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PREVENTION OF HAMSTRING INJURIES IN SPORT: A SYSTEMATIC REVIEW

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ABSTRACT

Hamstring strains are one of the most prevalent and recurrent injuries in sport. The main mechanism of hamstring injuries involves the eccentric muscle loading associated with the terminal swing-phase during sprinting. Risk factors for hamstring strains can be divided into intrinsic risk and extrinsic factors. The main aim of this study was to develop strategies for the prevention of hamstring injuries in sport. A systematic review methodology was used to analyse evidence-based strategies for preventing hamstring injuries in sport. The search strategies used online database searching, hand searching, snowballing and keyword searches. Only articles published between 2000 and 2013 were considered. Strict inclusion and exclusion criteria were applied. Of the 1153 articles reviewed, 32 articles were evaluated in depth. Finally, only four studies were analysed. Three of the four studies used interventions consisting of Nordic eccentric hamstring exercise training, while the fourth study used a variety of eccentric exercises. All reported a significant decrease in hamstring injuries (p<0.05). Two studies identified significant risk factors for hamstring injuries, namely increasing age (>24 years), previous hamstring injury (within the last 12 months) and thigh muscle imbalances. The performance of eccentric hamstring exercises has a preventative effect on hamstring injuries in sport.

Keywords: Hamstring; Injury prevention; Nordic hamstring eccentric exercise.

INTRODUCTION

Hamstring injuries are common, particularly among athletes who sprint, jump, kick and perform cutting manoeuvres (Petersen & Holmich, 2005; Ekstrand *et al*., 2011; Liu *et al*., 2012; Mason *et al*., 2012; Orchard *et al*., 2013). Hamstring strains are also one of the most recurrent injuries experienced in the sporting world and often result in significant time out of sport activities (Woods *et al*., 2004; O'Sullivan *et al*., 2009; Liu *et al*., 2012).

Hamstring injuries account for about 29% of injuries among sprinters (Lysholm & Wiklander, 1987), 12% to 17% of injuries in professional soccer players (Woods *et al*., 2004; Ekstrand *et al*., 2011; Goldman & Jones, 2011), 8% to 23% of injuries in Australian Rules Football (Gabbe *et al*., 2006b), and 6% to 15% in rugby union (Brooks *et al*., 2006). Hamstring strains in sport have a re-injury rate of between 12% and 34% (Woods *et al*., 2004; Orchard *et al*., 2005; Petersen & Holmich, 2005; Gabbe *et al*., 2006a, 2006b; Hägglund *et al*., 2006; Mendiguchia & Brughelli, 2011) resulting in substantial playing time lost. This can result in large financial losses to both the athlete and his/her club or team, as well as to the sponsors (Woods *et al*., 2004; Gabbe *et al.*, 2006a).

Many risk factors have been associated with hamstring injury. These risk factors can be divided into intrinsic and extrinsic risk factors. Intrinsic factors include inadequate muscle strength, imbalance in the hamstring to quadriceps strength ratio, side-to-side differences, lack of flexibility, muscle fatigue, poor neuromuscular control, insufficient warm-up, male gender (men are 64% more at risk), increasing age (>24 years), ethnicity (black or Afro-Caribbean players or players from Aboriginal descent), previous hamstring injuries, anterior pelvic tilt and poor lumbo-pelvic stability. Extrinsic risk factors may include a high training volume (>12.5 hours/week), a high competition level (higher risk for injury at higher levels of play), cold weather and ground hardness (Cameron *et al*., 2003; Foreman *et al*., 2006; Soligard *et al*., 2008; Brukner & Khan, 2009; Liu *et al*., 2012; Twomey *et al*., 2012; Cross *et al*., 2013; Hrysomallis, 2013).

As common as hamstring injuries are, their causes can also be complex and multi-factorial (Foreman *et al*., 2006; Liu *et al*., 2012). Hamstring injuries that occur during activities, such as dancing or kicking occur during movements that involve simultaneous hip flexion and knee extension (Heiderscheit *et al*., 2010). Hamstring injuries commonly occur in sports where sprinting is involved, in sports requiring rapid knee extension and maximal hamstring muscle lengthening, as well as rapid acceleration and kicking (Gabbe *et al*., 2006a; Gabbe *et al.*, 2006b; Higashihara, *et al*., 2010; Goldman & Jones, 2011). The main mechanism of hamstring injuries during sprinting is the eccentric contraction associated with the terminal swing phase during high-speed running (Gokaraju *et al*., 2008; Heiderscheit *et al*., 2010). The biceps femoris muscle is most commonly damaged in injuries occurring as a result of sprinting (Koulouris & Connell, 2006; Askling *et al*., 2007), with injuries most commonly presenting at the muscle origin at the ischial tuberosity (Croisier, 2004; Gibbs *et al*., 2004; Heiderscheit *et al.*, 2010).

PURPOSE OF STUDY

The rationale for this study is based on the fact that since hamstring injuries have a high incidence in competitive sport and because these injuries impact negatively on performance, income and medical costs, the prevention of hamstring injuries is an important goal in competitive sports settings. Previous research on the prevention of hamstring injuries in sport has been conducted with varying findings (Foreman *et al.*, 2006; Hibbert *et al*., 2008; Goldman & Jones, 2011; Rogan *et al*., 2013).

Thus, the aim of this systematic review was to determine the effectiveness of different exercise interventions in preventing hamstring injuries in competitive sport. The research question was formulated in accordance with the well-known PICOS model (Hemingway & Brereton, 2009; Uman, 2011):

Population: Competitive athletes older than 16 years, but younger than 35 years;
Interventions: Physical exercise training;
Comparator: Different exercise interventions compared to each another and/or to controls;
Outcomes: Incidence of hamstring injuries;

Study design: Randomised controlled trials (RCTs) and cohort studies were eligible for inclusion.

METHODOLOGY

Research design

The present systematic review followed the five steps suggested by Hemingway and Brereton (2009):

1. *Defining an appropriate healthcare question*: "Which exercise interventions are effective in preventing hamstring injuries in competitive sport?";
2. *Searching the literature*: Using strict inclusion and exclusion criteria;
3. *Assessing the studies*: Using levels of evidence (AHRQ, nd; OCEBM, 2015);
4. *Combining the results*: Arriving at a consensus statement by using independent reviewers (CPG & LL);
5. *Placing the findings into context*: Discussing the findings.

Search methods

On-line databases (EBSCO Host Academic Search Complete, SciVerse & Springer Link) were used to conduct a comprehensive search for articles on the prevention of hamstring injuries in sport (Hek, 1996; Hemingway & Brereton, 2009). The search strategies used were online database searching and snowballing. The following keywords were used during electronic searches: "hamstring" and "injury" and "prevention" and "sport" (Foreman *et al*., 2006). All searches were undertaken between December 2011 and October 2013. A manual search was performed using the reference lists of retrieved articles (Hek, 1996; Foreman *et al*., 2006).

Eligibility criteria

Predetermined *inclusion criteria* were used to prevent selection bias when articles for the systematic review were obtained. The following inclusion criteria were used in the selection of research studies:

- Hamstring injuries;
- Sports-related injuries only (training and match injuries);
- Male and female competitive athletes (>16 years & <35 years);
- Professional and amateur athletes;
- Peer-reviewed articles published in scholarly journals;
- Publications between 2000 and 2013 (14 years);
- Full-text articles with references;
- Primary sources and well-referenced secondary sources;
- English-language sources;
- Randomised controlled trials and prospective cohort studies;
- Only studies that utilised "exercise training" to prevent hamstring injuries.

The following *exclusion criteria* were used in the selection of research studies:

- Systematic reviews;
- Literature reviews;
- Inadequately referenced secondary sources;
- Abstracts;
- Foreign language sources;
- Studies involving fewer than 100 participants;
- Studies with serious methodological flaws;
- Studies that reported poor compliance with regard to the intervention (<45% compliance);
- Social and recreational athletes;
- Studies focusing on the rehabilitation of hamstring injuries;
- Studies that utilised strategies other than "exercise training" to prevent hamstring injuries;
- Studies focusing on the prevention of multiple injuries, such as "lower-limb injuries" (the focus had to be hamstring injuries).

Study selection and bias

The titles and abstracts of studies were assessed for inclusion on the basis of the eligibility criteria, and studies that did not meet the criteria were excluded. If there was insufficient information in the title or abstract to make a sound judgement regarding inclusion or exclusion, the full text was assessed. Disagreements on inclusion of studies between the two reviewers were solved by consensus. By adhering to the strict pre-determined eligibility criteria mentioned above, the risk of selection bias was minimised. Selection and/or allocation bias that may have occurred within the studies under review was highlighted (non-randomised group allocation in clinical trials) and the blinding of researchers and participants within each trial was evaluated.

Quality assessment of studies

The level of evidence of each article was rated using two different methods: the Oxford Centre for Evidence-Based Medicine scale (OCEBM, 2011) and the Agency for Healthcare Research and Quality scale (AHRQ, nd).

Data collection process

All searches were performed between December 2011 and October 2013. Data was extracted using a standardised form that included the following headings: authors, research design, participants, interventions and outcomes.

Analysis

The findings from the individual studies were analysed to produce a "bottom line" or consensus statement on the effectiveness of exercise interventions in preventing hamstring injuries in competitive sport. The minimum level of statistical significance accepted was a confidence level of 95% ($p<0.05$). This study did not set out to perform any meta-analysis or other means of pooled statistical analyses.

RESULTS

Results of the search

The systematic review search strategy resulted in a total of 1152 articles that were evaluated (511 from EBSCO Host, 304 from SciVerse, 336 from Springer Link and one article from manual searching). Of the 1152 articles, 42 were excluded due to duplication. The article titles of the remaining 1110 were reviewed and the abstracts assessed of which 1077 were not specifically related to the prevention of hamstring injuries in sport. A total of 33 articles were subsequently reviewed and evaluated in depth. Finally, only four studies were included in the present study (Figure 1).

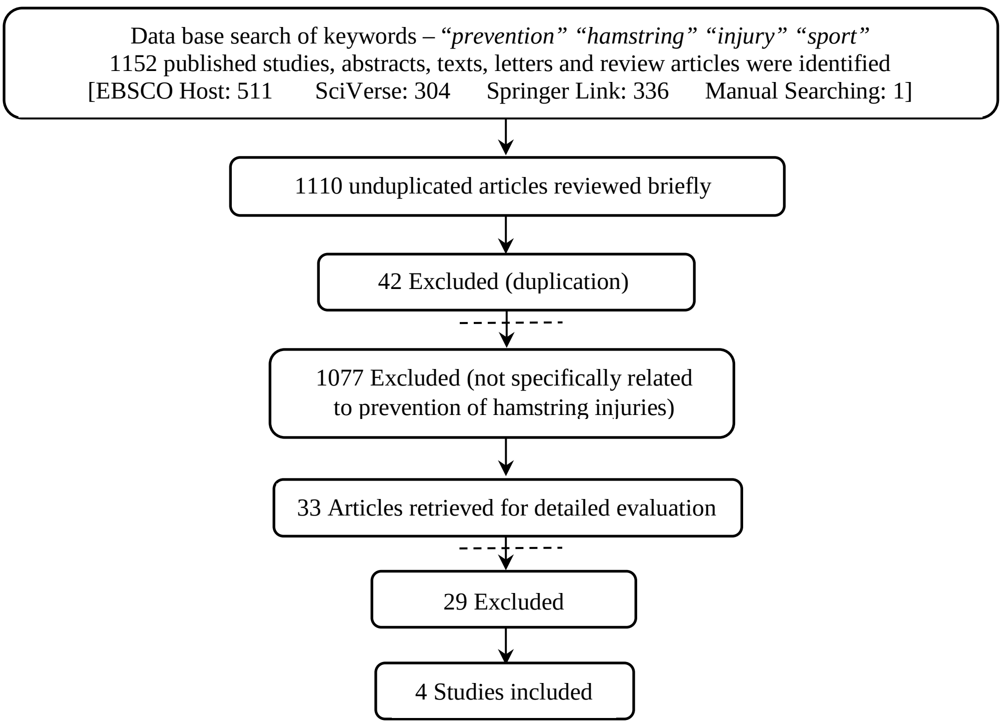

Figure 1. **SUMMARY OF ARTICLE SELECTION PROCESS**

Setting

The studies included represented research from the UK, Denmark, Iceland, Norway, Belgium, Brazil and France. Three studies utilised soccer/football players (n=4140), while the fourth utilised rugby union players (n=546). All the participants were professional players, except for one study that used both amateur and professional players (Petersen *et al*., 2011), and only male participants were included. Study durations varied between nine months and four years and the total sample consisted of 4686 players.

Methodological quality

Three cohort studies and one cluster-randomised controlled trial were utilised. The levels of evidence for the included studies ranged between I and III (Table 1) and their methodological quality varied between "fair" (PEDro: 4-5; 3 studies) and "good" (PEDro: 6-8; one study) (PEDro, 2016).

Table 1. **SUMMARY OF METHODOLOGICAL QUALITY**

Study	**Research design**	**Level of evidence** (OCBM, 2011)	**Level of evidence** (AHRQ, nd)
Arnason *et al. (*2008) Prevention of hamstring strains in elite soccer: An intervention study	Quasi-experimental cohort study	III	III
Brooks *et al. (*2006) Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union	Prospective cohort study	III	III
Croisier *et al. (*2008) Strength imbalances and prevention of hamstring injury in professional soccer players: A prospective study	Prospective cohort study	III	III
Petersen *et al*. (2011) Preventative effect of eccentric training on acute hamstring injuries in men's soccer: A cluster-randomised controlled trial (RCT)	RCT	I	II

A summary of details of the four included studies is displayed in Table 2 (to follow). Two studies included a 'Control Group' for comparing the effectiveness of their interventions. The major limitations of the selected studies were the absence of randomisation and the lack of blinding of participants, therapists and assessors/researchers. The aforementioned limitations are characteristic of most research performed in a competitive athletic setting, since individual randomisation is not well tolerated by coaches and the blinding of researchers precludes the execution of large research studies that are conducted in more than one country or in more than one team. Thus, the risk of bias was not eliminated in the four studies, resulting in lower PEDro scores.

***Table 2*. SUMMARY OF STUDIES INCLUDED**

Authors	Research design	Participants	Group allocation	Outcomes
Arnason *et al.* (2008) Prevention of Hamstring Strains in Elite Soccer: An Intervention Study	Prospective cohort study using a control group and 2 intervention groups; Study duration: 4 years	2736 Elite, male soccer players from Iceland and Norway	Control group; Added stretch training: 3x/week in preseason & 1-2x/week during season; Added Nordic ECC hamstring exercises: 3x/week in preseason & 1-2x/week during season. *Note:* All 3 groups utilised hamstring stretches (in a straddled position) (3 x 20 seconds) during their normal warm-up.	• Adding Nordic ECC hamstring exercises resulted in a 65% lower incidence of hamstring strains compared to the Control Group (RR: 0.35; p<0.001); • The incidence of hamstring strains was lower in teams who used the eccentric training programme compared with teams that did not use the programme (RR: 0.43; p=0.01), as well as compared with baseline data for the same intervention teams (RR:0.42; p=0.009); • Adding stretching exercises did not significantly lower hamstring injury rate (p=0.22) compared to the Control Group (RR: 1.53), but it reduced the severity of injury compared to the Control Group (p=0.006); • Furthermore, no difference was found in incidence of hamstring strains between stretching intervention group and all teams of previous year (RR: 1.03; p=0.91); • The proportion of re-injuries was not different between the intervention (36%) and control teams (39%) (p=1.0).
Brooks *et al.* (2006) Incidence, risk, and prevention of hamstring muscle injuries in professional Rugby Union	Prospective cohort study using 3 intervention groups; Study duration: two years & two seasons (2002-2003 & 2003-2004).	546 Male, professional rugby union players from the English Premiership	Strengthening (CON & ECC) Group (n=148); Strengthening (CON & ECC) & static stretching Group (n=144); 3. Strengthening (CON & ECC) & static stretching plus Nordic eccentric hamstring exercises Group (n=200)	• Adding Nordic ECC hamstring exercises significantly reduced the incidence hamstring injuries (p<0.05) in Group 3, compared to strengthening alone (Group 1); • No significant difference was observed for incidence of hamstring injuries between Group 1 2 (p>0.05); • 164 injuries in total (127 new & 37 recurrent injuries); • Group 1: 1.1 injuries/1000 player hours; 17 days lost); • Group 2: 0.59 injuries/1000 player hours; 21 days lost); • Group 3: 0.39 injuries/1000 player hours; 14 days lost).

Authors	**Research design**	**Participants**	**Intervention**	**Outcomes**
Croisier *et al.* *(*2008) Strength imbalances and prevention of hamstring injury in professional soccer players: A prospective study	Prospective cohort study using four different groups; Study duration: 9 months.	687 Male, professional soccer players from Belgium, Brazil and France (143 players lost to follow-up, thus 462 players completed the follow-up).	Players divided into 4 groups according to observed isokinetic imbalances and management approach: No preseason isokinetic imbalances (n=246); Preseason isokinetic imbalances and no compensating training (n=91); Preseason isokinetic imbalances and compensating training but no further isokinetic testing (n=55); Preseason isokinetic imbalance and compensating training until normalisation verified by subsequent isokinetic testing (n=70)	• A significant reduction in hamstring injury was observed in the players who received effective correction of isokinetic imbalances (Group 4) compared to the players with untreated isokinetic imbalances (Group 2) (RR: 0.31; p=0.044), but not significantly different to Group 1 (RR: 1.43; p=0.56); • The rate of hamstring injury was significantly increased in players with untreated isokinetic muscle imbalances (Group 2) compared to players with normal isokinetic values (Group 1) (RR: 4.66; p=0.0003); • Compensating training without further isokinetic testing (Group 3) did not result in significant lower risk for hamstring injury compared to players with untreated isokinetic imbalances (Group 2) (RR: 0.62; p=0.36), but Group 3 had a significantly higher risk for injury compared to Group 1 (RR: 2.89; p=0.0493).
Petersen *et al*. (2011) Preventive effect of eccentric training on acute hamstring injuries in men's Soccer: A cluster-RCT	Cluster-randomised controlled trial Control Group & Intervention Group; Study duration: 12 months	942 Danish male amateur and professional soccer players	Intervention Group: performed Nordic ECC hamstring exercises (n=461; 36 lost to follow-up) Control Group: followed usual training programme (n=481; 43 lost to follow-up)	• Intervention Group (Nordic ECC hamstring exercises) experienced 60% fewer new hamstring injuries (RR: 0.410; p=0.034) and 85% fewer recurrent injuries (RR: 0.137; p=0.003) compared to Control Group. Intervention Group experienced significantly fewer total number of hamstring injuries compared to the Control Group (RR: 0.293; p<0.001). NNT to prevent one injury: 13; NNT one new injury: 25; NNT one recurrent injury: 3.

None of the four studies contained incomplete outcome data and none of the studies reported selectively on the outcomes. Although there was a moderate risk of bias, the projects were conducted in a real-world, competitive athletic setting that poses real problems to investigators wishing to conduct research. Wood *et al.* (2008) emphasised that the use of an objective measure, defined as an outcome that cannot be influenced by the researcher's judgement (an injury), minimises the risk of introducing bias attributed to group allocation in open studies.

Another weakness of the included studies was that an injury was not defined in a uniform manner. Some researchers described an injury as an incident that prevented the player from taking part in one or more training session or match (Brooks *et al*., 2006; Arnason *et al*., 2008; Petersen *et al*., 2011), while other researchers described an injury as an event that resulted in a player missing four weeks of playing time (Croisier *et al*., 2008).

Strong points of the selected studies included the clear eligibility criteria used for inclusion, with the result that only injury-free, competitive players were included in all four studies. All four of the studies also excluded contusion and collision injuries, which strengthened the analysis (Brooks *et al*., 2006; Arnason *et al*., 2008; Croisier *et al*., 2008; Petersen *et al*., 2011).

Interventions

The following exercise interventions were used to try to prevent hamstring injuries:

- Warm-up;
- Static stretching;
- Strengthening;
- Nordic eccentric hamstring exercises.

Compliance in all four studies was good, with a compliance of more than 50% reported for all studies. Training frequency varied between once a week and three times per week. In some studies, interventions were combined, like warm-up and stretching or stretching and strengthening. The duration of interventions varied between one season and four seasons. Three of the four studies explicitly utilised Nordic eccentric hamstring lowers as part of their intervention protocol (Brooks *et al*., 2006; Arnason *et al*., 2008; Petersen *et al*., 2011), while the fourth study utilised undisclosed isolated manual, isotonic and isokinetic hamstring strengthening exercises (Croisier *et al*., 2008).

Outcomes

No conflicting findings were reported among the four different studies selected. The three studies that utilised Nordic eccentric hamstring exercise training as an intervention all reported significant ($p<0.05$) reductions in the incidence of hamstring muscle injuries compared to controls and compared to other exercise interventions (Brooks *et al*., 2006; Arnason *et al.*, 2008; Petersen *et al*., 2011). The fourth study indicated that hamstring injuries may be reduced if preseason isokinetic muscle imbalances between the quadriceps and hamstrings were corrected – more specifically, when the eccentric hamstring to concentric quadriceps ratio (H_{ecc}/Q_{con}) was corrected (Croisier *et al*., 2008). Including additional static stretching to the players' normal training programme did not significantly lower their hamstring injury rate

($p>0.05$) (Brooks *et al*., 2006; Arnason *et al*., 2008), but it significantly reduced the severity of hamstring injury ($p<0.05$) compared to the controls (Arnason *et al.*, 2008). Preseason isokinetic testing was an effective method to predict the risk of future hamstring injuries in male, professional soccer players (Croisier *et al*., 2008).

DISCUSSION

Since hamstring injuries are extremely prevalent in sport, researchers have been searching for effective strategies to reduce the number of new and recurrent injuries. The main aim of this study was to determine the effectiveness of different exercise interventions in preventing hamstring injuries in competitive sport. A systematic review methodology was utilised to achieve this aim.

Only four studies were eligible for inclusion and of the four studies only one study (Petersen *et al*., 2011) was a clustered-randomised controlled trial. Due to the heterogeneous nature of the four studies the present researchers performed a qualitative analysis on the four studies included. The levels of evidence for the included studies ranged between I and III and their methodological quality varied between "fair" and "good" (PEDro, 2016). Only two studies included a control group for comparing the effectiveness of their interventions. The major limitations of the selected studies were the absence of randomisation and the lack of blinding of participants, therapists and assessors/researchers. Three themes emerged from the four included studies.

The first theme that emerged was that adding Nordic eccentric hamstring exercises to normal training significantly reduced the number of new and recurring hamstring injuries (Brooks *et al*., 2006; Arnason *et al.*, 2008; Petersen *et al*., 2011). The overall incidence of hamstring injuries decreased significantly by 65% to 70% in two of the three studies using Nordic eccentric hamstring exercises compared to their controls (Arnason *et al.,* 2008; Petersen *et al*., 2011) and the number of recurring hamstring injuries reduced by 85% (Petersen *et al*., 2011). The third study (Brook *et al*., 2006) did not provide exact data, but they reported that adding Nordic eccentric hamstring exercises to stretching and strengthening resulted in significantly fewer hamstring injuries compared to either stretching and strengthening or strengthening alone.

Previous systematic reviews that also reported on the effectiveness of eccentric hamstring exercises in preventing hamstring injuries did not come to definitive conclusions. Porter and Rushton (2015) reported that although two RCTs (Askling *et al*., 2003; Petersen *et al*., 2011) reported statistically significant reductions in hamstring injuries when eccentric exercise was used as an intervention, more RCTs were needed to confirm this finding. Goldman and Jones (2011) concluded that their findings on the possible benefits of using eccentric hamstring exercises were inconclusive, since two studies (Gabbe *et al*., 2006b; Engebretsen *et al*., 2008;) did not show any reduction in hamstring injuries, while one study (Askling *et al*., 2003) showed a lower incidence of hamstring injuries when eccentric hamstring exercises were used. Hibbert *et al*. (2008) suggested that although eccentric hamstring training was effective in preventing new and recurring hamstring injuries, more RCTs were needed to confirm their findings.

It has been suggested that one of the reasons for a hamstring injury is the rapid change in muscle contraction from eccentric to concentric (Hoskins & Pollard, 2005). It is hypothesised that eccentric muscle training causes neuro-adaptation of the muscle group that would help protect it when under strain and thus decrease the injury rate (Clark *et al*., 2005; Brooks *et al*., 2006; Gabbe *et al*., 2006b; Naclerio *et al*., 2013). FIFA's Medical Assessment and Research Centre (FMARC) utilises both concentric and eccentric isokinetic knee testing during the pre-participation examination in an attempt to prevent injuries during the season (Brito *et al*., 2010).

Muscular adaptations resulting from eccentric training include an increase in the cross-sectional area of the muscle and specific neural adaptations, such as increased motor unit activation, a decreased activation of antagonistic muscles and a change in the angle of peak torque that may prevent hamstring strains (Higbie *et al*., 1996; Gabbe *et al*., 2006b; Brughelli & Cronin, 2007; Naclerio *et al*., 2013). In addition, eccentric exercise also relies on the involvement of the non-contractile components of the muscle, such as the connective tissue layers (epimysium, perimysium and endomysium).

It is also hypothesised that actomyosin cross-bridge bonds are mechanically disrupted during intense eccentric muscle contractions, as opposed to the ATP-dependent detachment that occurs during concentric actions. This mechanical detachment will initially result in tissue damage until the athlete's muscles have adapted to these new stresses that occur during eccentric actions (McLester & St. Pierre, 2005). Thus, eccentric exercise would result in additional training adaptations when compared to concentric exercise (Fridén & Lieber, 2001). Eccentric contractions are also an integral part of normal functional activities like running. The current authors are of the opinion that the above-mentioned unique attributes of eccentric exercise training are responsible for its injury prevention properties.

Although performing Nordic hamstring curls does carry with it some degree of risk for injury and delayed onset muscle soreness (DOMS), none of the four studies included in this review reported an injury as a result of the eccentric hamstring strength training. This finding by the present researchers is supported by previous research (Mjølsnes *et al*., 2004). However, several reports of extreme DOMS and athletes discontinuing the exercises were reported. This should be taken into account in future research studies (Askling *et al*., 2003; Gabbe *et al*., 2006b).

Other themes that emerged from this systematic review were, firstly, that the addition of extra static stretching exercises to normal training did not significantly reduce the incidence of hamstring injuries (Brooks *et al*., 2006; Arnason *et al*., 2008), but that it reduced the severity of injury (Arnason *et al*., 2008). A second theme that emerged was that isokinetic testing of players during the preseason was an effective method of identifying an increased risk for hamstring injuries in players who had muscle imbalances between the quadriceps and the hamstrings and that by correcting these imbalances the number of injuries could be reduced (Croisier *et al.*, 2008).

STRENGTHS AND LIMITATIONS

Possible limitations of the present study included the fact that non-English papers and "grey" literature were excluded from the systematic review and that the present review study included only male athletes. Another limitation is the small number of high-level studies available for review and the presence of bias in most large cohort studies.

Possible strengths of the current study are the large number of participants included and the fact that all four of the included studies found that eccentric training resulted in a significant reduction in both new and recurrent hamstring injuries. The small number of eligible articles currently available on the prevention of hamstring injuries in sport, highlights the need for well-designed RCTs in future, especially in female athletes and in sports other than soccer and rugby union.

CONCLUSIONS

In summary, four studies were included in this review following a comprehensive analysis of the available literature between 2000 and 2013. Significant reductions in the incidence of new and recurrent hamstring muscle injuries were reported by all four of the studies. Three of the four interventions consisted of Nordic eccentric hamstring exercise training, while the fourth study used a variety of eccentric exercises. In addition, two studies identified significant risk factors for hamstring injuries, namely increasing age (>24 years), previous hamstring injury (within the last 12 months) and thigh muscle imbalances. Thus, the main finding of the present study is that the performance of eccentric hamstring exercises has a preventative effect on hamstring injuries in sport.

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