

EFFECTIVENESS OF NORDIC EXERCISES ON THE INCIDENCE OF HAMSTRING INJURIES IN MALE PROFESSIONAL AND AMATEUR SOCCER PLAYERS AGED 15-41 YEARS. SYSTEMATIC REVIEW

EFFECTIVIDAD DE LOS EJERCICIOS NÓRDICOS SOBRE LA INCIDENCIA DE LESIONES DE ISQUIOTIBIALES EN FUTBOLISTAS PROFESIONALES Y AMATEUR MASCULINOS ENTRE LOS 15 Y 41 AÑOS. REVISIÓN SISTEMÁTICA

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ABSTRACT

Introduction: muscular injuries are the most common among soccer players, being hamstring injury the most frequent. Objective: The aim of this study was to analyze the existing evidence on the effects of Nordic exercises on the incidence of hamstring injuries in professional and amateur male soccer players between 15 and 41 years of age. Methods: A systematic review was carried out following the PRISMA guidelines recommendations, a search was carried out for articles in PubMed, BVS, Cochrane, Web OF Science and SCOPUS, in addition Google Scholar was consulted. The search was performed based on the PICO strategy with the following terms: hamstring muscles, exercise, rehabilitation, therapy, athletic injuries, soccer. Results: a total of 257 articles resulted from the search, 5 of which were included in this study. All studies showed positive effects of Nordic exercises for athletes. Conclusions: Nordic exercises reduced the

incidence of hamstring injury in 4 of the studies analyzed, the percentage of compliance with the intervention sessions conditioned the quality of the effects while the moment of application of the intervention (pre- or post-training) had no influence.

KEY WORDS: hamstring muscles, exercise, rehabilitation, injuries in athletes, soccer

INTRODUCTION

Adequate muscle development, function and performance is of particular importance in soccer players, especially due to the high injury rates reported in this tissue (1) especially because of the high injury rates reported in this tissue associated with the overuse and high demands of the game that require the best possible physical condition in terms of strength, speed, and flexibility performance (2-4).

The presence of this type of injury is so critical in this sport that it has been estimated that a loss of 12% of the competitive season has been attributed to the absence of players due to injuries associated with their sports practice, with the consequent economic loss of sports results (5).

In both amateur and professional soccer players, the most common injuries usually occur at the level of the hamstring muscles. The affectations in this muscle group represent 37% of the injuries of muscular type in this discipline. Moreover, they are usually recurrent injuries, and it is estimated that the recurrence rate ranges from 12% to 33%, which implies long recovery periods (6).

The hamstring muscle complex that has the joint function of hip extension and knee flexion is made up of the semimembranosus, semitendinosus and biceps femoris muscles (7). They become more susceptible to injury due to age, presence of previous injuries and muscle architecture, fatigue, flexibility, lumbo-pelvic stabilizing strength and mainly due to decreased eccentric strength (8). The latter plays an important role during running, being of great importance, not only to support and decelerate knee extension during the late swing phase, but also to balance the isokinetic strength of the contralateral lower limb (9).

Hamstring injury is one of the most prevalent injuries in soccer and the mechanism of injury has been associated with overstretching of the myotendinous junction (muscle strain), mainly at the level of the biceps femoris that usually occurs during powerful and long races (10). The increase in running speed in turn generates an increase in the forces acting on this muscle group making it susceptible to injury, this mechanism represents between 60% and 80% of hamstring injuries, being predominant during the final phase of the swing or swing, when the fibers perform a maximum eccentric contraction in response to the movement of knee extension and hip flexion in order to decelerate the

gesture. For these reasons, the eccentric strength deficit in this muscle group, especially at high speed, has been postulated as a clear risk factor (11).

With this in mind, hamstring eccentric training has been positioned as one of the most cost-effective strategies to prevent this type of injury (12). It has been suggested that eccentric training produces an increase in the length and strength of this muscle group favoring the correct development of sports practice (13). Additionally, it has been demonstrated that eccentric training helps to increase the hip flexion ROM, which can be translated into a greater tolerance to muscle stretching (14). However, current hamstring injury prevention protocols such as FIFA 11 employ different strategies that include various types of exercises, including Nordic exercises, which, by not clearly reproducing the functional conditions of these muscles, could lead to confusion about the true effects of these exercises (15).

In this context, the current evidence on the effects of Nordic exercises on the incidence of hamstring injuries remains heterogeneous. Despite the existence of some studies suggesting the inclusion of eccentric strengthening exercises in hamstring injury prevention programs to decrease the incidence of hamstring injuries, the effects of Nordic exercises on the incidence of hamstring injuries remain heterogeneous (3, 9). The effects of Nordic exercises alone have not yet been specifically addressed. Additionally, it is necessary to clarify the relevance of this type of exercises in adults and adolescents, given that the ages between 15 and 40 years old are characterized for being more demanding competitively, besides being a risk factor in themselves, demonstrating that it is necessary to verify the relevance of this type of exercises in adults and adolescents (8). The effectiveness and usefulness of these specific exercises in reducing the incidence of injury to the hamstring muscles needs to be verified.

MATERIALS AND METHODS

Study design

A systematic review following the recommendations of the PRISMA (Preferred Reporting Items for Systemic Review and Meta-Analyses) statement was conducted to analyze the evidence on the effectiveness of hamstring eccentric exercises focused on the prevention of hamstring injuries in male soccer players. (16) to analyze the evidence on the effectiveness of eccentric hamstring exercises focused on the prevention of hamstring injuries in male soccer players.

Documentary sources consulted

Data collection took place from March through June 2022 using electronic databases: PubMed, BVS (MEDLINE), Cochrane (PubMed, EMBASE, CT.gov, CINAHL), Web OF Science (Web of Science Core Collection, MEDLINE®),

Current Contents Connect, SciELO Citation Index) and SCOPUS. The last search was performed on June 6, 2022.

Search strategy

The following keywords were used: "Hamstring Muscles"[Mesh], "Exercise"[Mesh], "rehabilitation"[Subheading], "therapy"[Subheading]), "Athletic Injuries"[Mesh], "Soccer"[Mesh], which were combined with the following free term synonyms with the Boolean operators "AND" and "OR": "Hamstring Injuries", "Hamstring Strain", "Hamstring Muscles", "Eccentric Exercise", "Nordic Hamstring Exercise", "Eccentric Training", "Eccentric Strength", "Strength Training", Prevention, Prevent, "Injuries Prevention", "Soccer", "Soccer Athletes", "Soccer Players" and "Football".

Inclusion criteria

The articles were included according to the following criteria: (i) randomized controlled clinical trials, (ii) had at least one intervention group with Nordic exercises; (iii) had as outcome or secondary variable the incidence of hamstring injuries, (iv) were carried out with male soccer players between 15 and 41 years of age.

Exclusion criteria

Studies were excluded when: (i) the population included female soccer players or other sports; (ii) the study did not report the incidence of hamstring injuries; (iii) the results of the intervention were not compared with a control group; (iv) the full text of the article was not accessible.

Study selection process

The Rayyan platform (<https://rayyan.qcri.org/welcome>, accessed March 2022) was used to select the articles analyzed in this systematic review (17). Initially, the elimination of duplicate articles was performed to subsequently filter from the abstract and title those articles that were candidates for full reading according to the previously mentioned selection and exclusion criteria. Finally, a complete reading of the pre-selected articles was carried out to determine the studies to be included in this systematic review.

Data extraction

In order to respond to the objectives of this study, we included data on the authors, year of publication, country of publication, population characteristics, intervention characteristics, follow-up time and the results obtained with the main variable being the incidence of hamstring injuries after an intervention based on Nordic exercises.

Methodological quality assessment tool

The PEDro scale was used to assess methodological quality (18). The PEDro scale is composed of 11 items, of which 10 can be qualified as YES (1) and NO (0) for a maximum score of 10 points. An article is considered "excellent" when it has a score >9, "good" from 6 to 8 points, "fair" between 4 and 5 and "poor" when the score is <3 (19).

RESULTS

Study identification and selection process

A complete search was carried out in different databases, resulting in 253 articles plus another 4 that were found in other sources such as Google Scholar, yielding a total of 257 articles. After screening, 54 duplicate articles were eliminated, leaving a total of 203 articles that were reviewed by title and abstract. After reading, 165 articles were excluded because they did not meet the inclusion criteria, leaving a total of 38 articles for full-text analysis, of which only 5 met the inclusion criteria (20-24)(Figure 1).

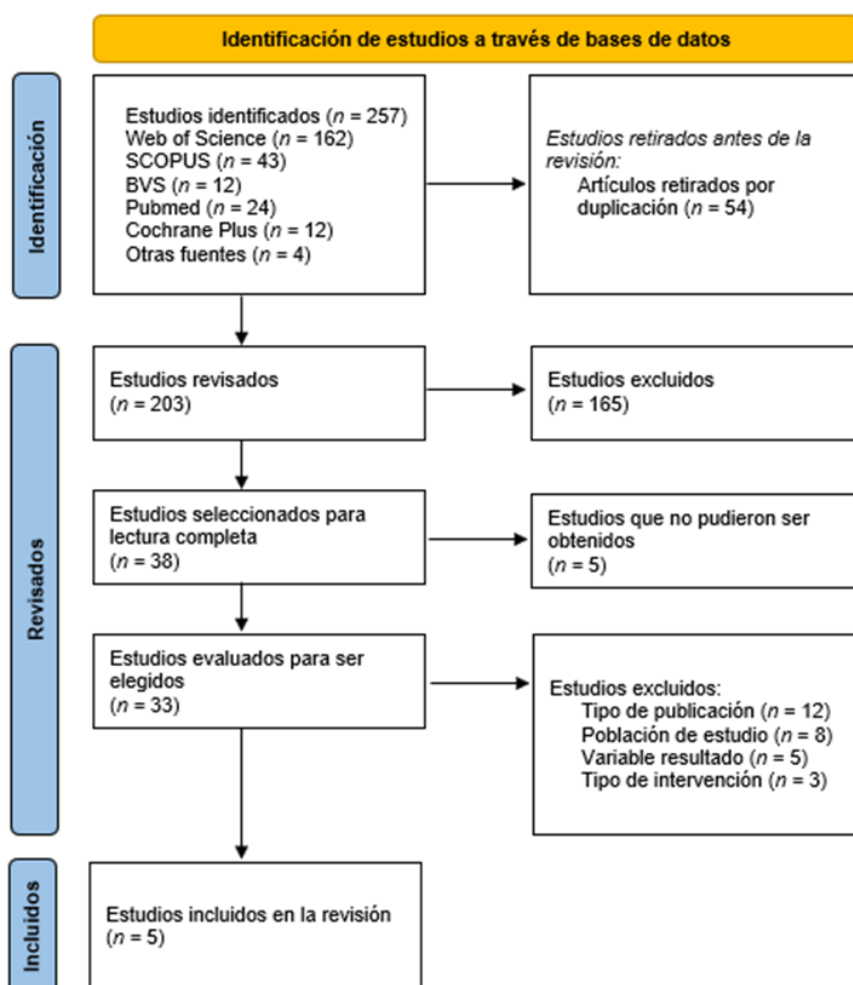


Figure 1. Flow chart of the selection process. Prisma guideline 2020

Methodological quality

Methodological quality was assessed using the PEDro scale. Of the articles included in the review, three were rated on the PEDro platform, while the remaining two were evaluated manually (20, 21, 23) platform, while the remaining two were evaluated manually (22, 24). The articles presented a score between 5 and 8, with 1 article classified as fair and 4 as good (21) and 4 as good (20, 22-24). Neither study blinded the subjects or the therapists (20-24) one of them did not establish eligibility criteria, another did not perform concealed allocation (20) another did not perform concealed allocation, yet another did not present a baseline comparison, while three studies did not blind subjects or therapists (23) while three studies did not blind the evaluators (20-22). Only two studies did not perform adequate follow-up (20, 23) while only one of them did not perform an intention-to-treat analysis (Table 1) (20) (Table 1).

Table 1. Methodological quality scale of the included articles.

Authors	Items	1	2	3	4	5	6	7	8	9	10	11	Total
Petersen et al. 2011 (20)		N	Y	Y	Y	N	N	N	Y	N	Y	Y	6
van der Horst et al. 2015 (21)		Y	Y	N	Y	N	N	N	N	Y	Y	Y	5
Elerian et al. 2019 (22)		Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Hasebe et al. 2020 (23)		Y	Y	Y	N	N	N	Y	N	Y	Y	Y	6
Chebbi et al. 2022 (24)		Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8

Items: 1 = eligibility criteria; 2 = random allocation; 3 = concealed allocation; 4 = baseline comparability; 5 = blind subjects; 6 = blind therapists; 7 = blind assessors; 8 = adequate follow-up; 9 = intention-to-treat analysis; 10 = between-group comparisons; 11 = point estimates and variability; . Y = Yes; N = No.

General characteristics of the included studies

All articles included in this review are Randomized Controlled Trials (RCT), conducted in Denmark (20-24) conducted in Denmark (20), The Netherlands (21), Egypt (22), Japan (23) and Australia (24). Their respective publications were produced in 2011 (20), 2015 (21), 2019 (22), 2020 (23) y 2022 (24). In all cases, the language of publication was English (20-24) (Table 2).

Sample characteristics

A total of 1871 men participated in the studies analyzed. The age of the participants ranged from 15 to 41 years. All the studies were conducted with soccer players (20-24). In 2 studies, the athletes were part of amateur leagues, while in 2 other studies they belonged to amateur leagues (21, 23) and in only one (20), the players were part of both amateur and professional leagues. A total of 961 athletes were part of the intervention groups and 910 of the control groups (Table 2).

Table 2. Characteristics of studies

Author	Sample (I/C)	Age	Intervention	# sesiones	Control	Data collection	Results
Petersen et al. 2011 (20)	461/481	23,25±4,00	NE pre-workout + HT	27	HT	Prior to the intervention, a report of the number of injuries presented during the last 12 months was requested. Additionally, the medical team was trained on what a hamstring injury was and asked to record them throughout 2008.	A 10-week intervention with ND decreases the rate of hamstring injury in amateur soccer players after a 12-month follow-up (p = <0.001).
van der Horst et al. 2015 (21)	292/287	24,50±3,80	NE pre-workout + HT	25	HT	Prior to the intervention, a report of the number of injuries presented during the last 12 months was requested. Additionally, the medical team was trained on what a hamstring injury was and asked to record them throughout 2013.	The injury incidence rate was 0.7 per 1000 hours of play, 0.33 in training and 1.2 in matches. Injury incidence rates were significantly (p = 0.005) different between the intervention (0.25; 95% CI, 0.19-0.35) and control (0.8; 95% CI, 0.61-1.15) groups
Elerian et al. 2019 (22)	17/17	24,35±3,80	IG1: NE pre-training + HT IG2: HT + NE post-training	23	Previous data of the team	3 months after surgery	The use of Nordic exercises as a prevention protocol was effective in reducing all hamstring injuries, regardless of whether it was pre-training or post-training.
Hasebe et al. 2020 (23)	156/103	16,50±0,55	HT + NE post-workout	54	HT	During the 27 weeks of the intervention	Nordic hamstring exercise in high school soccer players significantly reduced the severity of hamstring injuries compared to a control intervention, however, it did not reduce the number.
Chebbi et al. 2022 (24)	135/22	18 - 41 años	NE pre-workout + HT	S2013/2014= 36 S2014/2015= 20 S2015/2016= 53	HT	5 consecutive competitive seasons	The implementation of an NHE prevention program has a positive effect on the injury rate in a soccer team; however, player compliance with the interventions can be critical to its success

NE: Nordic Exercises; HT: Habitual Training; T: Season; #: Number

Intervention of studies

All studies included Nordic exercise as an intervention. (20-24). Three studies performed the intervention just before the usual training, another one performed it after the training (20, 21, 24), another one performed it post-training (23) and only one study compared pre- and post-training effects (22).

The number of intervention sessions in the studies was different, Elerian et al. (22) established two intervention groups, performing 50 sessions for the first group in which they combined pre- and post-training training while the second group only performed 25 pre-training sessions. Three of the studies ranged from 25 sessions (20), 27 sessions (21), up to 54 sessions (23).

Finally, in the study by Chebbi et al. (24) 3 different interventions were performed, ranging from 20, 36 and 53 sessions.

The duration of the interventions was also different between studies, ranging from 10 weeks (20), 12 weeks (22), 13 weeks (20), 27 weeks (23) and up to 5 years (24). The control groups in four studies (20, 21, 23, 24) training while only one study considered as a control group data from the same subjects (22) considered as control group data from the same subjects taken 3 months before the intervention.

Regarding the progression of the intervention, three of the studies followed a stepwise (20, 21, 24) followed a gradual increase protocol designed by Petersen et al. (20) in which, during the first week, the athletes performed 1 session of 2 sets of 5 repetitions each of Nordic exercises, then in week 2 it was increased to 2 sessions per week of 2 sets of 6 repetitions, during week 3, 3 sessions of 3 sets of 6 to 8 repetitions were performed, in week 4 the 3 sessions and 3 series were maintained but with an increase of 8 to 10 repetitions per series to finally reach in week 5 a frequency of 3 sessions of 3 series starting with 12 repetitions, then 10 and ending with 8 repetitions, maintaining this volume of work for the number of weeks that each study design was carried out. Hasebe et al. (23) followed the protocol of Petersen et al. (20) but extended it for a greater number of weeks, making the increase more staggered, starting with one session per week, with two sets of five repetitions until reaching a maximum of two sessions per week, each of 3 sets of 10, 9 and 8 repetitions in week 14. Finally, Elerian et al.

(22) Finally, Elerian et al. proposed the progression of the pre-training intervention group following the guidelines of Lovell et al. (25) starting with a workload in the first week of 10 repetitions divided into 2 sets until reaching a total of 96 repetitions divided into 4 sets in week 12 of their intervention, while for the post-training intervention group they established a lower volume, starting with 5 repetitions in week 1 until progressing to a volume of 48 repetitions in week 12.

Incidence of hamstring injury

All studies included in this review (20-24) measured the incidence of hamstring injury during or following Nordic exercise intervention. In one of them (20) the incidence of injury per 100 players was measured and a significant difference was found between the intervention group and the control group ($p < 0.001$, CI: 0.150 - 0.572), three studies measured the total number of injuries per 1000 hours played (21, 22, 24) van der Horst et al. (21) reported an injury incidence of 0.7 (95% CI, 0.6-0.8). Elerian et al. (22) reported a significant difference between both intervention groups ($p < 0.05$), showing that the percentage of injury in intervention group 1 (pre-training ND) was 5.9%, intervention group 2 (post-training ND) 17.6% and the control group 35.1%. In turn, Chebbi et al. (24) after a 5-year follow-up reported an incidence of injury corresponding to 0.95 per 1000 hours of play, showing a higher risk of injury in the group with low compliance with the ND protocol (OR: 1.77, CI: 0.57 - 5.47, $p = 0.32$). Finally, the study by Hasebe et al. (23) measured the incidence of injury per 10,000 hours of competition, finding a non-significant difference ($p = 0.83$) between the control group (1.04) and the ND intervention group (0.88).

Follow-up of subjects

Follow-up of athletes was different for each study. Two studies followed up only while the intervention was being performed; of these, one study followed up for 3 months while the other study followed up for 7 and a half months. (22) was done for 3 months while the other was followed for 7.5 months. (23). Two other studies (20, 21) two studies followed up for 12 months after the intervention and, finally, one study followed up for 5 years. (24).

Treatment compliance

All studies measured (20-24) measured treatment compliance. One study reported 99.3% compliance, the highest among all the studies analyzed. (22)the highest among all the studies analyzed. Two other studies (20, 21) mentioned that the percentage of compliance was 91% while one study presented a compliance of 88%. (23). Finally, Chebbi et al. (24) stratified the athletes studied according to the level of compliance with the protocol, those athletes who complied with <20% were classified as low, between 20 and 70% moderate and >70% as high.

Results of the studies

All the studies (20-24) concluded that the implementation of Nordic exercises during training in professional and amateur soccer players has positive effects in decreasing the incidence of hamstring muscle injuries in soccer players. A study (22) evidenced that the decrease in injury rate is indifferent to the timing of the Nordic exercises, either pre-workout or post-workout. In terms of injury severity, Peterson et al. (20) reported that Nordic exercise does not modify injury severity, while Hasebe et al. (23) stated the opposite. Finally, one study (24) concludes that compliance with interventions could be associated with success in decreasing the incidence of hamstring injury.

DISCUSSION

The aim of this study was to determine the effects of eccentric hamstring training from Nordic exercises on the incidence of hamstring injuries in male soccer players. The results of this systematic review showed that Nordic exercises, pre- or post-training, reduce the incidence of hamstring injuries in male soccer players as long as there is a high compliance rate with the Nordic exercise program. However, there is no consensus regarding the influence on the severity of these injuries, an aspect that may be mainly linked to the methodological differences employed by the studies.

Other authors had already performed a systematic review with meta-analysis to study the effects of eccentric training on hamstring

injuries, however, compared to this study, there were multiple methodological differences. On the one hand, Goode et al. (26) focused their study on the effects of eccentric exercises, including different training methods, among these Nordic exercises; additionally, they contemplated different sports disciplines and included as an outcome variable the gross number of hamstring injuries, concluding that eccentric training was not effective for the prevention of hamstring injuries. However, these authors attributed their results to adherence and compliance to intervention protocols. On the other hand, Al Attar et al. (27) in their systematic review with meta-analysis also studied the incidence of hamstring injury in soccer players, however, like Goode et al. (26) implemented intervention protocols that combined Nordic exercises with other types of training. Additionally, this review with meta-analysis expanded its sample to include women, and was conducted 7 years ago, and new evidence has since emerged that focuses solely on Nordic exercises. Finally, none of these reviews looked at the follow-up time of the players, the duration of the intervention protocols or the timing of the intervention, pre- or post-training.

Given that Nordic exercises produce a significant improvement in knee flexor strength on the hamstrings, which translates into an improvement in running (33). (28) which translates into an improvement in running (29) and in addition produce an increase in the length of the long head of the biceps femoris (30) In addition, it is inferred that these effects may directly influence the mechanisms of injury that occur in soccer players, who show ruptures in the final swing phase of the stroke. (31, 32). Taking into account these considerations, increasing the length of the long head of the biceps femoris could improve the eccentric phase of the gesture, helping to support the different forces that are generated during sudden changes of direction and the running gesture on these structures. (33) This could translate into a decrease in the incidence of this type of injury.

In this sense, Petersen et al. (20), Van der Horst et al. (21), Elerian et al. (22) and Chebbi et al. (24) agree that Nordic exercises decrease the incidence of hamstring injuries. Only Hasebe et al. (23) concluded that Nordic exercises would have no effect on the incidence of this type of injury. However, although their results were not statistically significant, they were clinically relevant as they observed a decrease in the incidence of injury in the Nordic exercise group when compared to the control group. The results of Hasebe et

al. (23) could be mainly due to the sample used, given that they conducted their study in an adolescent population, with a sample calculation that was not entirely clear, without initial comparison or adequate follow-up of the population, suggesting interpretative bias in their results.

Of the studies analyzed, only Petersen et al. (20) and Van der Horst (21) conducted a prolonged follow-up of the subjects after their interventions. Although Chebbi et al. (24) based their study on data collected for 5 seasons of competitive soccer, these authors did not end their interventions at a clear time, they maintained them throughout the observation period, as did Elerian et al. (22) and Hasebe et al. (23).

The incidence of different injuries in high level soccer has remained constant during the last years, regardless of the improvements in the protocols or their innovation; multiple reasons have been found for this problem: gaps in the scientific evidence to support intervention protocols (34), communication problems between the staff of the different teams (35), and, of course, problems of adherence and compliance with the protocols (36, 37). Different authors agree that one of the main factors associated with the success of Nordic exercise intervention is the adherence to protocols. (22, 38). In this sense, a high percentage of compliance with the protocols in the studies analyzed, with the exception of Chebbi et al. (24) could be the reason for the effects observed.

Additionally, this systematic review analyzed the effectiveness of Nordic exercises performed pre-training, post-training or a combination of both, evidencing that the favorable effects of Nordic training are obtained regardless of when it is performed. This is contrary to the findings of Van der Horst (21) who concludes that pre-training Nordic exercises are not sufficient to prevent hamstring injury. However, multiple authors (20, 31) have evidenced favorable effects from the pre-training application, in addition, Elerian et al. (22) in their study did not find significant differences in relation to the incidence of injury, although they did find an increase in muscle length of 0.2 cm and a change in the angle of fascicle penetration of 2.14°, both necessary conditions for reducing the risk of injury.

Sport is a science of constant reinvention, where injuries play a fundamental role since they reduce the playing time of athletes, which translates into monetary losses. This study sought to establish the scientific bases that allow the design and implementation of training programs, based on Nordic exercises, that decrease the incidence of hamstring injuries in male soccer players, highlighting duration and compliance as key factors.

LIMITATIONS AND FUTURE PATHS

This systematic review has several limitations, such as the great heterogeneity among the studies in terms of time of application of the protocols and follow-up of the subjects. Additionally, a geographical bias should be taken into account, given that the studies were published in Europe (40%), Africa (20%), Australia (20%) and Asia (20%), there is a possibility that the effects of Nordic exercises cannot be generalized to the Americas. Finally, given that the studies analyzed do not specifically mention the activities carried out by the control groups, we should not rule out the possibility of interaction of covariables that could generate alterations in the results.

CONCLUSIONS

Nordic exercises decrease the incidence of hamstring injuries in male Soccer players between the ages of 18 and 41 years, however, their effects in 15- to 18-year-olds have not yet been adequately demonstrated.

The effects of this type of exercise depend mainly on the percentage of compliance with the protocols. Consequently, a low level of compliance is associated with a higher incidence of injury. However, the timing of execution of Nordic exercises, whether pre-, post-workout or a combination of both, does not seem to influence the benefits provided by these exercises in decreasing the incidence of injury to the hamstring musculature.

Additionally, due to the heterogeneity of the evidence, a direct relationship between the effects of Nordic exercises and the severity of hamstring injury cannot yet be established. More research in the field, better follow-up of the study subjects and standardization of the intervention protocol both in number of weeks, progression and volume of the exercises are still required. The standardization of a

protocol would allow adequate evidence of the effects of Nordic exercises in soccer players.

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