.[17]

From the literature: an update

The relationship between the hamstring injuries incidence and the demands of fast running is today a central nucleus in research aimed at prevention, as well as relevant is the muscle synergies analysis in very high intensity running.[3,10,18]

In a recent study, 60 amateur footballers were recruited and assessed through electromyographic analysis while performing a sprint action.[3] Subsequently they were monitored for 18 months to detect the number of injuries to the hamstring district: the group of players who suffered injuries was distinguished from those who did not suffer injuries (control) with the aim of assessing whether there were correlations between activation of the core and gluteal muscles and indirect muscle trauma to hamstring.

The sprint test was carried out over a distance of 40 meters and the EMG analysis (normalized with respect to the maximum voluntary isometric contraction) was conducted in the 15-25 meter phase, in order to reduce the influence of the first acceleration phase.

The results showed that for the players who did not have reported injuries, the gluteus were more active ($p=0.027$) during the frontal oscillation phase (already from the very first phases of this); trunk muscles were observed to be more active ($p=0.042$) during the backward swing phase.[3]

The results of the study therefore lead to the hypothesis (as other Authors have already hypothesized) that the activity of the core muscles and the gluteus may influence[19,20] injuries in the hamstring district and how it is necessary to introduce the preventive sessions considering the lumbopelvic balance and complexity.

The study of biomechanical and functional requirements in fast running has recently been completed with the evaluation of activation of the long head of the hamstring and the semi-tendon during the acceleration phase and during the maximum speed phase of the sprint which involved 13 sprinters.[21] The study is extremely interesting because it deals with and tries to describe any differences in the recruitment of the two muscular districts in question in two different moments of the fast race: the acceleration phase and the maximum speed. During the initial phase of contact of the lower limb with the ground, during the acceleration phase, there was a greater activation ($p < 0.05$) of the long head of the BF compared to the ST. In the initial phase of the lower limb swing, the prevalence of the ST begins ($p < 0.01$) and then finds a substantial synergy with the long head of the BF.

During the race at maximum speed, the long head of the BF activation, overcomes the other district activation in the initial phase foot ground contact, while in the late phase of foot ground contact, the semitendinosus becomes more active again ($p < 0.001$).

In the last stage of the swing phase, the two muscular districts collaborate synergistically as has been observed in the acceleration race, without major substantial differences.[21] Considering these observations, the results of this study seem to indicate that the long head of the BF seems to be more recruited in the extension of the hip in the initial phase of acceleration (Figure 3). This analysis also allows us to understand how the hamstring demands change in relation to the sprint phase.[21,22]

Figure 2a Figure 2b

Figure 2a-b Laying kick: Starting and final position.

Figure 3a Figure 3b

Figure 3a-b.Standing kick: Starting and final position.

Figure 4a Figure 4b

Figure 4a-b Nordic hamstring. In the traditional execution, the athlete brakes the trunk, contracting eccentrically the hamstrings.

Figure 5a Figure 5b

Figure 5a-b Nordic hamstring with return. It represents a variation of the traditional Nordic in which the athlete associates the eccentric phase with a concentric one with which he returns to the starting position.

Figure 6a Figure 6b

Figure 6a-b Nordic bump. It represents a variant of the traditional Nordic in which the athlete extends and bends the upper limbs quickly while moving a load of 5 kg.

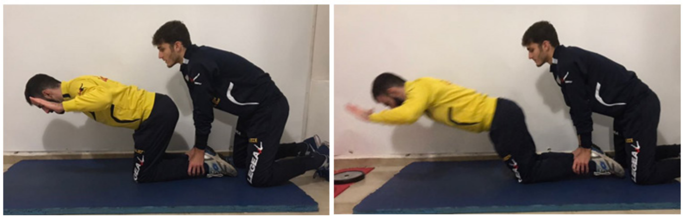

Figure 7a Figure 7b

Figure 7a-b Cranes. The exercise derives from Nordic and requires the eccentric phase to be performed with a bended trunk: this position stresses the hamstrings more, which are also eccentrically stretched in the proximal and distal insertion.

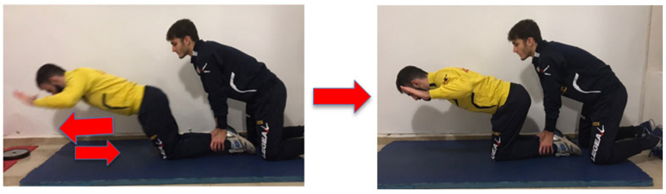

Figure 8a Figure 8b

Figure 8a-b Cranes with return. It represents a variant of the Cranes and also provides the concentric phase with which the athlete returns to the starting position.

Prevention exercises and sprint requests: what relationships?

The literature provides very interesting insights for prevention. The study relating to the muscle interventions analysis involved the comparison between two exercises widely used to eccentrically training: Nordic hamstring and ball leg curl. Of the two exercises, only the eccentric phase was assessed and electromyography activity between 60 and 0 degrees of knee flexion was recorded.

No statistically significant difference was found between the two exercises regarding the activation of the BF and the ST.[23]

Another analysis concerned the comparison between Nordic hamstring (NHE) and stiff-leg deadlift (SDL) using high density electromyography, with the aim of examining the differences in local / regional activation of hamstrings. The muscles whose activity was measured during only the eccentric phase alone were the biceps femoris, long head (BFlh) and the semitendinosus (ST) in their proximal, medial and distal portions.[24]

The subjects tested were 12 and all reported no injuries in the past year.

As regards the SDL, the protocol provided for 5 repetitions with 80% 1RM with an execution speed of about 2 sec both for the eccentric and concentric phase of the movement; also for the NHE there were 5 repetitions with a controlled speed of 18 °s-1. For both exercises the repetitions were not carried out in a subsequent way but a 2 'pause between the various repetitions was expected. The results report, as already highlighted in the literature, that the NHE stresses the BFlh more, while there are no activation differences between the two muscles as regards the SDL.

When the Authors moved to the analysis of local activation, the mid-proximal region of the ST and the distal region of the BFlh showed the highest activity, regardless of the exercise performed by the participants.

As regards the BFlh, the difference between the three muscle portions was higher during the NHE than the SDL.

As for ST, large differences in activity between regions were detected during NHE.

During the NHE the distal region of the ST showed the lowest activation level while the highest one of the BFlh was observed. During the SDL these regional differences were less evident.[24]

Among the numerous exercises useful for training and the prevention of hamstring injuries, two main categories of exercises can be distinguished, namely dominant hip and dominant knee.

Very recently, a very useful review[25] monitored a series of studies that had used hip-dominant (hip extension) and knee-dominant (knee flexion) exercises.

It emerged that the hip-dominant exercises allow to recruit more the long head of the BF, while the knee-dominant exercises involve more the ST.

Although there are many studies that have measured the muscle activation levels of the various hamstring exercises, none of these have related the level of activation of the individual exercises with what happens during a sprint.

An interessant work sought to examine some hamstring exercises by comparing their activation with the muscle activity produced during maximum sprints.[26] The study was carried out on only few athletes, but it provides interesting reflection reasons. The electromyographic activity (EMG) was measured in the ST, SM and in the BFlh. The exercises monitored were Laying Kick, Standing Kick, Nordic hamstring, Nordic whit return, Nordic bump, Cranes and Cranes return (Figures 2–8).

The comparison was made between what was recorded during the execution, often used for preventive purposes and the activation obtained by the muscles analyzed during the sprint, which was considered by the Authors the gold standard for the hamstring recruitment and therefore this value is considered the 100% of the hamstring activation.

It is easily understandable and foreseeable, in fact, how the activation can be maximal in the sprint since the latter simultaneously stimulates the hamstring proximal and distal portion, through very rapid angular movements both at the hip and knee level.

From the literature it is known how hamstrings are most activated in the swing late phase, when they must decelerate the action of the leg.[19,20,22,27]

The hamstring high activation during the fast running action must therefore be sought in the type of contraction (eccentric) during this phase.[26]

The first data obtained reported that the activity of the various exercises was on average between 40 and 65% for the semitendinosus, between 18 and 40% for the BF and between 40% and 75% for the SM, compared to the maximum activity achieved during the sprint. Cranes and Standing Kick returned the most modest activation levels for the SM.

All monitored exercises highlighted the EMG activation peak at different angles to what occurs in the sprint.

Both the ST and the BF returned their maximum activation in the sprint, while the SM only in the Laying Kick exercise did not return significantly lower values than what occurred in the sprint. Most of the exercises observed showed an activation always below 70% threshold; only the ST has returned an activation between 70% and 80% in the three Nordic exercises and in the Laying Kick: these values were not statistically different from what occurred in the sprint.

These considerations are relevant because from the literature it is known how, if we want to obtain stresses relevant to the increase in force, the muscle must reach an EMG activation of at least 70%.[28,29] The BF was the muscle district that was least activated by the proposed exercises, never reaching the minimum threshold of 70%.

This result is particularly interesting for training practice: the exercises chosen by the staff often do not meet the sport functional requirements.

In fact, the data obtained from this comparison agree with what was already known in the literature, namely that Nordic and its variants call for an adaptation to the BF fascicles length but do not promote an adaptation in terms of hypertrophy.[30]

The values obtained in the aforementioned study regarding the Nordic exercise, however, must not be considered in absolute terms, as an improvement in the maximum activation threshold was observed following a 6-week training period,[31] probably also attributable to a better technical execution.

Considering the BF biarticularity, Cranes' exercises are often adopted in preventive training, but they certainly need a review, if the activations detected in the study were to be confirmed by other similar studies; or at least, the trunk forward bending angle should be reconsidered.

However, the most interesting results of the study are those that allow you to obtain valuable information about the hip and knee angle in which the highest EMG activation was recorded, both in the sprint and in the individual exercises, because this comparison allows to understand if the exercises introduced in prevention programs are specific or more generic.[26]

Ultimately, the layng kick, the nordic and its two variants, were the exercises that made it possible to achieve the highest activations, and allowed the maximum EMG activation at substantially the same angles where this maximum activation was recorded in the sprint, as regards the hip joint.

The Nordic with the different variants and the Cranes allowed instead a substantial overlap between what occurs in the exercises and what is required in the sprint as regards the knee angles.[26]

Despite these very interesting data, the Authors highlighted that none of the exercises analyzed allowed to exceed the activation level recorded and achieved during the sprint;[26] hence the call to pay attention to the need to provide different tasks for different muscle targets in preventive sessions.

Conclusions

The puzzle of prevention in the hamstring district is continually being enriched with new pieces that can help outline increasingly effective programs 2,8,16,17,18. Knowing the complexity of the anatomical district and obtaining valuable information from the electromyographic analyzes that return the activation levels of the individual muscle heads that make up the hamstrings, can allow careful and modulated preventive selection and integration of preventive tasks based on scientific evidence.

Authors' contribution

Italo Sannicandro has contributed to the study design structuring, to the bibliographic research and to the study writing; Paolo Traficante has contributed to the bibliographic research, to the literature study interpretation and to the realization of the exercises; Giacomo Cofano has contributed to the study design structuring, to the bibliographic research and to and study revising.

Conflicts of interest

No conflict of interest to be declared.

References

1. van Dyk N, Behan F.P, Whiteley R. Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries: a systematic review and meta–analysis of 8459 athletes. *Br J Sports Med.* 2019;53:1362–1370.
2. Sannicandro I, Traficante P, Cofano G. Hamstring injury prevention: the strength assessment in young soccer players. *MOJ Sports Med.* 2019;3(2):28–32.
3. Schuermans J, Danneels L, Van Tiggelen D, et al. A prospective study with electromyography time–series analysis during maximal sprinting. *AJSM.* 2017;6:1315–1325.
4. Ekstrand J, Walden M, Hagglund M. Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13–year longitudinal analysis of the UEFA Elite Club injury study. *Br J Sports Med.* 2016;50(12):731–737.
5. van Beijsterveldt AM, van de Port IG, Krist MR, et al. Effectiveness of an injury prevention programme for adult male amateur soccer players:a cluster–randomised controlled trial. *Br J Sports Med.* 2012;46:1114–1118.
6. Ekstrand J, Lundqvist D, Davison M, et al. Communication quality between the medical team and the head coach/manager is associated with injury burden and player availability in elite football clubs, *Br J Sports Med.* 2019;53(5):304–308.
7. Buckthorpe M, Wright S, Bruce–Low S, et al. Recommendations for hamstring injury prevention in elite football: translating research into practice. *Br J Sports Med.* 2019;53(7):449–456.
8. Lehnert M, De Ste Croix M, Xaveroval Z, et al. Changes in injury risk mechanisms after soccer–specific fatigue in male youth soccer players. *J Hum Kinet.* 2018;62:33–42.
9. Oakley A.J, Jennings J, Bishop C.J. Holistic hamstring healt: not just the Nordic hamstring exercise. *Br J Sports Med.* 2018;52(13):816–817.
10. Malone S, Roe M, Doran D.A, et al. High chronic training loads and exposure to bouts of maximal velocity running reduce injury risk in elite Gaelic football. *J Sci Med Sport.* 2017;20(3):250–254.
11. Bahr R, Clarsen B, Ekstrand J. Why we should focus on the burden of injuries and illnesses, not just their incidence, Br J Sports Med. 52(16):1018–1021.
12. Emlund L, Vieira L.A, Hamstring injuries: update article. *Rev Bras Ortop.* 2017;52(4):373–382.
13. Bisciotti GN. Le lesioni degli hamstring, Calzetti–Mariucci, Perugia. 2013.
14. Timmins RG, Shield AJ, Williams MD, et al. Biceps femoris long head architecture: a reliability and retrospective injury study. *Med Sci Sports Exerc.* 2015;47:905–913.
15. Volpi P, Bisciotti G.N. The hamstring muscles: anatomy, biomechanics and risk injury. *Med Sports.* 2016;69(2):297–307.
16. Hegyi A. Within– and between–muscle hamstring electromyography activity in various exercises and at different running speeds, Thesis YHU Dissertation 187, University of Jyväskylä. 2020.
17. Cuthbert M, Ripley N, McMahon J.J, et al. The effect of Nordic Hamstring exercise intervention volume on eccentric strength and muscle architecture adaptations: a systematic review and meta-analyses. *Sports Med.* 2020;50(1):83–99.
18. Edouard P, Mendiguchia J, Guex K. Sprinting: a potential vaccine for hamstring injury?, *Sport Performance & Science Reports (SPSR).* 2019;48(1):1–2.
19. Chumanov E.S, Heiderscheit B.C, Thelen D.G. Hamstring musculotendon dynamics during stance and swing phases of high–speed running. *Med Sci Sports Exerc.* 2011;43(3):525–532.
20. Chumanov E.S, Heiderscheit B.C, Thelen D.G. The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *J Biomech.* 2017;40(16):3555–3562.
21. Higashihara A, Nagano Y, Ono T, et al. Differences in hamstring activation characteristics between the acceleration and maximum–speed phases of sprinting. *J Sports Sci.* 2018; 36(12):1313–1318.
22. Higashihara A, Ono T, Kubota J, et al. Functional differences in the activity of the hamstring muscles with increasing running speed. *J Sports Sci.* 2010;28(10):1085–1092.
23. Monajati A, Larumbe–Zabala E, Goss–Sampson M, et al. Analysis of the hamstring muscle activation during two injury prevention exercises. *J Hum Kinet.* 2017;60:29–37.
24. Hegyi A, Péter A, Finni T, et al. Region–dependent hamstrings activity in Nordic hamstring exercise and stiff–leg dead lift defined with high–density EMG. *Scand J Med Sci Sports.* 2018;28(32):992–1000.
25. Bourne MN, Timmins RG, Opar DA, et al. An Evidence–Based Framework for Strengthening Exercises to Prevent Hamstring Injury. *Sports Med.* 2018;48(2):251–267.
26. Van den Tillaar R, Brevik Solheim JA, Bencke J. Comparison of hamstring muscle activation during high–speed running and various hamstring strengthening exercises. *Int J Sp Phys Ther.* 2017;12(5):718–727.
27. Jönhagen S, Ericson MO, Nemeth G, et al. Amplitude and timing of electromyographic activity during sprinting. *Scand J Med Sci Sports.* 1996;6(1):15–21.
28. Andersen LL, Magnusson SP, Nielsen M. Neuromuscular activation in conventional therapeutic exercises and heavy resistance exercises: implications for rehabilitation. *Phys Ther.* 2006;86(5):683–697.

29. Boren K, Conrey C, Le Coguic J, et al. Electromyographic analysis of gluteus medius and gluteus maximus during rehabilitation exercises. *Int J Sports Phys Ther*. 2011;6(3):206–223.
30. Bourne MN, Duhig SJ, Timmins RG, et al. Impact of the Nordic hamstring and hip extension exercises on hamstring architecture and morphology: implications for injury prevention. *Br J Sports Med*. 2017;51(5):469–477.
31. Delahunt E, McGroarty M, De Vito G, et al. Nordic hamstring exercise training alters knee joint kinematics and hamstring activation patterns in young men. *Eur J Appl Physiol*. 2016;116(4):663–672.