Injury Prevention in Ice Hockey

Presented by

Romana Franceschini-Brunner

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Cumulative Dissertation presented by

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Cumulative Dissertation
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Colophon

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Summary

Ice hockey is a high-impact sport with a high risk of a wide variety of injuries. Several injury risk factors including high velocity on the ice, unintended collisions, rapid changes in direction and injuries from the board, puck and sticks can lead to player injuries. Although different extrinsic preventive strategies have been applied in ice hockey, intrinsic prevention strategies, e.g. exercise training programs, have scarcely been described. The overall objective of this thesis is to develop a protocol for a cluster-randomized feasibility study to evaluate an evidence-based injury prevention program for ice hockey players, addressing the most common overuse and traumatic injuries to the lower extremity. To achieve the overall objective, the available evidence of systematic reviews and meta-analyses on the effect of preventive exercise interventions for the lower extremity in team-sport athletes was synthesized; traumatic and overuse injuries of different Swiss professional ice hockey teams were assessed; and barriers and facilitators among players and staff members for adhering to an injury prevention program in professional male ice hockey teams were identified.

List of abbreviations

FAIS	Femoroacetabular Impingement Syndrome
NHL	National Hockey League
NL	National League
NZZ	Neue Zürcher Zeitung
OSTRC	Oslo Sports Trauma Research Centre
PEDro	Physiotherapy Evidence Database
RCT	Randomized Controlled Trial
SIHF	Swiss Ice Hockey Federation

Chapter 1

Introduction

Lachschon [Internet]. Die Anfänge der NHL. [cited 2018, April 18]. Available from: http://www.google.ch/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiDnqT9osHaAhUyMuwKHXi0C3gQjRx6BAgAEAU&url=http://www.lachschon.de/item/173705-DieAnfaengederNHL/&psig=AOvVaw2Hfleyb2-qVfi-UoEisq-t&ust=1524053263773572

1.1 Swiss ice hockey

Ice hockey is a popular high-impact, stop-and-go sport, especially in North America and Northern Europe. In Switzerland, ice hockey is nearly as popular as soccer with 30,655 registered players.[1] Swiss ice hockey received international attention with the first Spengler Cup tournament 1923 in Davos, which is considered the oldest annual invitational ice hockey tournament in the world. The highest national ice hockey level in Switzerland is the National League (NL) with 12 teams followed by the Swiss League. The Swiss men's national ice hockey team won the silver medal at the adult men's World Championships in 2013 and 2018. Several Swiss male ice hockey players are playing in the National Hockey League (NHL) in North America since 1987, which is considered the best league in the world.

1.2 Injury definition

An injury is defined as: 'A physical complaint or observable damage to body tissue produced by the transfer of energy experienced or sustained by an athlete during participation in athletics training or competition, regardless of whether it received medical attention or its consequences with respect to impairments in connection with competition or training'.[2] Injuries can be categorized either as a result of a traumatic event, i.e. a condition caused by an identifiable single external transfer of energy such as, for example, a collision leading to bone fracture, or overuse, i.e. there is no identifiable single external transfer of energy, but the condition is caused by multiple accumulative bouts of energy transfer such as multiple micro trauma leading, for example, to tendon tears.[2] Injuries can result in decreased sporting function, loss of playing time, high financial burden for the athlete's employer as well as the health care system, and an increased risk of re-injury and chronicity.[3-6] It is therefore important to develop an injury prevention program for professional ice hockey players to prevent the risk of traumatic and overuse injuries.

1.3 Epidemiology of ice hockey injuries

Ice hockey injury patterns have been evaluated in Northern Europe mainly in the 1990s,[7-11] but not yet in Switzerland. However, injury patterns may have changed over time as a result of increased player speed and aggressiveness.[12 13] Depending on the surveillance methods used, the overall time-loss injury incidence in professional and collegiate Division I men's ice hockey ranged from 4.9 to 15.6 per 1,000 athlete exposures with approximately 50-60 injuries per 1,000 player game-hours.[13-15] Most traumatic injuries were localized to the head and face and to the thigh and knee region of the lower extremity.[13-15] Overuse injuries mainly affected the hip/groin, knee and lumbar spine.[6 10 11 16] By applying different surveillance methods and injury definitions, this has often led to reporting discrepancies in the frequency and type of both traumatic and overuse injuries.[14] Previous surveillance systems mainly focused on traumatic injuries only and might not have captured the real number of overuse injuries due to the lack of surveillance methods.[6 11 16] In fact, the evaluation of overuse injuries in ice hockey is scarce, although prevalences ranging from 8-69% have been reported.[6 10 11 13 16] A new method for registration of overuse sport injuries has recently been developed,[17] but is scarcely applied in ice hockey.[6 11 16]

1.4 Ice hockey injury risk factors

Injury risk factors may have extrinsic, e.g. sports venue, equipment and environmental, and intrinsic, e.g. age, sex, general health, physical fitness, origins.[18 19] Body contact is common during ice hockey games; body checking is permitted in men's ice hockey[15] and represents, in fact, the greatest risk factor for all traumatic ice hockey injuries.[7 8 13-15 20] Other risk factors including high velocity on the ice, rapid changes of direction, unintended collisions with the board, puck and sticks can lead to a wide variety of player injuries.[7 8 13-15 20 21] Furthermore, a previous history of injuries increases the risk for a new injury.[5 22] Muscle weakness has also been identified as a risk factor for traumatic

muscle injuries.[23] The ice hockey skating pattern has been described to increase the risk for overuse injuries to the hip such as femoroacetabular impingement syndrome (FAIS),[24] i.e. external rotation in hip abduction during push-off phase and internal rotation in hip flexion during recovery phase. In addition, muscle imbalance between hip and abdominal muscle strength, i.e. strong adductor muscles versus weak lower abdominal muscles, might be an underlying cause of athletic pubalgia.[25] Another factor influencing the risk of overuse injuries might be the high training load during the summer months followed by a high match load during the season with an often full calendar, i.e. 2-3 games per week, including short recovery times.[11] In general, lower levels of sport-specific training are associated with an increased risk of injury in sport.[5]

1.5 Injury prevention in ice hockey

In order to successfully prevent injuries, a systemic approach is necessary. The fundamental four-step model of van Mechelen et al.[26] has been developed to guide prevention research. It is important to (A) determine the extent of the problem including the incidence and severity, (B) identify the causes including risk factors and mechanisms of injuries, (C) develop and implement an injury prevention strategy and (D) evaluate the strategies outcome (Figure 1).

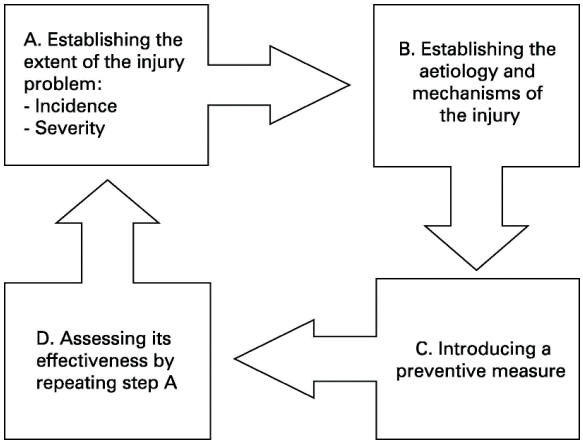

Figure 1: The "sequence of prevention" of sports injuries as described by van Mechelen et al., 1992.

The model begins with establishing the extent of injuries through a validated injury surveillance system followed by identifying injury risk factors and mechanisms through prospective analysis of specific injury patterns, developing and introducing preventive strategies to implement in the specific setting and finally, by evaluating these strategies through determining their impact on injury incidence.[5] To develop preventive strategies in a sport-specific setting, it is important to first identify which exercise combinations are most effective as part of a lower extremity injury prevention program. For this reason, we initially conducted an umbrella review before evaluating the incidence, type and causes of ice hockey injuries.

To achieve team success in decreasing injury rates, it is important to further understand influencing factors and their relationship.[27]

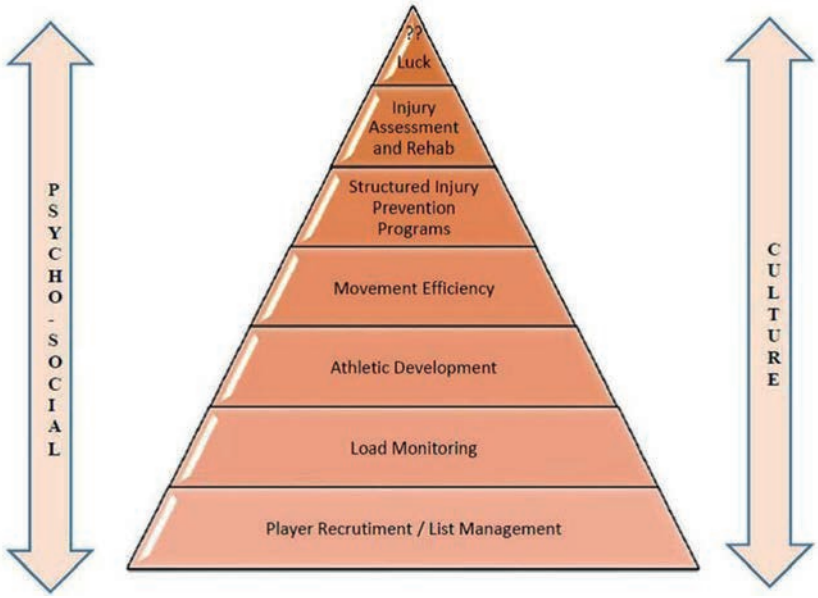

Figure 2: The injury prevention pyramid for elite sports teams described by Coles, 2017.

According to the injury prevention pyramid for elite sports teams (Figure 2),[27] the fundamental part of a team is to recruit players that are less prone to injuries followed by the optimal level of load that each player will tolerate during training sessions to increase players performance. In addition, high-quality strength and conditioning programs are crucial for an athlete's development. Structured injury prevention programs can then be added to prevent specific injuries. At the top of the pyramid, it is of relevance to assess the level of function of a player with an ongoing injury until return to play and lastly, luck might play a small but important part if an athlete gets injured. The culture of a team as a whole as well as the psycho-social factors on each player within the team can influence every stage of the pyramid.[27] Hence, developing an injury prevention program for the most common injuries in ice hockey is an important aspect for decreasing the risk of injuries besides other influencing team-related factors.

Common extrinsic injury prevention strategies for ice hockey players comprise tougher rules and regulations, rink adaptations and equipment.[28] Full-body protective equipment is required for ice hockey players and a helmet with a face protector became mandatory for all players being born after 1974 to protect the body from injuries. Flexible boards are not yet mandatory for ice hockey rinks in Switzerland, however they seem to have the potential to reduce the risk of injuries.[15 29] Conversely, intrinsic intervention strategies such as training, e.g. muscle strength and endurance, range of motion, reaction time, proprioception, are only rarely described.[23] The focus in this thesis will therefore be on the prevention of injuries using exercise training programs for the lower extremity in men's ice hockey.

1.6 Objectives of this thesis

The overall objective of this thesis was to develop a protocol for a cluster-randomized feasibility study to evaluate an evidence-based injury prevention program for ice hockey players, addressing the most common overuse and traumatic injuries to the lower extremity. To achieve the overall objective, the specific aims for this thesis were the following:

1. To summarize the available evidence from systematic reviews on the effects of injury prevention programs for the lower extremity in team-sport athletes - Study I
2. To assess the frequency, type, location and incidence of traumatic injuries as well as the prevalence and the relative impact of overuse injuries in professional male ice hockey players in Switzerland during a one-year study period - Study II
3. To identify barriers and facilitators among players and staff members for adhering to an injury prevention program in professional male ice hockey teams - Study III

4. To develop an evidence-based injury prevention program for ice hockey players, addressing the most common overuse and traumatic injuries to the lower extremity - Protocol

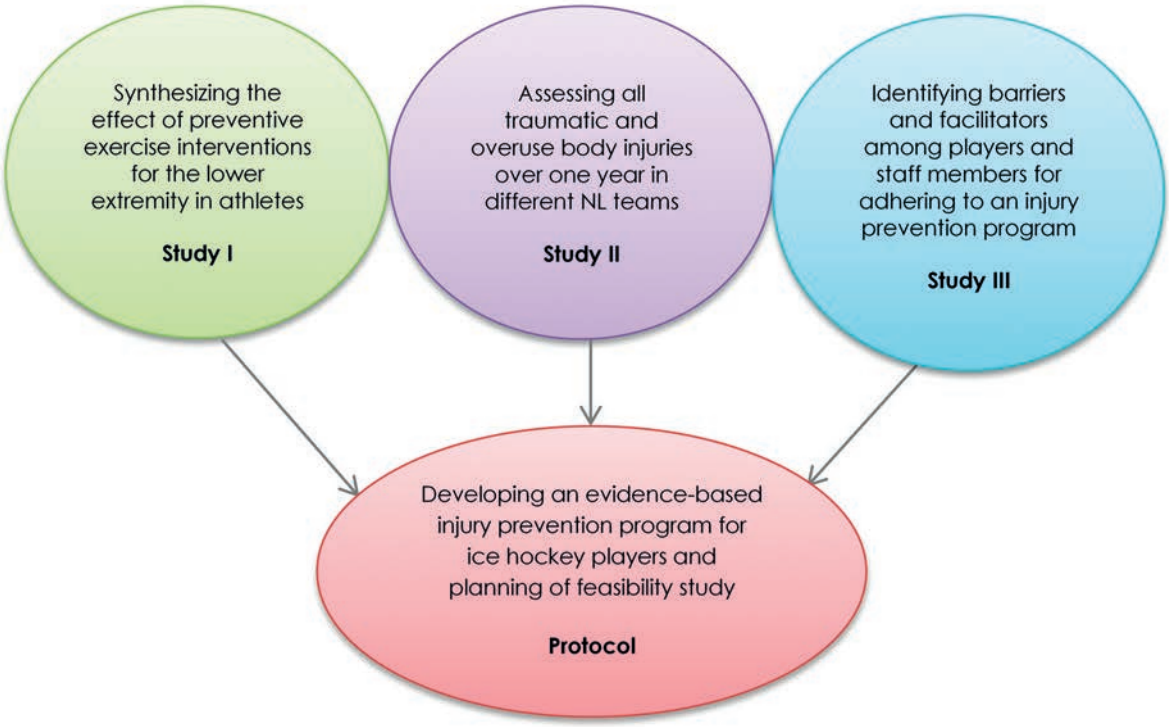

Figure 3: Overview of specific study objectives forming the overall objective of this thesis.

1.7 Outline

To achieve the overall objective, three studies were conducted. On this basis, an evidence-based injury prevention program and a feasibility study protocol were developed. Each study and the protocol for an injury prevention program represent one chapter in this doctoral thesis. The final chapter discusses the main findings resulting from the different studies and describes implications and future directions.

1.8 Methodology

The first study (Chapter 1) aims to synthesize the available evidence of systematic reviews and meta-analyses on the effect of preventive exercise interventions for the lower extremity in team-sport athletes. To design an evidence-based injury prevention program for ice hockey players, it is important to identify effective combinations of single elements. Due to the lack of evidence in ice hockey team sport, the evidence of injury prevention programs was summarized, in general, in team-sport athletes. There is a large number of systematic reviews available on the effectiveness of injury prevention programs for the lower extremity in team-sport athletes, and thus we aimed to perform an umbrella review. A literature search was performed until March 2016 using various databases: Pubmed/Medline, Scopus, The Cochrane Library and Physiotherapy Evidence Database (PEDro). The following search code was used for PubMed: (athlete OR sportsman OR sportswoman OR sport) AND (prevention OR intervention OR prophylaxis OR avoidance) AND (sport injury OR athletic injury OR sport accident OR sport trauma). Title and abstract screening of the retrieved hits were performed by two authors. The relevant full-text studies were read and selected independently by two authors. To evaluate the quality of the included systematic reviews, a measurement tool to assess systematic reviews (AMSTAR) was used.[30] To extract the data, a data extraction form for review of systematic reviews and research syntheses was used.[31] Data extraction was performed independently by two reviewers.

The second study (Chapter 2) aimed to assess injury incidence of all traumatic body injuries as well as the prevalence and burden of overuse injuries of different body parts in professional male ice hockey players in Switzerland during a one-year period (preparatory phase and season). Traumatic injuries were assessed using a standardized injury report form[13] that was filled out by one person

responsible for data collection, i.e. physiotherapist or massage therapist, of every participating team. The Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire[17] was used to assess overall and substantial overuse injuries of the shoulders, lower back, hip/groin and knees and their relative burden for ice hockey players. The questionnaire was handed out to all ice hockey players for completion and thereafter collected by the person responsible for data collection of each team every second week.

The third study (Chapter 3) aimed to identify barriers to and facilitators for an injury prevention program in professional male ice hockey teams among players and staff members. According to the social marketing theory,[32] long-term adherence to an innovation, e.g. an injury prevention program, does not start with a ready product, e.g. specific exercises for an injury prevention program. However, the setting in which the innovation will be implemented needs, firstly, to be explored as well as the target group(s) needs to further develop change strategies and plan the implementation.[32] In total, six professional ice hockey teams of the Swiss NL participated in this study, including a total of 148 ice hockey players and 11 staff members. The participants filled out a questionnaire regarding the future implementation of an injury prevention program for the lower extremity in their teams. Frequency of ratings related to knowledge and perceptions, beliefs, adherence and habits were analyzed. Binary logistic regression analysis was applied to predict a relationship between the perceived benefit of an injury prevention program (high versus low) and player characteristics, i.e. age, nationality, level of education, total experience in the NL, previous lower extremity injuries.

Based on the outcomes of study I–III and the available literature, a protocol (Chapter 4) was developed that aimed to plan the evaluation of the feasibility of an injury prevention program for the hip/groin, due to the high prevalence of

traumatic and overuse injuries affecting that region in ice hockey. In order to increase the chance of adherence, the injury prevention program comprises - besides standardized ice hockey specific strength and balance exercises - individual strength exercises for each hip muscle group. Feasibility of the program in a setting of ice hockey teams will be studied based on recruitment and dropout rates, use and adherence to the intervention, responsiveness and number of adverse events. The program will be applied to a junior ice hockey team in Switzerland and evaluated for its feasibility in the specific setting.

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Chapter 2

Effectiveness of multicomponent lower extremity injury prevention programmes in team-sport athletes: an umbrella review

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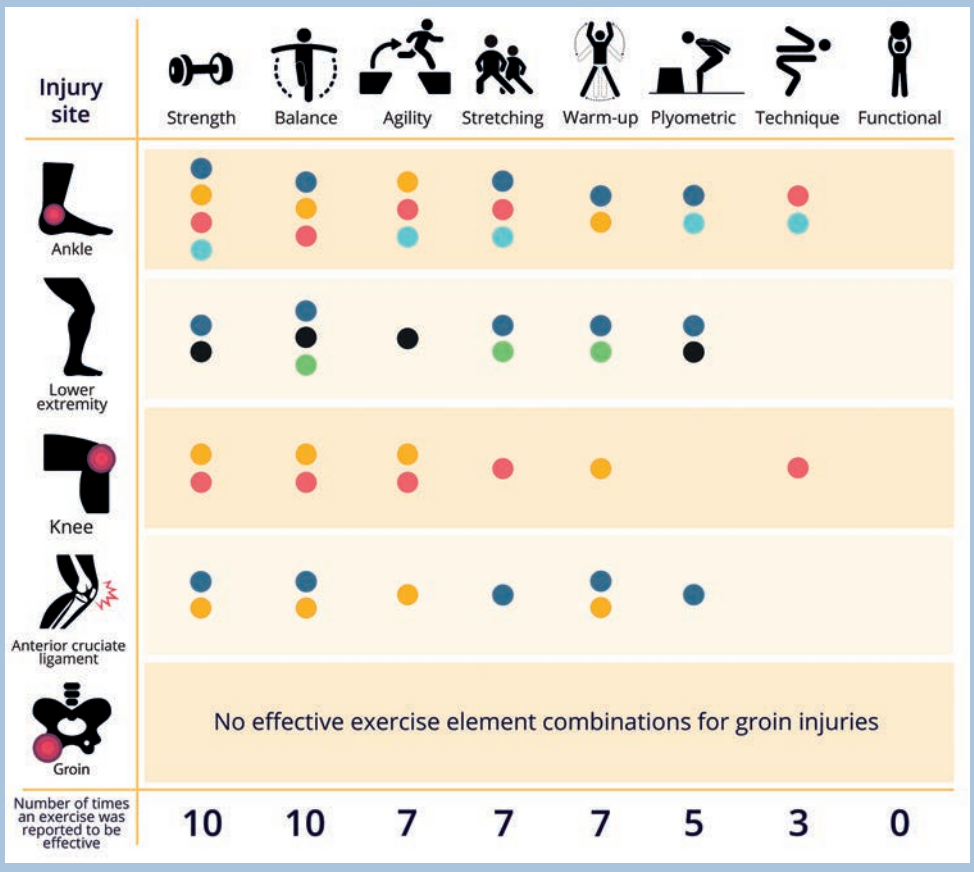

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Effectiveness of multicomponent lower extremity injury prevention programmes in team-sport athletes: an umbrella review

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ABSTRACT

Objective To identify which exercise combinations are most effective as part of a lower extremity injury prevention programme for team-sport athletes.

Design Umbrella review.

Data sources A comprehensive literature search was performed in PubMed, Scopus, Cochrane Library and PEDro databases. Studies published between January 2000 and March 2017 were included in this umbrella review.

Study eligibility criteria Moderate to high-quality systematic reviews that investigated the effectiveness of a combination of two or more exercise components, that is, strength, agility, plyometrics, balance, stretching, technique, warm-up and functional activity, regarding injury incidence/rate of lower extremity injuries in team-sport athletes. The methodological quality of the included systematic reviews was independently assessed by two reviewers using the Assessing the Methodological Quality of Systematic Reviews measurement tool and the Grading of Recommendations Assessment, Development and Evaluation guidelines were used to assess the overall quality of evidence for particular outcomes.

Results Twenty-four systematic reviews met the inclusion criteria. Multicomponent exercise interventions were effective in reducing the injury incidence/rate of lower extremity, knee, ACL and ankle injuries, but not groin injuries. Strength and balance exercise components were included in 10 of 11 effective injury prevention programmes for the lower extremity, knee, ACL and ankle injuries.

Summary/conclusion Lower extremity injury prevention programmes in team sports are effective in preventing lower extremity, knee, ACL and ankle injuries. Lower extremity muscle strength and balance exercises should be prioritised in lower extremity injury prevention programmes for team-sport athletes.

INTRODUCTION

An average of 8.6 million sports-related injuries were documented per year between 2011 and 2014 in the USA, which equates to an incidence rate of 34 injuries per 1000 persons.[1] The majority of these injuries were lower extremity strains and sprains sustained during basketball, American football and soccer (42%).[1] A similar rate of 26 injuries per 1000 persons was calculated for the European Union, with a peak occurring in the 15–19 years age group.[2] The most common traumatic injuries in team ball sports, such as basketball, volleyball, soccer and field hockey, are ligament injuries of the ankle (15% of all reported sports injuries), followed by the knee (3% of all reported sports injuries),[3 4] whereas overuse injuries mostly affect the groin area[5] and represent 5%–10% of all sports-related injuries.[6]

Injury risk factors may have intrinsic (eg, age, sex, general health, physical fitness) and extrinsic (eg, sports venue, equipment and environmental) origins.[7 8] The risk for injuries associated with these intrinsic and extrinsic risk factors can be reduced if athletes complete specific exercise programmes.[9–16] Previous systematic reviews have focused on evaluating the effectiveness of single exercise components (eg, balance) or combinations of two or more exercise components (eg, strength, agility, plyometrics and stretching); however, injury prevention programmes including balance training as a single-component exercise did not reduce the incidence of knee ligament injuries.[10 14] Similarly, stretching did not reduce the incidence of lower extremity sports injuries.[17]

Injury prevention should be a primary goal for team-sport athletes of all ages and participation levels (eg, recreational, semiprofessional, professional) since an injury results in performance disability, loss of playing time, high financial burden for the athlete's employer as well as the healthcare system and an increased risk of reinjury and chronicity.[6] However, it remains unclear which combinations of exercise components are most effective in preventing lower extremity injuries. To identify the most effective exercise combinations, high-level synthesis of the available data, in the form of an umbrella review, is necessary.[18]

The objective of our umbrella review was to identify the most effective combinations of exercise elements for training programmes to prevent lower extremity injuries in team-sport athletes.

METHODS

This umbrella review was performed according to guidelines established by the working group of Aromataris *et al*.[19] The study is registered in the International Prospective Register of Systematic Reviews (PROSPERO ID CRD42016041667).

Inclusion criteria

We applied the Assessing the Methodological Quality of Systematic Reviews (AMSTAR) rating system to rate and classify all reviews into low quality (scores of 0 to ≤3 points), moderate quality (3 to ≤7) and high quality (7 to ≤11).[20] Only moderate and

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high-quality reviews were included. Reviews were included if published in either English or German between 1 January 2000 and 31 March 2017. The following inclusion criteria were considered according to the Participant-Intervention-Comparison-Outcome process for evidence-based practice.[21]

Participants

Male and/or female athletes of all ages who participated in team sports at any level (ie, recreational, semiprofessional, professional).

Interventions

All types of multicomponent exercise interventions to prevent lower extremity injuries. Interventions using protective devices (ie, braces, tapes) or exercise programmes including only one exercise component were excluded (eg, injury prevention programmes using eccentric strength exercises only to prevent hamstring injuries).

Comparison group

Usual training (no additional training).

Outcome measures

Injury incidence or injury rate.

Search strategy

A systematic literature search was performed by one reviewer (RB) in the following electronic databases: PubMed, Scopus, Cochrane Library (Cochrane Database of Systematic Reviews) and Physiotherapy Evidence Database (PEDro). The following search terms were used for PubMed: (athlete OR sportsman OR sportswoman OR sport) AND (prevention OR intervention OR prophylaxis OR avoidance) AND (sport injury OR athletic injury OR sport accident OR sport trauma). Search terms for the Scopus and Cochrane Library databases were: ('injury prevention' AND athlete OR sport). For the PEDro database, the following advanced search for systematic reviews was conducted: (injur* prevent* sport*). An expert in the field of preventive sports medicine (MB) identified through citation tracking any missing but relevant studies on the topic. Duplicates were identified and removed by one reviewer (RB).

Two reviewers (RB and NCC) then independently screened the titles and abstracts of all retrieved studies, and determined the eligibility of the potentially relevant full-text articles. If the decision of eligibility differed, a third reviewer was consulted (NAM) to evaluate the identified articles and reach final consensus on the inclusion of selected articles.

Methodological quality evaluation

Two reviewers (RB and KN) independently assessed the methodological quality of the included systematic reviews using the AMSTAR tool. If the assessment was unclear, consensus was either reached by discussion or with the help of a third reviewer (NAM). The AMSTAR checklist is a reliable and valid instrument, which assesses the risk of systematic review bias.[22] It comprises 11 different domains that are answered with the following options: 'yes'; 'no'; 'cannot answer'; and 'not applicable'; only a 'yes' answer is nominated with a score of 1 point.

To assess the overall quality of evidence of all included systematic reviews, we applied an adapted form of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) principles.[23] There are five GRADE categories: high; moderate; low; very low; and no evidence from systematic review. A high GRADE defines a systematic review or meta-analysis consisting of at least two high-quality primary studies. A moderate GRADE defines a review including at least one high-quality primary study or at least two moderate-quality primary studies. Low GRADE defines a review on only moderate-quality primary studies and/or inconsistent results in the primary studies. Very low GRADE refers to 'no medium to high quality systematic review identified on this topic'. If the authors of the systematic review did not assess the quality of the primary studies (ie, no risk of bias assessment was conducted), they were classified as 'no evidence from systematic review' and the GRADE system was not applied.

Table 1 Description of study outcomes and exercise elements

Study outcomes	Description
Lower extremity injuries	Lower limb injuries, all sports injuries, all injuries
Groin injuries	Groin injuries
Knee injuries	Knee joint injuries, acute knee injuries, undefined knee injuries
ACL injuries	ACL injuries, non-contact ACL injuries
Ankle injuries	Acute ankle injuries, ankle sprains, undefined ankle injuries
Exercise elements	
Strength	Eccentric or concentric strength training, weight training, core stability or power training
Agility	Sport cord drills, sports-specific drills or running techniques
Plyometric	Jumping and rebounding exercises
Balance	Proprioception, neuromuscular training with wobble boards or balance mats, dynamic stability, body control or one-leg coordination
Stretching	Flexibility exercises
Technique	Single-leg jumps with focus on leg alignment, jumping and landing techniques, and neuromuscular control during landing manoeuvers
Warm-up	Aerobic exercises, muscle activation or unspecified basic warm-up (ie, jogging, trunk twists, jumping jacks)
Functional activities	Unspecified exercises for the lower and upper extremities

Data extraction and analysis

Two reviewers (RB and BF) used a standardised data extraction form as part of the established umbrella review protocol to collect data from the included reviews.[19] A third reviewer (NAM) was consulted when any ambiguity arose during this process. All data were stored and managed in Microsoft Excel 2010.

Injury incidences/rates were analysed separately for five lower extremity injury categories: (1) lower extremity injuries; (2) groin injuries; (3) knee injuries; (4) ACL injuries; and (5) ankle injuries. This categorisation was defined based on the terms mainly used to describe lower extremity injuries in the included systematic reviews/meta-analyses and primary studies. A detailed description of each injury category is listed in table 1.

We defined eight exercise element categories according to the common terms found (table 1): (1) strength; (2) agility; (3) plyometric; (4) balance; (5) stretching; (6) technique; (7) warm-up; and (8) functional activities. Terms 1–5 were previously adopted from one of the included meta-analyses that tested the effectiveness of each exercise component on ACL injury prevention.[15] Terms 6–8 were included because they represent frequent exercise concepts. Term 6, technique, encompassed a correct lower extremity alignment technique while performing demanding weight-bearing tasks (eg, single-leg jumps with a focus on leg

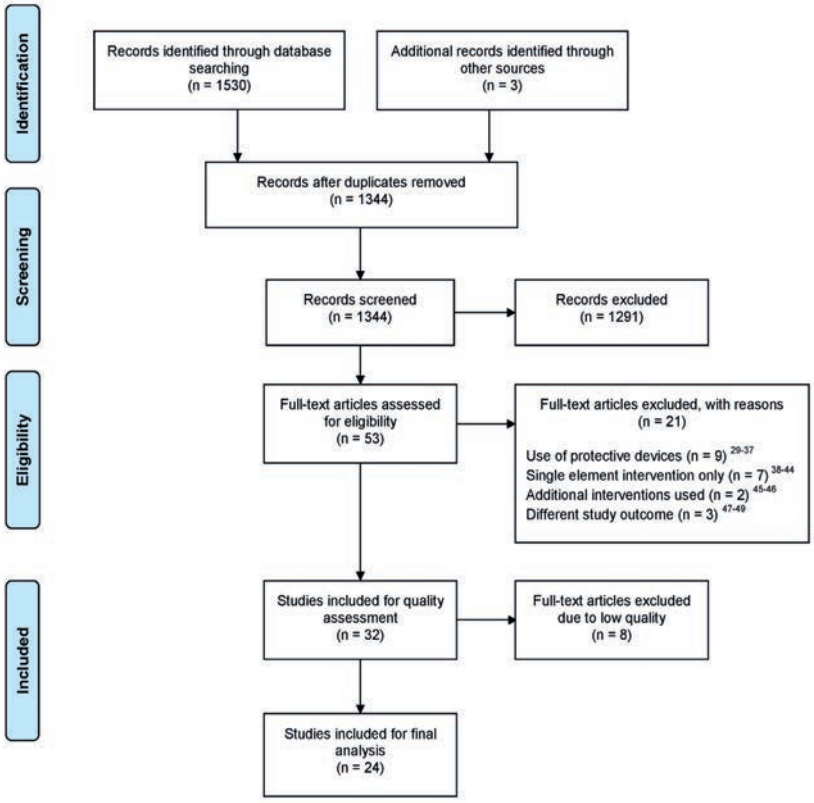

Figure 1 Flow chart of the study selection process.

alignment; jumping and landing techniques; neuromuscular control during landing).[24–27] Term 7, warm-up, included aerobic exercises, muscle activation or non-specific basic warm-up exercises such as jogging, trunk twists and jumping jacks. Term 8, functional activities, comprised all non-specific exercise elements for lower and upper extremities as part of the injury prevention programmes found in the studies included in this umbrella review.

Characteristics of the selected systematic reviews/meta-analyses including the AMSTAR and GRADE scores, number of participants, combination of exercise elements, heterogeneity between primary studies (I^2) as well as results, findings and authors' conclusions are presented in online e-Supplement 1. Within each review/meta-analysis one[28] to ten[11] different combinations of exercise elements were presented.

A summary of the effectiveness of exercise element combinations was made for each injury category, including the mean methodological quality (summary of AMSTAR scores divided by the number of systematic reviews including the exercise element combinations to strengthen the overall results) and overall results. We used a traffic light system to visually summarise the effectiveness of each exercise element combination in reducing the injury incidence/rate per injury category. A green light was set for studies with effective overall results (ie, agreement on the effectiveness of exercise element combinations). An orange light was indicative of studies with inconsistent overall results (ie, disagreement on the effectiveness of exercise element combinations), and a red light of ineffective overall results (ie, agreement on the ineffectiveness of exercise element combinations).[19]

RESULTS

Our database search identified a total of 1530 records with three additional studies found by our content expert (MB) (figure 1). After duplicates were removed, 1344 records were screened for titles and abstracts. A further 1291 studies were excluded, mainly because the study outcome did not match the one defined at the outset of our review. Of 53 full-text articles evaluated, 21 systematic reviews were excluded for various reasons (figure 1: Eligibility).[29–49] The 32 remaining systematic reviews were evaluated for methodological quality.

Methodological quality evaluation

The overall methodological quality of the 32 included reviews is summarised in figure 2. Eight reviews had a total AMSTAR score of ≤3 and were excluded.[50–57] For the remaining 24 reviews,[6 9–11 13–17 24 28 58–70] the following AMSTAR criteria were under-reported: using the status of publication as an inclusion criterion[11 29 56–58 61 64]; providing an a priori design[6 12 17 64]; listing all included and excluded primary studies[9 10 17]; and stating a conflict of interest.[30] The majority (n=17) of the 24 included systematic reviews were based on high-quality primary studies (ie, high GRADE) for the outcome of lower extremity, knee, ACL and ankle injuries. Two systematic reviews were of moderate

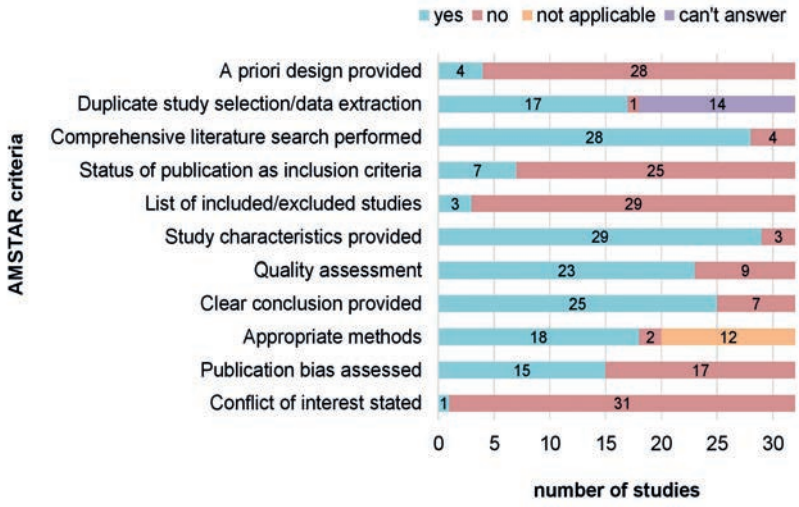

Figure 2 Overall results of the Assessing the Methodological Quality of Systematic Reviews (AMSTAR) checklist (n=32).

GRADE regarding the outcome of ACL injuries[24 68] and four systematic reviews were of low GRADE regarding the outcome of lower extremity, groin and ACL injuries[6 13 64 67]; one systematic review did not assess the quality of the primary studies regarding the outcome of ACL injuries.[16]

Effectiveness of exercise element combinations

Twenty-six primary studies were included in the analysed systematic reviews.

Ten systematic reviews evaluated eight different exercise element combinations, of which three exercise element combinations were effective in reducing the lower extremity injury incidence/rate (table 2). These effective injury prevention programmes encompassed three different combinations: strength, plyometric, balance, stretching, warm-up; strength, agility, plyometric, balance; and the combination of balance, stretching and warm-up exercises.

For the groin, there were no effective exercise element combinations identified in five systematic reviews (table 2).

Eight systematic reviews reported two combinations of exercise elements as effective in preventing knee injuries (table 2). These effective injury prevention programmes encompassed two different exercise combinations: strength, agility, balance, stretching, technique; and strength, agility, balance, warm-up.

From a total of 10 exercise element combinations focused on reducing ACL injuries, two different exercise combinations were considered effective: strength, plyometric, balance, stretching, warm-up; and strength, agility, balance, warm-up (table 2).

Four combinations of exercise elements were effective in preventing ankle injuries (table 2); these injury prevention programmes included the exercise elements of strength, agility, plyometrics, balance, stretching, technique and warm-up.

Overall, there were 11 combinations of exercise elements that were effective in reducing the injury incidences/rates. Strength and balance exercises were included in 10 effective injury prevention programmes. For lower extremity injuries, balance exercises were included in all three effective injury prevention programmes. Strength, plyometrics, stretching and warm-up exercises were included in two programmes. For knee injuries, strength, balance and agility exercises were included in all three effective injury prevention programmes. Stretching, technique and warm-up exercises were included in two programmes. For ACL injuries, the two effective injury prevention programmes included strength, balance and warm-up exercises. Strength was included in all four effective ankle injury prevention programmes. Balance, agility and stretching exercises were included in three effective ankle injury prevention programmes.

DISCUSSION

Based on 24 moderate to high-quality systematic reviews and meta-analyses, we found that multicomponent exercise interventions were effective in reducing the injury incidence/rate of lower extremity, knee, ACL and ankle injuries, but not of groin injuries. The most frequent elements of a neuromuscular training programme were a combination of strength and balance exercises.

Several meta-analyses included in this umbrella review showed a beneficial effect of multicomponent exercise programmes for different outcomes (ie, lower extremity, knee, ACL and ankle injuries).[10 13–17] The combination of strength and balance exercises enhanced the effect of an injury prevention programme.[17] Strengthening and proximal control exercises (eg, exercises involving segments proximal to the knee joint) were associated with a reduction in ACL injuries.[14] On the other hand, injury prevention programmes including balance exercises compared with programmes without balance exercises did not reveal any additional effect in reducing ACL injuries.[14 16] However, the authors of the systematic reviews did claim the importance of balance exercises in combination with other types of exercises for reducing ACL injuries.[14 16]

In contrast to strength and balance exercises, the exercise components stretching, agility, plyometrics and technique were less frequent in programmes aimed at reducing lower extremity, knee, ACL and ankle injury incidence/rate. According to a meta-analysis included in this umbrella review, stretching added no beneficial effect in decreasing sports injuries.[17] Several other studies[31–34 71 72] also found limited evidence to support the benefits of stretching before or after training for injury prevention. Stretching increases flexibility,[73] which is an important quality in specific team sports and playing positions (eg, an ice hockey goalkeeper needs more hip flexibility compared with a field player). Yet higher flexibility

Table 2 Summary of findings for each outcome

References	Combination of exercise elements								Mean methodological quality (AMSTAR)	Effectiveness of exercise element combinations (traffic light indicator*)
	Strength	Agility	Plyometrics	Balance	Stretching	Technique	Warm-up	Functional activity		
Lower extremity injuries										
van Beijsterveldt, Steffen, Soligard, Longo, Owoeye, Hammes, Gatterer, Grooms included in SRs 9; 10; 17; 57; 64–66; 70	x	x	x	x			x		6.75	Inconsistent
Pasanen included in SRs 10; 17; 59	x		x	x	x		x		7	Effective
Emery and Meeuwisse included in SRs 17; 65; 66; 70	x	x		x	x	x			7	Inconsistent
LaBella included in SRs 9; 17; 65	x	x	x	x					7.6	Effective
Olsen included in SRs 10; 50; 65; 66	x	x		x			x		6.5	Inconsistent
Emery included in SRs 10; 17; 65; 66				x	x		x		7.5	Effective
Bixler included in SR 60					x		x		5	Inconsistent
Wederkopp included in SRs 60; 65; 66				x				x	6.3	Inconsistent
Groin injuries										
van Beijsterveldt, Steffen, Soligard included in SRs 6; 9	x	x	x	x			x		7	Ineffective
Engebretsen included in SRs 6; 59; 64	x			x		x	x		7.3	Ineffective
Holmich included in SRs 6; 59; 64	x			x	x				7.3	Ineffective
Wederkopp included in SRs 6; 17; 59				x				x	8	Ineffective
Knee injuries										
van Beijsterveldt, Steffen, Soligard included in SRs 9; 62	x	x	x	x			x		6.5	Inconsistent
LaBella included in SR 9	x	x	x	x					6	Inconsistent
Emery and Meeuwisse included in SR 62	x	x		x	x	x			7	Effective
Gilchrist included in SRs 9; 10; 59; 62	x	x	x		x		x		6.25	Inconsistent
Olsen included in SRs 10; 17; 60	x	x		x			x		7	Effective
Engebretsen, Kiani, Walden included in SRs 9; 62; 64; 65	x			x		x	x		7.5	Inconsistent
ACL injuries										
van Beijsterveldt, Steffen, Grooms included in SRs 9; 11; 14; 15; 58; 61; 62; 67; 69	x	x	x	x			x		5.8	Inconsistent
Gilchrist, Heidt, Mandelbaum included in SRs 9; 11; 13–17; 24; 59; 61; 62; 65; 67–69	x	x	x		x		x		6.1	Inconsistent
Pasanen included in SRs 11; 14; 61; 69	x		x	x	x		x		6	Effective
LaBella included in SRs 9; 11; 14; 15; 69	x	x	x	x					6	Inconsistent
Olsen included in SRs 11; 14; 15; 24; 61; 69	x	x		x			x		6	Effective
Myklebust included in SRs 11; 14–16; 24; 61; 67–69	x		x	x			x		5.5	Inconsistent
Hewett included in SRs 11; 13–16; 24; 61; 65; 67–69	x		x		x	x			5.8	Inconsistent
Kiani, Walden included in SRs 11; 14; 15; 17; 61; 62; 65; 67; 69	x			x		x	x		6.6	Inconsistent
Pfeiffer included in SRs 9; 11; 13–16; 61; 65; 67–69		x	x						5.9	Inconsistent
Petersen included in SRs 11; 13–16; 24; 61; 67–69			x	x					5.6	Inconsistent
Ankle injuries										
van Beijsterveldt, Steffen, Soligard included in SRs 9; 63	x	x	x	x			x		6	Inconsistent

Continued

Table 2 Continued

References	Combination of exercise elements								Mean methodological quality (AMSTAR)	Effectiveness of exercise element combinations (traffic light indicator*)
	Strength	Agility	Plyometrics	Balance	Stretching	Technique	Warm-up	Functional activity		
Pasanen included in SR 10	x		x	x	x		x		7	Effective
LaBella included in SR 9	x	x	x	x					6	Ineffective
Olsen included in SRs 10; 17; 60	x	x		x			x		7	Effective
Engebretsen included in SRs 59; 63; 64	x			x		x	x		6.7	Inconsistent
Emery and Meeuwisse included in SR 63	x	x		x	x	x			6	Effective
Heidt included in SR 63	x	x	x		x	x			6	Effective

*Representing the effectiveness of the exercise element combination in reducing the injury incidence/rate applied in per injury category.
AMSTAR, Assessing the Methodological Quality of Systematic Reviews; SR, systematic review.

was not associated with a lower risk of injuries.[71] Thus, the component stretching may not add much additional benefit to a lower extremity injury prevention programme.

Our finding of no beneficial effect of prevention programmes with and without plyometric exercises on ACL injuries supports previous research.[14] However, this area is not unanimous, and it is possible that plyometric exercises may be effective for ACL injury prevention.

No subgroup analysis within a meta-analysis to assess the specific effectiveness of agility exercises was conducted. Only one systematic review included in this umbrella review claimed the importance of agility exercises incorporated into a multicomponent injury prevention programme to reduce the risk of ACL injuries in female athletes.[24] It has been shown that a combination of agility and plyometric exercises contributed to a risk reduction that was associated with knee valgus angles and moments.[4] A combination of plyometric and agility exercises might therefore protect the knee joint during dynamic movements[14] and be beneficial in reducing ACL injuries when included in injury prevention programmes.

Technique exercises described in the included reviews focused on leg alignment during landing manoeuvers following a jump. Technique exercises may be less important because jumping was not a usual action in all the team sports considered in this umbrella review (ie, floorball and soccer). Nevertheless, landing technique exercises have been successfully applied to decrease knee varus/valgus moments[27]; various studies used visual feedback and/or education on dangerous knee postures to modify landing manoeuvres.[25-27 74 75] However, the authors might not have classified that as an exercise itself, which might lead to a reporting bias of technique exercises, and is therefore considered as less important in this umbrella review.

There are two types of injuries that require differentiation based on their occurrence: traumatic and overuse. All articles considered in this umbrella review focused on traumatic injuries. Therefore, making any conclusions about the effects of injury prevention programmes on reducing the rate of overuse injuries is not justified. It was previously reported that groin injuries are mainly overuse in origin[5] and represent a serious problem in many sports.[76 77] However, a recent meta-analysis, included in our umbrella review,[6] reported a total number of groin injuries that was very low in comparison to other injury types. Despite the relatively large sample size, there were only traumatic injuries examined, which may indicate a reporting bias. It is important to systematically assess all overuse injuries in addition to traumatic injuries in future primary studies. Detailed prevalence data of overuse injuries may support the development of overuse-specific prevention programmes.

Strengths and limitations

Our umbrella review ensured a high-level synthesis of the evidence[18] regarding injury prevention programmes in team-sport athletes and allowed to identify the most frequent exercise combinations for lower extremity injury prevention.

Due to study participant heterogeneity, it was not possible to stratify the main findings by age, sex, type of sports and level of play. One problem inherent in a study of this kind is the definition of outcomes assessed in the reviews. For example, various reviews used the outcome knee injuries, whereas others specifically used the outcome ACL injuries. We presume that some reviews with the outcome knee injuries might also have included ACL injuries. However, this did not influence the outcome of this umbrella review because ACL injuries were considered as knee ligament injuries. Some reviews used different exercise descriptions or

poorly reported the type of exercise element in the prevention programmes. This may have led to a misclassification of exercise elements. Various authors classified jumping as plyometrics, which can also be interpreted as landing technique exercises. We also speculate that participants in the primary studies may have been trained to focus on leg alignment during landing, while alignment during landing was not considered as an exercise itself. Therefore, there is a risk for reporting bias.

Many of the reviews included in our umbrella review included the same primary studies and concluded on the same available data, which reveals a large overlap among published systematic reviews and meta-analyses. What appears to be a large number of primary studies and evidence could partly be due to an over-publication of systematic reviews and meta-analyses on the topic of injury prevention. We encountered some reporting bias within the reviews and primary studies regarding a detailed description of the types of intervention and degree of compliance. Therefore, we could not formulate recommendations for specific exercise modalities (eg, contraction type, load or execution speed when performing strength exercises). A systematic documentation of prevention programmes including the target group, a detailed exercise description using the frequency, intensity/type, time principles, and description of delivery agents should be considered in future studies to enhance generalisability and reproducibility.[78] Particularly for groin injuries, improved reporting of prevalence data is required. More high-quality intervention studies are also needed to accurately evaluate the effectiveness of multicomponent programmes for specifically preventing traumatic as well as overuse injuries.

CONCLUSIONS

Multicomponent lower extremity exercise programmes were effective in preventing lower extremity, knee, ACL and ankle injuries in the team sports of soccer, floorball, Australian and American football, basketball, handball and volleyball for all age levels and sex. Muscle strength and balance exercises seem to be the most frequent components in a lower extremity injury prevention programme.

What is already known

- There is a large number of systematic reviews available on the effectiveness of injury prevention programmes for the lower extremity in team-sport athletes.
- Injury prevention programmes reduce the risk of traumatic injuries of the lower extremity in athletes.
- Multicomponent prevention programmes are more effective compared with single element prevention programmes.

What are the new findings

- In 10 of 11 effective injury prevention programmes regarding lower extremity, knee, ACL and ankle injuries, strength and balance are considered the most important exercise elements for team-sport athletes.
- Agility and plyometric exercises might be beneficial in reducing the ACL injury incidence/rate when performed in combination with strength and balance exercises as part of an injury prevention programme.
- Due to the heterogeneity of methodological descriptions in the reviews, it is impossible to draw conclusions about the specific intervention(s) for each exercise category as well as the frequency and intensity of an injury prevention programme.

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Chapter 3

Epidemiology of traumatic and overuse injuries in Swiss professional male ice hockey players

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Epidemiology of Traumatic and Overuse Injuries in Swiss Professional Male Ice Hockey Players

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Background: Ice hockey injury patterns in Europe were last evaluated in the 1990s.

Purpose: The aim of this study was to assess the frequency, type, location, and incidence of traumatic injuries, as well as the prevalence and relative effect of overuse injuries in professional male ice hockey players.

Study Design: Descriptive epidemiology study.

Methods: Traumatic injuries were assessed using a standardized injury report form over a 1-year period (including the preparatory phase and season). The Oslo Sports Trauma Research Centre Overuse Injury Questionnaire was used to determine overall and substantial overuse injuries and their relative effect on ice hockey players.

Results: Five Swiss National League teams participated in the study. From a total of 321 recorded injuries, 179 led to time loss from sport. The game-related time-loss injury incidence during the season was 88.6/1000 player-game hours.Time-loss injuries affected mainly the hip/groin/thigh region (23%), followed by the head (17%). Most time-loss injuries were classified as muscle strains (24%), followed by concussions (18%). The most common injury mechanism involved collision with an opponent's body (31%), and right forward players (23%) were most likely to report a game-related injury. Most injuries (27%) occurred within the defending zone along the boards. The average prevalence rates of all overuse and substantial overuse injuries were 49% and 13%, respectively. The hip/groin displayed the highest average prevalence for all overuse problems (16%), translating to the highest relative effect.

Conclusion: Muscle strains and concussions were the most frequent time-loss injuries in Swiss professional ice hockey players. The hip/groin was the most affected region for both traumatic and overuse injuries.

Keywords: traumatic injuries; overuse injuries; epidemiology; ice hockey

Ice hockey is a popular high-impact sport, especially in North America and northern Europe. A number of injury risk factors, including high velocity on the ice, unintended collisions, rapid changes in direction, and injuries from the board, puck, and sticks, lead to a high risk of a wide variety of player injuries.[24,27] Injuries can be categorized as a result of either a traumatic event (ie, a condition caused by an identifiable single external transfer of energy, such as a collision leading to bone fractures) or overuse (ie, there is no identifiable single external transfer of energy, but the condition is caused by multiple accumulative bouts of energy transfer, such as multiple microtraumas leading to, for example, tendon tears).[26] Depending on the surveillance methods used, the overall injury incidence in collegiate and professional men's ice hockey currently ranges from 4.9 to 15.6 per 1000 athlete-exposures, with approximately 50 injuries per 1000 player-game hours.[11,20,27]

Ice hockey injury patterns in Europe were last evaluated in the 1990s[19,21-23]; however, they may have changed over the past 2 decades as a result of increased player speed and aggressiveness.[3,11] Most traumatic injuries in previous investigations occurred at the head and face, followed by the thigh and knee region.[20,27] On the other hand, the most common types of overuse injuries mainly affected the groin, followed by the shoulder, elbow, and wrist region.[23]

Applying different surveillance methods and injury definitions has often led to reporting discrepancies in the frequency and type of both traumatic and overuse injuries.[20]

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Previous surveillance systems mainly focused on traumatic injuries only and might not have captured the real number of overuse injuries because of the lack of surveillance methods.[11] In fact, the evaluation of overuse injuries in ice hockey is scarce, although proportions of 8% to 15% of all injuries have been reported.[11,23] A new method for the registration of overuse sport injuries has recently been developed,[6] although it has not yet been applied in ice hockey. The validated self-reported questionnaire contains 4 multiple-choice questions to document overuse problems of different anatomic regions, which are often underreported because most of these problems might not lead to time loss.[6] For ice hockey, there is still a lack of injury prevention research, as only 1 study has shown the effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players.[28]

The aim of this study was to assess the frequency, type, location, and incidence of traumatic injuries using a standardized report form,[11] as well as the prevalence and the relative effect of overuse injuries in professional male ice hockey players using the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire,[6] over a 1-year period (including the preparatory phase and game season).

METHODS

Participants

Approval for this study was granted by the local ethics committee. Study inclusion criteria were the ability to understand written/oral German or English and provide informed consent to use the collected survey data for research purposes. After the initial invitation was sent to 9 Swiss National League teams, including their medical staff (ie, physicians, sports physical therapists, massage therapists, and athletic trainers), 6 teams decided to participate in the study; the remaining 3 teams declined their participation because of either a language barrier (ie, Italian- or French-speaking medical staff) or an excessive amount of additional workload. Another team left the study during the preparatory phase after experiencing the workload associated with the study. Overall, 5 teams comprising 122 ice hockey players successfully completed the study.

Data Collection

Data were collected for approximately 1 year, which included a preparatory phase during summer 2017 (from week 0 to week 19) and the 2017-2018 season (ie, regular season and playoffs/playouts from week 20 to week 50). One person from each team's medical staff was responsible for active data collection. Two were sports physical therapists, and 3 were massage therapists. All persons responsible for data collection were in charge of the initial care after an injury. They were present at all games and trainings. They were asked to complete a standardized report form for each traumatic injury occurring during dryland, weight lifting, or on-ice training sessions or games. Each person responsible for data collection was trained by the primary investigator (R.B.) on how to complete the injury report form correctly before study initiation because injuries in Swiss ice hockey are not documented on a regular basis. The final diagnosis of each reported traumatic injury was made by the team physician. The person responsible for data collection was also asked to gather information on the number of dryland and on-ice training sessions per week. To ensure compliance, this person was asked to send the data collected to the corresponding author (R.B.) on a weekly basis. In the case of incorrect completion of the injury report form or missing data, this person was immediately contacted by the primary investigator for clarification.

For each player, we extracted the total time on ice during the season from the individual statistics page of the Swiss Ice Hockey Federation website (www.sihf.ch/de/game-center/national-league/#/mashup/players/playerTimeOnIce/timeOnIce/desc/page/0/2017/2158). All players were asked to complete the OSTRC Overuse Injury Questionnaire biweekly (every second week) during the 1-year study period to collect information regarding overuse injuries.

Assessment of Traumatic Injuries

We used a standardized ice hockey injury data capture form, which was previously developed and evaluated by Flik et al,[11] to assess traumatic injuries. As noted, the form was completed by the person responsible for data collection for each team. The form comprised 32 questions, the majority of which were multiple choice and focused on determining the following information: individual player's characteristics at the time of injury; whether the injury occurred during a game (home vs away) or a training session and, if so, during on-ice, dryland, or weight lifting sessions; the game period and exact time when the injury occurred; and the player position and playing zone where the injury occurred. The cause of injury was documented, and it was also ascertained if the player was able to continue playing or had to stop. Last, if applicable, the injury was classified according to its grade, the diagnostic procedures, and the treatment(s) undertaken. A time-loss definition of injury, which implied that the player missed 1 or more training sessions or game events because of the injury, was used.[26]

Assessment of Overuse Injuries

The validated, self-reported OSTRC Overuse Injury Questionnaire was used to assess overuse injuries of different body parts.[6] The questionnaire was handed out to all ice hockey players before and after the first training session of every second week and thereafter collected by the person responsible for data collection for each team. For the non–German speaking players (n = 27), the English version of the questionnaire was used. For the German-speaking players (n = 95), we translated the questionnaire according to the guidelines for cross-cultural adaption of self-reported measures[1] because only a version of the OSTRC Questionnaire to capture general health problems and illnesses—

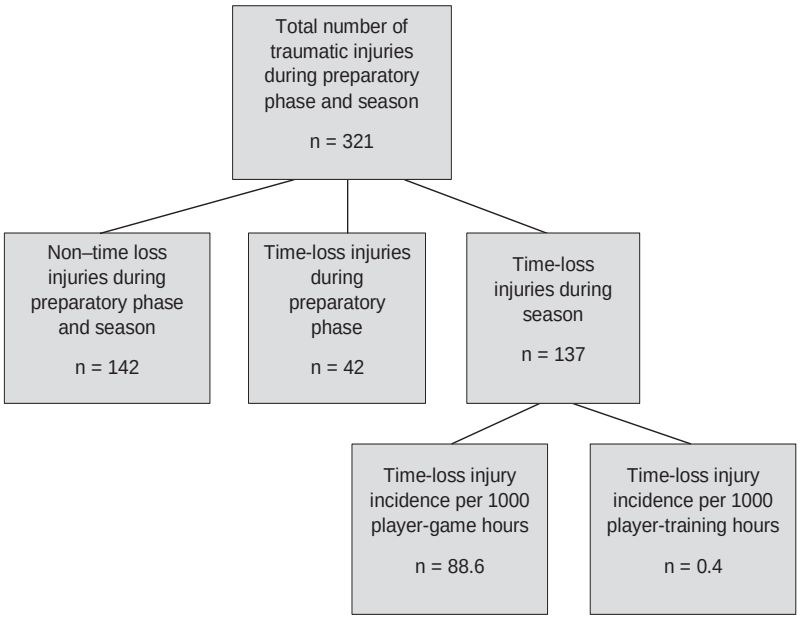

Figure 1. Overview of the number of traumatic ice hockey injuries.

not targeting specific body parts—has been validated in German.[13] The OSTRC Overuse Injury Questionnaire used in the present study contains 4 multiple-choice questions targeting shoulder, low back, hip/groin, and knee injuries, with questions about (1) the difficulties participating in normal training and competition during the past 2 weeks, (2) the amount of training volume reduction, (3) the extent of performance impairment, and (4) the degree of pain related to ice hockey. The responses to each of the 4 questions were allocated a numerical value between 0 (no problems/limitations) and 25 (maximum problems/limitations) and were subsequently summed to calculate a severity score between 0 and 100 for each body part.[6,18]

Data Analysis

Descriptive statistics are presented as frequencies and proportions of any recorded traumatic injury. The overall incidence of traumatic injuries was calculated as the number of injuries per 1000 game or training hours during the season.

The prevalence of overuse injuries was calculated as the number of players who reported any overuse problem, identified by a score >0 on any of the 4 questions or substantial overuse problems, divided by the total number of respondents.[6] Substantial overuse problems included only those leading to moderate or severe reductions in training volume or performance or an inability to participate in normal training/competition.[18] The prevalence of overuse injuries was calculated biweekly and for each body part; that is, shoulder, low back, hip/groin, and knee. The cumulative severity score was then calculated for each body part as the sum of the severity scores of the respective body part for all players over the study period divided by the number of respondents on that 2-week interval.[6] The cumulative severity score was the basis for comparison of the relative effect of overuse problems in each body part.[5,18] For 6 of the 26 biweekly periods (ie, weeks 0, 2, 4, 12, 48, and 50), we received questionnaire data from ≤3 teams because of holidays or different start periods of the preparatory phase, and therefore the data sets for these time points were not included in the analyses.

RESULTS

Participants

The 122 players who participated in this study were from 10 different nations and had a mean age of 26 years. Seventy-seven players had >3 years of experience in the National League.

Traumatic Time-Loss Injuries

The incidence of time-loss injuries per 1000 player-game hours during the season was 88.6, and it was 0.4 per 1000 player-training hours (Figure 1). Team injury incidence ranged between 80 and 96 per 1000 player-game hours and between 0.2 and 0.5 per 1000 player-training hours.

Overall, 23% of injuries were localized to the hip/groin/thigh region; 17%, to the head; and 15%, to the lower leg/foot (Figure 2). Twenty-four percent of injuries were diagnosed as muscle strains; 18%, as concussions; and 17%, as contusions (Figure 3).

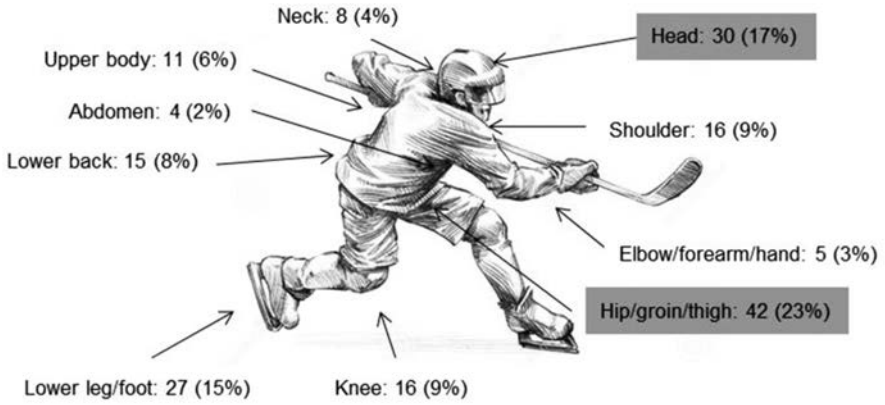

Figure 2. Time-loss injuries per body region (n = 179).

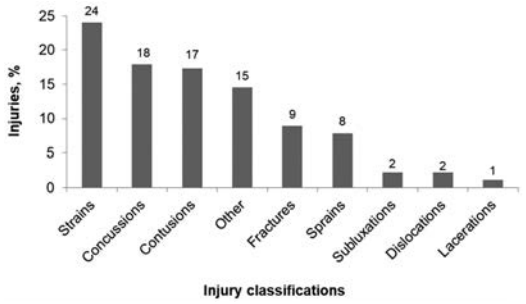

Figure 3. Time-loss injury classifications (n = 179).

Frequency, Type, and Location of Traumatic Time-Loss and Non–Time-Loss Injuries

Seventy-five percent of all injuries occurred during games. Of the remaining 25% of training-related injuries, 63% occurred on-ice, 30% occurred during dryland, and 7% occurred during weight lifting sessions. On average, a player missed 32 training sessions and 7 games after an injury. Eighteen percent of all injuries were localized to the hip/groin/thigh region; 13%, to the face; and 11%, to the head. Twenty-eight percent of all injuries (ie, time-loss and non–time loss) were diagnosed as contusions, and 21% were diagnosed as muscle strains. The 3 main causes of all traumatic injuries were collisions with the opponent's body (31%), hits by a puck (16%), and collisions with the board (13%). A game-related injury was reported in 23% of the right forwards, 21% of the right defenders, and 20% of the left forwards, followed by 17% of the center players, 15% of the left defenders, and 4% of the goalkeepers. Twenty-seven percent of injuries occurred in the defending zone along the boards, followed by the attacking zone along the boards (20%) and the neutral zone (16%) (Figure 4). Forty-four percent of all injuries were reported during the central part (minutes 7-13) of the second game period compared with 26% in the first period and 30% in the third period.

Prevalence of Overuse Injuries

The average response rate of the OSTRC Questionnaire was 83%. The average number of players per team who completed the questionnaire was 21. The yearly prevalence rates of all overuse and substantial overuse injuries were 49% and 13%, respectively. The average prevalence rate for all overuse hip/groin injuries was 16% (Figure 5D). The shoulder, hip/groin, and knee regions alike accounted, on average, for 4% of substantial overuse injuries (Figure 5, B, D, and E). The average prevalence rates of all overuse and substantial overuse injuries during the preparatory phase were 58% and 15% and during the season were 43% and 14%, respectively (Figure 5A).

Hip/groin injuries and shoulder injuries showed the highest and lowest cumulative severity scores, respectively (Figure 6).

DISCUSSION

We investigated the frequency, type, location, and incidence of traumatic injuries as well as the prevalence and relative effect of overuse injuries affecting different body regions in professional male ice hockey players from Switzerland over a competitive season.

Traumatic Time-Loss Ice Hockey Injury Incidence

The incidence of traumatic time-loss injuries per 1000 player hours during the season was >1.5 times higher in our study compared with National Hockey League (NHL) statistics,[20] even though the European style of play was considered to be less aggressive and physical compared with the American style.[11] Because we collected data over only 1 season, our results cannot be easily compared with those of the prospective study of McKay et al,[20] which

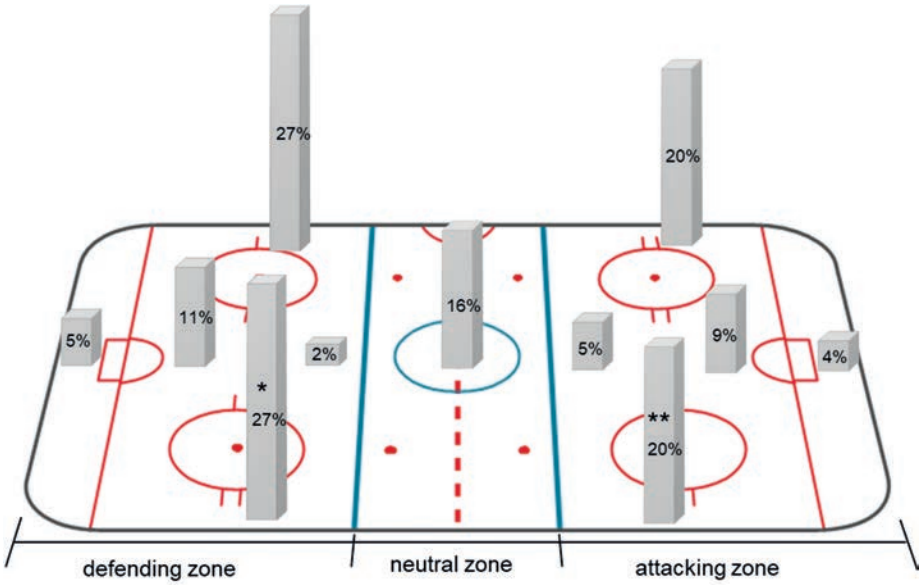

Figure 4. Number of time-loss and non–time loss injuries per playing zone (n = 256). *Twenty-seven percent of injuries occurred in the defending zone along the boards on the right or left side. **Twenty percent of injuries occurred in the attacking zone along the boards on the right or left side.

spanned over 6 NHL seasons; they reported a range of traumatic injuries per 1000 player-games of 39 to 67 versus the 80 to 96 in our current study. On the other hand, the incidence of 66 to 83 injuries per 1000 player-game hours reported by a number of earlier studies focused on European ice hockey leagues[19,21-23] was more in line with our range. However, injury definitions vary across the studies, which makes a comparison difficult.

Frequency, Type, and Location of Traumatic Time-Loss and Non–Time Loss Injuries

In agreement with other studies,[11,20,27] the incidence of all traumatic injuries of our cohort was higher during games than during training sessions, and the most common injury mechanism was body checking. Most injuries occurred along the boards even though body checking was the more common injury mechanism compared with collision with the boards. This may be explained by the fact that the "event" of players getting checked by an opponent, followed by collision with the board, was not specifically captured by the injury report form. Thus, it was considered as a limitation of the injury report form. We found that injuries were more frequent in the second period, which corresponds to previous observations from 7 World Championship tournaments,[27] followed by the third period. This might be attributed to the fact that the level of fatigue may progressively increase during a game, thus leading to more injuries. Interestingly, a greater number of injuries occurred in the first period of NHL games[20]; McKay and collaborators[20] speculated that, because players were not fatigued, they had the capacity for greater physical play, which could lead to a higher risk of injuries. Our results also showed that the goalkeepers were at a lower risk of sustaining injuries than were the field players, whereas the risk was highest for the forwards, closely followed by defenders.[19,21,27] There is a notable difference in the physical style of play associated with each of these positions, which can explain the different risk of injuries among goalkeepers, defenders, and forwards.[20]

Hip/Groin and Head Injuries as Major Problems in Ice Hockey

Similarly to the NHL study of McKay et al,[20] we found that the most commonly injured lower and upper body regions were the hip/groin/thigh and the head, respectively. Ice hockey players are particularly susceptible to adductor muscle strains,[29] and this was confirmed by our data, as muscle strains in the hip/groin/thigh region were the most common traumatic time-loss injuries. Besides muscle strains, the most common injuries leading to time loss were concussions.[9,17] Ice hockey is a high-impact stop-and-go sport, where body checking is permitted and players are exposed to environmental risk factors such as, ice, boards, sticks, and pucks, thus leading to a high risk of injuries, especially to the head.[17] In 1997, the NHL and NHL Players Association (NHLPA) launched the NHL-NHLPA Concussion Program in order to improve the scientific knowledge about concussion in professional ice hockey players.[2] Hutchison et al[15,16] reported how a systematic video analysis of NHL concussions contributed to

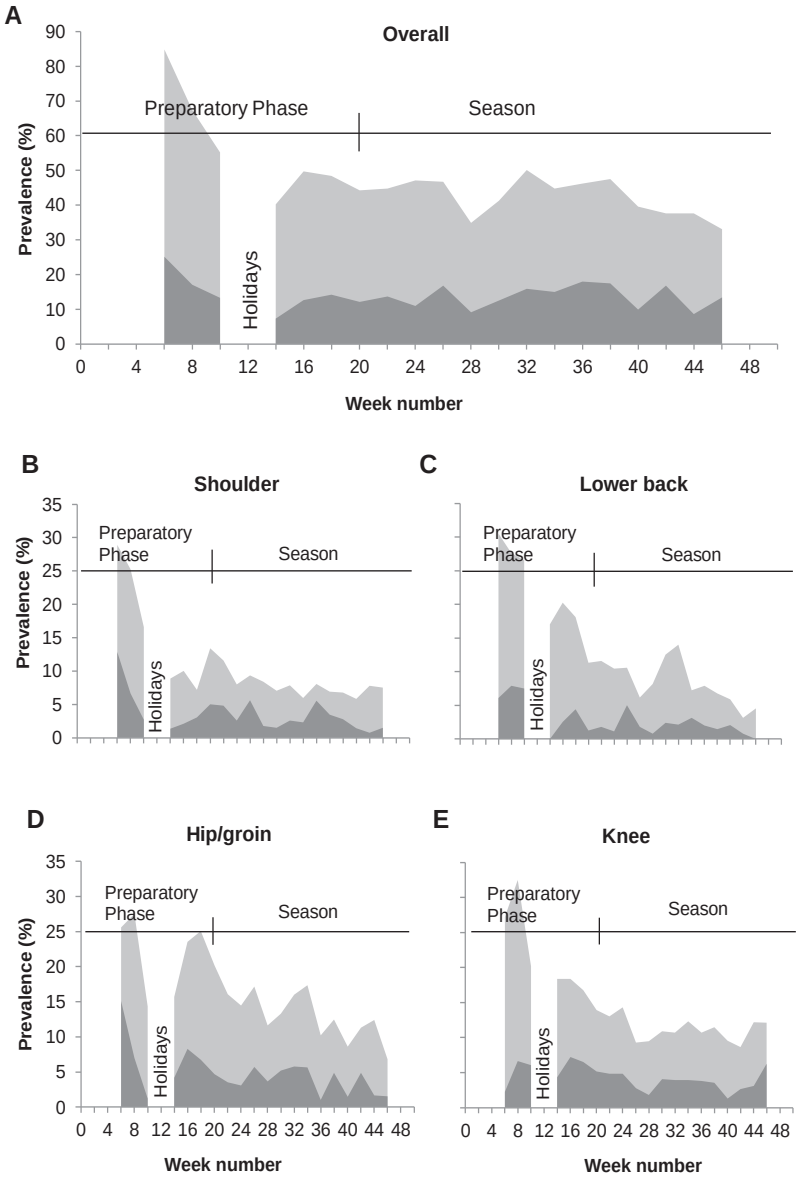

Figure 5. Prevalence of all overuse problems (light gray area) and substantial overuse problems (dark gray area) (A) overall and located at the (B) shoulder, (C) low back, (D) hip/groin, and (E) knee.

identifying the injury mechanisms and various factors associated with concussions, therefore helping the development of education, evaluation, management, and prevention strategies. Muscle strains and concussions might be reduced via specific preventive strategies such as, injury prevention training programs, modifications of game rules, and/or implementation of arenas with flexible boards and glass,[27,29] which should definitely require more attention in ice hockey.

Overuse Injuries in Ice Hockey

Ice hockey seems to be associated with a high risk of overuse injuries (49%) compared with those in other sports, such as football (13%) and cross-country skiing, floorball, handball, road cycling, and volleyball (39%).[5,18] To our knowledge, this is the first epidemiological study investigating overuse injuries in professional ice hockey players. Based on our results, the hip/groin region, which was

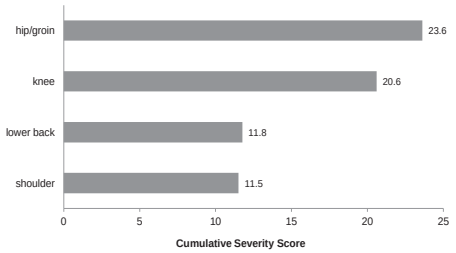

Figure 6. Relative effect of overuse injuries affecting the shoulder, low back, hip/groin, and knee, indicated as the cumulative severity score.

previously reported as the most problematic region for ice hockey players,[4,10,25,29,31] showed the highest relative effect of overuse injuries. Clinical entities, such as adductor-related pain,[14] hip-related groin pain,[30] and femoroacetabular impingement syndrome (FAIS),[12] are often used to classify hip/groin pain in ice hockey players. Ice hockey skating patterns (ie, external rotation in hip abduction during the push-off phase and internal rotation in hip flexion during the recovery phase) were previously described to be at-risk positions for FAIS in Peewee ice hockey players and should be taken into consideration in the prevention of overuse injuries of the hip.[25] Furthermore, the imbalance between hip and abdominal muscle strength (ie, strong adductor muscles versus weak lower abdominal muscles) might be an underlying cause of athletic pubalgia.[8] However, a classification, such as a specific diagnosis of hip/groin overuse injuries, using the OSTRC Overuse Injury Questionnaire is not possible because it only captures self-reported overuse problems of different anatomical regions. A recent investigation[31] showed a high prevalence of hip/groin problems in ice hockey players regardless of the playing position, thus indicating that all players might potentially benefit from prevention strategies for overuse injuries.

The highest prevalence of all overuse (85%) and substantial overuse (25%) injuries during the preparatory phase—at the beginning of this study—might be attributed to the fact that players were just starting out the summer training and were not in as good condition as they were later in the season and thus were more prone to injuries. Another reason might be the high training load during the summer months (on average, there were 14 h/wk of dryland training during the preparatory phase vs 3 h/wk during the season) leading to overuse injuries. After the preparatory phase load, there is also the season match load, with often a congested calendar (2-3 games per week), including short recovery times; this, in turn, can lead to a generally high injury rate, as previously seen in professional soccer players.[7]

Limitations

One of the limitations of this study is the sampling of approximately 50% of invited teams, which might have led to a potential detection and sampling bias. This limitation can only be addressed by increasing the total number of teams; however, this was not possible because our current study was restricted to ice hockey teams with the ability to understand German or English. One of the major limitations involves the reporting bias of traumatic injuries by the person who was responsible for data collection for each team. However, this was anticipated by the primary investigator training each person using the injury report form before data collection. A comparison among the teams highlighted that some medical staff members were more likely to report minor non–time loss injuries, such as contusions by pucks. For example, in some teams, contusions were consistently treated using an ice pack by the person responsible for data collection, whereas other teams did not treat them and therefore did not report them. The number and type of time-loss injuries among teams were, however, comparable. Another limitation is associated with the OSTRC Overuse Injury Questionnaire, which only focuses on predefined injury regions and does not allow other overuse injuries (eg, FAIS) to be classified. Ideally, each problem reported by an athlete is quickly followed up with a confirmatory medical examination; however, this obviously may increase the logistical difficulty and cost of conducting a study.[6]

Perspectives

The high prevalence and relative effect of overuse injuries, with hip/groin problems at the top, highlight a significant medical concern in ice hockey athletes that should be addressed in the future. Future research should focus on the development of injury prevention programs, especially for the hip/groin area and head, to decrease the prevalence of injuries. It is of high importance to further develop implementation strategies in order to address injury prevention program adherence in different ice hockey teams.

CONCLUSION

Muscle strains and concussions were the most frequent time-loss injuries in Swiss professional ice hockey players. The high prevalence and relative effect of overuse injuries, particularly affecting the hip/groin, highlight a significant medical concern in ice hockey athletes that should be carefully addressed in the future.

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Chapter 4

Perceived barriers to and facilitators of an injury prevention program among professional male ice hockey players and staff members

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Picture taken by Romana Franceschini-Brunner [August 8, 2020].

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Human Kinetics
ORIGINAL RESEARCH REPORT

Perceived Barriers to and Facilitators of an Injury Prevention Program Among Professional Male Ice Hockey Players and Staff Members

Romana Brunner, Mario Bizzini, Nicola A. Maffiuletti, and Karin Niedermann

Context: Injury prevention programs for the lower extremities are effective in team-sport athletes. ***Objective:*** To identify barriers and facilitators among professional ice hockey players and staff members for adhering to an injury prevention program. ***Design:*** Cross-sectional survey. ***Setting and Participants:*** A questionnaire about barriers and facilitators related to knowledge/perceptions, beliefs, adoption, and habits about injury prevention was filled out by Swiss professional male ice hockey players and staff members. ***Main Outcome Measures:*** Frequencies of ratings were calculated and binary logistic regression analysis was applied to predict a relationship between a high/low perceived benefit of an injury prevention program and player characteristics. ***Results:*** Knowledge, perceived benefit, and relevance of injury prevention as well as awareness of high risk of injuries in ice hockey were identified as important facilitators. Players' habit of exercise performance was identified as a barrier. Program understanding of staff members was identified as a facilitator and barrier. No significant relationships were observed between a high/low perceived benefit of an injury prevention program and age ($P = .85$), nationality ($P = .53$), level of education ($P = .63$), National League experience ($P = .50$), or occurrence of lower-extremity injuries in the previous season ($P = .10$). ***Conclusions:*** Players and staff members clearly rated perceived benefits of an injury prevention program, which can be considered an important facilitator of the uptake and adoption of such a program in ice hockey teams. Players should be educated about well-performed injury prevention exercises. Staff members should be educated about the aim of a regular injury prevention program. An injury prevention program might be implemented in players of all ages, levels of education, and experience in the National League, irrespective of previous injuries. Identified barriers and facilitators should be addressed when implementing an injury prevention program in a setting of professional ice hockey teams in the future.

Keywords: athletes, implementation, injury prevention exercises, perspective, preventative training programs

Ice hockey is a popular high-impact sport with a high risk of head and lower extremity (LE) injuries, mainly affecting the hip/groin/thigh and knee region.[1–5] Injuries can result in decreased sporting function, loss of playing time, high financial burden for the athlete's employer as well as the health care system, and an increased risk of reinjury and chronicity.[5,6] Recent studies on musculoskeletal injuries showed that the majority of problems in ice hockey were of overuse origin, not leading to time loss but related to reduced self-reported function.[4,5,7] Common extrinsic intervention strategies for players comprise tougher rules and regulations, rink adaptations, and equipment,[2,8] yet intrinsic intervention strategies such as training—for example, muscular strength and endurance, range of motion, reaction time, and proprioception—are only rarely described for ice hockey.[9,10] Only one study showed the effectiveness of a preseason exercise program to prevent adductor muscle strains in professional ice hockey players. Nevertheless there is still a lack of injury prevention research in ice hockey.[9]

To successfully implement injury prevention programs it is important to define an implementation strategy. For that to occur, the setting in which a program will be implemented needs to be explored. According to the social marketing theory,[11] uptake and long-term adherence to an innovation, such as an injury prevention program, should not start with a final product, such as specific exercises for an injury prevention program. Instead, the current practice needs to be explored beforehand including analysis of (1) the current dryland training sessions, (2) target group(s) and their perceived barriers to and facilitators of the innovation, and (3) the context in which the innovation will be implemented.[12] This important step provides the basis to develop the implementation strategy for the innovation, which is based on different implementation activities.[12] The application of implementation science illustrates how sports injury prevention should incorporate these important concepts.[13,14] Previous investigations examining the barriers and facilitators to implementing injury prevention programs in athletes have typically focused on athletes and/or coaches separately.[15–17] Adoption is defined as the initiation of a program in a team setting, whereas adherence relates to the long-term extent to which a team implements a particular intervention as prescribed.[18] Even though athletes are the end users and beneficiaries of prevention programs, the attitudes, knowledge, and beliefs of all staff members have greater influence than players' attitudes alone.[15] One of the characteristics of professional ice hockey teams is that the head coach is merely in charge of the technical and tactical aspects, whereas other staff members (athletic trainers, sports physical therapists, and massage therapists) are dedicated to the fitness training and rehabilitation of the players. Thus it is important to assess barriers and facilitators for the uptake and adoption of a program among players as well as the staff members—not only coaches, but also athletic trainers and physical therapists.[19]

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This study aimed to identify barriers and facilitators among professional ice hockey players and staff members for adhering to an injury prevention program for the LE. It was hypothesized that players' characteristics were associated with a high or low perceived benefit of an injury prevention program and that time would be a major barrier for program adoption.

Methods

Questionnaire Design

The development of this questionnaire was based on a previous survey related to the implementation of an injury prevention program in Australian football players.[17] Some of the questions were added based on social marketing strategies to explore the needs and culture of the target group.[11] All questions were adapted to ice hockey as well as formulated specifically for players and staff members. However, the questionnaire did not propose specific exercises because prior to the development of an injury prevention program it is important to obtain information about factors that may have an impact on the uptake and adoption of the program.[11,17] The questionnaire comprised a total of 25 items about injury prevention for the LE[2,3] over 4 categories: (1) knowledge/perceptions (definition and perceived benefits of injury prevention; 3 questions), (2) beliefs (about injury prevention; 13 questions), (3) adoption (initiation of a regular injury prevention program; 3 questions), and (4) habits (preferences of ice hockey players; 6 questions). The answer options to the questions were either multiple selection or single choice with answers ranging from "strongly disagree" to "strongly agree" on a 5-point Likert scale or open-ended questions. The preliminary version of the questionnaire was content- and face-validated by peer ice hockey players who were not involved in the study.[20]

Participants

In total, 8 professional male ice hockey teams of the National League (NL) of the German-speaking part of Switzerland and their staff members, that is, athletic trainers, sports physical therapists, massage therapists, and assistant coaches, were invited to participate in the study and complete the questionnaire during the preseason period (August 2017). Inclusion criteria were the ability to understand German or English and a signed informed consent. According to the screening question during consent, none of the invited teams engaged in nor had a history in engaging in an injury prevention program use. The study was approved by the local ethics committee of the Canton of Zürich (ID number 2017-00085).

Data Collection

The questionnaire was completed by players and staff members of each participating ice hockey team during a summer dryland training session to reach the highest possible response rate. The questionnaire was administered to all players and athletic trainers, massage therapists, sports physical therapists, or coaches who were present on the specific test day. Information on player characteristics, that is, age, nationality, level of education, total NL experience, and LE injuries sustained in the previous season, was collected with additional questions. Study participants needed approximately 5 to 10 minutes to complete the questionnaire.

Data Analysis

Data were collected, stored, and managed in Microsoft Excel (Redmond, WA). Player and staff member characteristics are presented as frequencies (in percentages) or means with SD where appropriate. The frequency of ratings related to knowledge/perceptions, beliefs, adoption, and habits is reported as absolute numbers and percentages. Due to the relatively small sample size, all 5-point Likert scale variables were reduced to 3 levels (strongly/rather disagree, undecided, and rather/strongly agree). Two authors (R.B. and K.N.) independently allocated the most-rated items of the different categories with multiple selection options and Likert scale questions as facilitators of and/or barriers to adoption of an injury prevention program based on the description in a recent study[21]: (1) no evidence for influence on program implementation; (2) evidence of positive influence on program implementation, that is, a facilitator; (3) evidence of negative influence on program implementation, that is, a barrier; and (4) evidence of a mixed influence on program implementation, that is, a facilitator of and a barrier to program implementation. If the identification was unclear, consensus was either reached by discussion or with the help of a third reviewer (N.A.M.). To verify the hypothesis, that is, that player characteristics were associated with a high or low perceived benefit of an injury prevention program, the question "How much would you rate the benefit of an injury prevention program?" and the answers on a 5-point Likert scale were categorized into the variables "high" or "low" for further analysis. It was accounted for a potential clustering effect by teams. Binary logistic regression analysis was applied using PASW Statistics (version 18.0; SPSS Inc, Chicago, IL) with the level of significance set at $P < .05$ to predict a relationship between the perceived benefit (high vs low) of an injury prevention program and the following player characteristics as independent variables: age, <25 years versus >25 years; nationality, European versus North American; level of education, high (university degree) versus low (up to high school certificate); total experience in NL, <3 years (novice players) versus >3 years (experienced players); time-loss LE injuries versus no injuries in the previous season (self-reported by players). The outcome of the binary logistic regression analysis was identified as either a facilitator of and/or barrier to adoption of an injury prevention program.

Results

Participants

Out of the 8 professional ice hockey teams invited, 6 participated in the study (75%). The remaining 2 teams were unavailable due to their busy schedule or lack of interest. A total of 148 ice hockey players (98% response rate) and 11 staff members (92% response rate)—that is, 3 sports physical therapists, 3 massage therapists, 4 athletic trainers, and one assistant coach—completed the questionnaire. The characteristics of the participating players and staff members are presented in Table 1.

Player and Staff Members' Knowledge and Perceptions About Injury Prevention

Table 2 shows the ratings of the multiple selection questions of players and staff members in the category of knowledge/perceptions. The most-rated items to the question of injury prevention definition were: "prevention of injuries with specific training" rated

Table 1 Player and Staff Member Characteristics

Participants' characteristics	Players (n = 148)	Staff members (n = 11)
Age, mean (SD), y	26.5 (4.7)	41.2 (9.2)
Nationality, n (%)		
Swiss	111 (75)	6 (55)
Austrian	2 (1)	—
German	1 (1)	—
Dutch	—	1 (9)
Latvian	2 (1)	—
Swedish	7 (5)	—
Finnish	5 (3)	—
Czech	3 (2)	—
Italian	1 (1)	2 (18)
French	1 (1)	—
United States	3 (2)	—
Canadian	7 (5)	—
Others	5 (3)	2 (17)
Level of education, n (%)		
Compulsory school education	32 (22)	—
Completed professional apprenticeship	44 (30)	2 (18)
High school certificate/professional qualification	41 (28)	1 (9)
Higher education (eg, master craftsman examination)	5 (3)	1 (9)
University degree	23 (16)	6 (55)
Other	2 (1)	1 (9)
Level of experience in NL, n (%)		
<3 y	54 (37)	2 (18)
≥3 y	93 (63)	9 (82)
LE injuries in previous season, n (%)		
No injury	90 (61)	
One or more injuries	57 (39)	

Abbreviations: LE, lower-extremity; NL, National League.

by 95% of the players and 91% of staff members; "prevention of injuries as the most perceived benefit of an injury prevention program performed on a regular basis" rated by 81% of players and 82% of staff members; and "injury prevention as a preparation of the body for training" rated by 82% of staff members and 64% of players.

Overall, 78% of the players and 91% of the staff members agreed upon a moderate to high perceived benefit of an injury prevention program (Table 2).

Player and Staff Members' Beliefs, Adoption, and Habits With Regard to Injury Prevention

Table 3 shows the ratings of the items on the Likert scale of players and staff members in the category beliefs, adoption, and habits.

The items in the beliefs category with rather strong or strong agreement were: "prevention of injuries by following a specific exercise program" rated by 91% of both players and staff members; "the importance of injury prevention for playing at the NL level" rated by 86% of players and 91% of staff members; and "ice hockey has a high risk of injuries" rated by 82% of players and 100% of staff members. The item "every player is exclusively responsible for injury prevention" was rated by 78% of players and 91% of staff members and "the trainers (off-ice/on-ice) are responsible for injury prevention with their training sessions" were rated by 41% of the players and 82% of the staff members. The item "an individual warm-up would be more useful than a standardized warm-up program with the whole team" was rated by 77% of players and 82% of staff members.

In the category adoption, 70% of players and 82% of staff members rather strongly or strongly agreed to the item "a standardised prevention program in form of a warm-up of 15 minutes at least 4 times per week is feasible" (Table 3). Thus, players and staff members both agreed to the uptake and adoption of an injury prevention program in their team.

The items getting rather strong or strong agreement by the players in the category habits were: "the players warm up before strength training" rated by 95%, followed by "it is important to the player that he carries out the exercises during the off-ice training correctly" and "the player assumes that his athletic trainer would inform him in the case that he performs an exercise incorrectly," both rated by 94%. The items getting rather strong or strong agreement by the staff members in the same category were: "it is important to the player that he observes the correct posture in the

Table 2 Player and Staff Members' Knowledge and Perceptions of Injury Prevention

Knowledge/perceptions	Item rated as *yes* by players (n = 148)	Item rated as *yes* by staff members (n = 11)
Definition of injury prevention		
Prevention of injuries with specific training	141 (95)	10 (91)
Prevention of injuries with flexible boards	81 (55)	8 (73)
Prevention of injury with equipment	44 (30)	5 (45)
Prevention of injuries by implementing tougher penalties	23 (16)	4 (36)
Other: showing respect toward other players, massages and recovery time, complete preseason/season dryland training, prevention of muscle imbalances that can cause problems, player education on regeneration and tissue repair, and individualization of the training program for each player	2 (1)	4 (36)
Perceived benefits of a regular injury prevention program		
Prevention of injuries	120 (81)	9 (82)
Preparation of the body for training	94 (64)	9 (82)
Improvement in flexibility	86 (58)	8 (73)
Improvement in strength	58 (39)	5 (45)
Better performance as a player	58 (39)	4 (36)
Improvement in balance	53 (36)	4 (36)
Safety, to avoid being injured	46 (31)	1 (9)
More interesting/good alternative to the normal warm-up procedure	21 (14)	1 (9)
Extent of perceived benefit of an injury prevention program		
High	35 (24)	4 (36)
Moderate	81 (55)	6 (55)
Undecided	28 (19)	—
Somewhat/very little	3 (2)	1 (9)

Note: Values are reported as numbers (%).

mirror during the training exercises" rated by all staff members, followed by "it is important to the player that he maintains the correct leg alignment during jump training" rated by 91% (Table 3).

Relationship Between Players' Perceived Benefit of an Injury Prevention Program and Characteristics

There was no significant relationship between a high or low perceived benefit of an injury prevention program and age ($P = .85$), nationality ($P = .53$), level of education ($P = .63$), NL experience ($P = .50$), or LE injuries in the previous season ($P = .10$).

Synthesis of Barriers to and/or Facilitators of Prevention

Table 4 provides a synthesis of items that have no evidence for influence on program adoption or act as either facilitator and/or barrier among players and staff members toward the adoption of an injury prevention program for the LE.

Discussion

This study aimed to identify barriers and facilitators among professional ice hockey players and medical staff members for adhering to an injury prevention program in professional ice hockey teams. The most prevalent facilitators for players and staff members were the knowledge, perceived benefit, and relevance of injury prevention as well as awareness of high risk of injuries in ice hockey. Players and staff members clearly agreed with the benefit of such a program, which can be considered as an important facilitator of the uptake and adoption of an injury prevention program in professional ice hockey teams.

Agreement and Disagreement of Players and Staff Members Toward Injury Prevention

The players and staff members agreed or disagreed on several topics relating to injury prevention; these were identified as facilitators and/or barriers.

The identified facilitators are similar to the outcome of a survey with Premier Division Australian football players.[17] These authors suggested that efforts aimed at educating players about the benefits of injury prevention programs were unnecessary[17] because the players already had the knowledge about injury prevention. Moreover, knowledge does not automatically lead to a behavior change although it is an important requirement to take action.[11]

The high importance of individualization of an injury prevention program for players and staff members is an essential facilitator for program maintenance. However, the individualization of an injury prevention program tailored to the needs of each player was reported to be rather unfeasible due to the lack of resources such as time for screening.[22] It might be an option to include a compilation of different prevention exercises to allow individualization of the program, in order to further increase the chance of long-term

Table 3 Player and Staff Members' Beliefs, Adoption, and Habits With Regard to Injury Prevention

	Items rated by players (n = 148) in %			Items rated by staff members (n = 11) in %		
Beliefs/adoption/habits	**Rather agree/ strongly agree**	**Undecided**	**Rather disagree/ strongly disagree**	**Rather agree/ strongly agree**	**Undecided**	**Rather disagree/ strongly disagree**
Beliefs about injury prevention						
Injuries can be prevented by following a specific exercise program	91	7	2	91	9	—
Injury prevention plays a big role for the level of play required in the NL	86	11	3	91	—	9
Ice hockey has a high risk of injuries	82	18	1	100	—	—
Every player is exclusively responsible for injury prevention	78	15	7	91	9	—
An individual warm-up is more useful than a standardized warm-up program	77	20	3	82	18	—
The off-ice training prevents injuries	74	19	7	82	18	—
The on-ice hockey training is beneficial for the prevention of injuries	49	33	18	58	18	18
The trainers (off-ice/on-ice) are responsible for injury prevention with their training sessions	41	44	15	82	18	—
An injured player does not have to be completely rehabilitated to play ice hockey again	39	26	35	27	18	55
A guided injury prevention program in form of a warm-up with the whole team is useful	35	36	29	55	9	36
Training should additionally focus more on injury prevention rather than on ice hockey performance	13	43	44	9	36	55
Program adoption						
A standardized prevention program in form of a warm-up of 15 min at least 4 times per week is feasible	70	21	9	82	—	18
Mean maximum acceptable time to perform an injury prevention program in form of a warm-up on a regular basis, min		19.2			18.8	
Source of knowledge						
The current trainers/physiotherapists have passed on their knowledge to the players about injury prevention	64	27	9	91	9	—
The fellow players have passed on their knowledge to the players about injury prevention	33	50	17	55	18	27
Habits about exercise performance						
The players warm-up before strength training	95	5	1	55	27	18
It is important to the player that he carries out the exercises during the off-ice training correctly	94	4	1	82	18	—
The player assumes that his athletic trainer would inform him in the case that he performs an exercise incorrectly	94	5	1	18	45	36
It is important to the player that he maintains the correct leg alignment during jump training	85	11	2	91	9	—
It is important to the player that he observes the correct posture in the mirror during the training exercises	64	22	14	100	—	—
The player ensures that his posture is checked by fellow players during the training exercises	34	39	27	73	27	—

Abbreviation: NL, National League. Note: Values are reported as percentages unless otherwise indicated.

Table 4 List of Player and Staff Members' Barriers to and/or Facilitators of an Injury Prevention Program

Barriers and/or facilitators	Most prevalent items	Players	Staff members
No evidence for influence	• Time (ie, maximum acceptable time of 20 min to perform an injury prevention program)	✓	✓
	• Players characteristics (ie, age, nationality, level of education, NL experience, or occurrence of lower-extremity injuries in the previous season)		
Facilitators	• Relevance of injury prevention	✓	✓
	• Awareness of high risk of injuries in ice hockey	✓	✓
	• Knowledge about injury prevention	✓	✓
	• Perceived benefit of injury prevention program adherence	✓	✓
	• Responsibility as a player/trainer for injury prevention	✓	✓
	• Individualization of exercises	✓	✓
	• Program adoption	✓	✓
Barriers	• Training sessions should not focus excessively on injury prevention	✓	✓
	• The athletic trainer is expected to provide feedback in case of incorrect exercise performance	✓	
	• Exclusive responsibility of players for injury prevention		✓
	• Access to an athletic trainer for injury prevention	✓	
Facilitator and barrier	• Injury prevention program to prepare the body for training		✓

Abbreviation: NL, National League.

program adherence. Specifically, it has been demonstrated that strengthening and proximal control training including verbal feedback had a higher prophylactic effect on reducing anterior cruciate ligament injury risk in athletes.[23] Staff members should therefore choose appropriate exercises within those broader categories and tailor the exercises to individual needs.

Most of the staff members and some players believed that the athletic trainers were responsible for injury prevention during the training sessions. Thus, the athletic trainers facilitate program uptake as they play a major role in an injury program's initiation and delivery.[15] Furthermore, an athletic health care provider likely has the most knowledge and experience to tailor and implement an injury prevention program. On the other hand, not having any/enough access to an athletic trainer could be a barrier for players.

The staff members and players agreed with the self-responsibility of players for injury prevention. This item was also identified as a facilitator for program uptake because awareness of responsibility is a precondition necessary to change a behavior.[11] However, this item can also act as a barrier for staff members, as they may consider themselves not responsible for injury prevention and neglect it.

Players expect athletic trainers to inform them if an exercise is not performed correctly. This can in turn act as a barrier for players to carefully perform prevention exercises and rely on their athletic trainers to perform the exercises correctly. Players' habits must be taken into account and can be improved by educating both program deliverers and players on the importance of maintaining proper technique and movement quality when performing injury prevention exercises.[24–26] Interestingly, most of the staff members saw a benefit of a prevention program in preparing the body for training, which can facilitate adoption of preventive exercises, for example warming up before each training session. Performing prevention exercises in the form of a warm-up before training sessions is also based on current evidence.[21,25] However, the program should not solely be seen as a preparation of the body for the actual training session, but rather acknowledged as injury prevention in general[17] to increase awareness and appreciate its importance. This item was therefore identified to act as a facilitator for program adoption and as a barrier for program understanding. Staff members should be properly educated about the primary goal of an injury prevention program.

Players and staff members disagreed that training sessions should focus more on injury prevention, which is an expected finding in a performance-driven context like professional ice hockey. Less than 40% of the players perceived the benefit "to better perform as a player" when endorsing an injury prevention program. Players and staff members might not believe that injury prevention exercises enhance performance if there are no clear performance outcomes.[17] Therefore, an injury prevention program should be quick and easy to perform before a regular training session and should be acknowledged as such.[25]

Implications for the Implementation of an Injury Prevention Program

Time was expected to be a major barrier to perform an injury prevention program on a regular basis. However, based on our results, a program of maximum 20 minutes seemed to be accepted, which is in line with the recommendations by Padua et al.[25] The authors suggested a 15- to 20-minute time period to perform a multicomponent injury prevention program.[25] On the other hand, an exercise volume greater than 20 minutes is associated with a higher prophylactic effect.[26,27] Thus, time was not considered a barrier to program implementation. Players and staff members rated a prevention program in the form of a warm-up of 15 minutes at least 4 times per week as feasible, which was therefore identified as a facilitator for program uptake and adoption. Nevertheless, the major challenge is long-term program adherence as described in previous investigations.[28,29] The factors of age, nationality, level of education, NL experience, or occurrence of LE injuries in the previous season were not associated with a high or low perceived benefit of an injury prevention program; hence, players

characteristics were identified as having no evidence for influence on program adoption. This is an important aspect for future program implementation in Swiss NL teams and among players with different characteristics.

Limitations

The self-reported questionnaire was only face and content validated. It was, however, not tested for reliability because the study design is a cross-sectional survey and the questionnaire will not be used again. Moreover, the questions were based on a previous survey with the Health Believe Model[30] and the Reach, Efficacy/Effectiveness, Adoption, Implementation and Maintenance framework as theoretical basis.[31] Another limitation was the low number of staff members and the fact that they included 4 different functions, that is, sports physical therapists, massage therapists, athletic trainers, and assistant coaches, resulting in limited generalizability of the findings. This limitation can only be addressed by increasing the total number of teams; however, this was not possible in the current study, which was limited to teams in the German-speaking part of Switzerland. The authors nevertheless think it is of great value to present staff members' knowledge, attitudes, and beliefs about injury prevention. Even though athletes are the end users and beneficiaries of prevention programs, the attitudes, knowledge, and beliefs of all staff members have greater influence than players' attitudes alone. Without that knowledge a program implementation in a team might not be successful because different barriers to and facilitators of program adoption and adherence might not be properly addressed.

Conclusions

This study has identified important perceptions of different team members that may act as barriers and/or facilitators to be taken into consideration when developing and implementing a LE injury prevention program in professional male ice hockey teams. An injury prevention program can potentially be applied with success in players of different age, level of education, and experience as well as in previously injured or noninjured players. Future studies should focus on developing an injury prevention program for the LE for ice hockey players and investigating the effectiveness of such a program.

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Chapter 5

Rationale for an injury prevention program for the hip/groin for ice hockey players: a randomized feasibility study protocol

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Picture taken by Tommaso Franceschini [June 15, 2017].

Rationale for a hip/groin injury prevention program for ice hockey players: a randomized feasibility study protocol

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ABSTRACT

Objective To define a plan for evaluating the feasibility of a hip/groin injury prevention program for ice hockey teams in preparation for a prospective cluster, randomized controlled trial.

Background Ice hockey players are at high risk of sustaining traumatic and overuse injuries, especially around the hip/groin region. Muscle weakness surrounding the hip joint has been identified as a risk factor for groin-related pain. However, injury prevention research in ice hockey is scarce. Only one previous investigation showed that an exercise prevention program significantly reduced the incidence of adductor muscle strains in professional ice hockey players. The feasibility of a hip/groin injury prevention program applied to one youth ice hockey team during a preparatory phase and consecutive season needs to be evaluated.

Design A cluster-randomized feasibility study protocol.

Methods Participants will be cluster randomized to either the intervention or control group. Feasibility will be based on the recruitment and dropout rates, use and adherence to the intervention, responsiveness and number of adverse events.

Intervention The hip/groin injury prevention program comprises the Copenhagen adduction exercise and ice hockey-specific functional strength and balance exercises. Each player will also perform individual strength exercises for each hip muscle group in the case of an identified hip muscle strength deficit.

Discussion High participation and low dropout rates, high program use and adherence as well as high responsiveness of players and staff members are expected to be achieved. Biases, e.g. contamination, injury reporting, that may occur will be addressed to minimize their risk when evaluated on a larger scale.

INTRODUCTION

Ice hockey players are at high risk of sustaining traumatic and overuse injuries that mainly affect the head and the lower extremity, especially at the hip/groin region.[1-7] The incidence of traumatic time-loss hip/groin/thigh injuries and the prevalence of overuse hip/groin problems in elite and professional ice hockey players have been reported to range between 10% and 23% and between 16% and 69%, respectively.[2-4 6 7] Long-lasting hip/groin problems can result in physical impairment, reduced ice hockey performance, loss of playing time and chronicity.[3 7-10] Furthermore, these outcomes may lead to a high financial burden for the athlete's employer as well as the health care system.[10] Ice hockey players might potentially benefit from injury prevention strategies focused on the hip/groin area,[3] yet injury prevention research in ice hockey is scarce. Only one previous investigation showed that an exercise prevention program can significantly reduce the incidence of adductor muscle strains in professional ice hockey players.[11] Muscle weakness, i.e. a deficit in maximal voluntary muscle strength, surrounding the hip joint has been identified as a risk factor for groin-related pain.[12 13] It is therefore important to develop an injury prevention program for ice hockey players that targets muscle strength in the hip/groin area, in order to reduce the incidence and prevalence of both traumatic and overuse injuries.[3-5]

According to implementation science, an injury prevention program should be performed by all ice hockey players, not just those identified through screening as "at risk" for a specific injury.[14 15] In particular, athletes aged between 12-25 years who participate in high-risk sports such as ice hockey may benefit from injury prevention programs.[14] Implementation of an injury prevention program early in their career might facilitate program adherence due to the implemented program routine. Multicomponent training programs for team sport athletes are most effective when implemented as a dynamic warm-up not only during the preparatory phase, but also throughout the season.[14 16] All ice hockey players ought to

benefit from injury prevention exercises for the hip/groin regardless of playing position and player characteristics, i.e. age, nationality, previous injuries.[3 17] It is important, however, to assess player and staff member facilitators and barriers that contribute towards adherence to an injury prevention program, so as to evaluate the program's effectiveness and its future implementation in teams.[17] A previous investigation showed that players and staff members reported a perceived benefit of such a program and that a program of 15 minutes 3 times a week is feasible; both were considered as important facilitators towards the uptake and adherence of an injury prevention program in ice hockey teams.[17] It is also important to evaluate program feasibility while incorporating all included stakeholders of an ice hockey team. The distinct stakeholders can be classified on three different levels: (1) the sports chief on the macro level who is part of the team management; (2) the head or assistant coach and medical staff, i.e. physicians, massage therapists, physiotherapists, athletic trainers, on the meso level who are responsible for program delivery; and (3) the players at the micro level who are the program end-users and beneficiaries. The feasibility of a program needs to be previously assessed on all three team levels as well as at the nationwide level involving, in this case, the Swiss Ice Hockey Federation (SIHF) to act on the highest level of the sports delivery hierarchy.[18]

Overall, the aim of this feasibility protocol is to propose and evaluate an evidence-based hip/groin injury prevention program for ice hockey players due to the high prevalence of traumatic and overuse injuries affecting this body region. Design issues for conducting a cluster, randomized controlled trial (RCT) in ice hockey teams in the near future will also be evaluated. This protocol is based on the CONSORT statement for feasibility studies.[19]

METHODS

Study design

The hip/groin injury prevention program will be evaluated using a cluster RCT design, where each team represents a cluster. Randomization of participants in the same team will not be practical in this study due to possible high contamination rates.[20] Hence, a training program in a team setting is naturally applied at a cluster level, which has the advantage of ensuring external validity of the trial results.[20 21]

Objectives

The main objective of this protocol is to plan the evaluation of the feasibility of a hip/groin injury prevention program for ice hockey players in order to conduct a prospective study on a larger scale. Feasibility will be based on the recruitment and dropout rates, number of adverse events, responsiveness, i.e. satisfaction, appreciation and acceptability of the program, and use and adherence to the intervention.

Participants

Two teams of the highest ice hockey junior level in Switzerland will be recruited to participate in the feasibility study. Inclusion criteria will be the ability to understand written/oral German or English and provide informed consent to use the collected data for research purposes. Exclusion criteria for players will be previous injuries to the hip/groin that prevent full participation during the preparatory phase. Parental consent will be required to participate in the study for all players younger than 18 years of age. Approval for this study will be obtained by the local ethics committee.

Injury prevention exercise program development

The specific exercises of the program were selected after reviewing the available literature on hip/groin injury prevention while also considering the previously identified context-specific barriers and facilitators for program adherence.[17 22 23] The injury prevention program will be proposed to medical team members, i.e. athletic trainers, physiotherapists and team captains of the National and Junior Leagues of the German speaking part of Switzerland, and discussed in form of a stakeholder dialogue approach[24] within each team to achieve consensus on the program, e.g. appropriate exercise progression, hockey-specific exercises.[25] One of the key elements for ensuring future program implementation and adherence is to actively involve different stakeholders in the associated activities, which range from needs assessment through to planning for implementation and conducting evaluation.[25-27] We will therefore involve medical staff members and team captains in the development process of the program in order to reach program agreement and to enhance program adherence for future implementation.[22 25 28]

Recruitment and randomization

Prior to recruiting players of the two ice hockey teams, informed consent will be obtained from the staff members of each team, i.e. sports chief, head coach, physiotherapist and athletic trainer. The participating teams will be randomized either to the control or intervention group after obtaining player informed consent.

Procedure

The study period will last approximately one year, which includes a preparatory phase (June until August) and a consecutive season (September until April). Prior to the beginning of the preparatory phase, agreement on the program must be reached by the different medical team members. The hip/groin intervention will be applied during the preparatory

phase as well as during the ice hockey season to one of the participating teams.[16] The program deliverer, i.e. athletic trainer, will supervise the exercise performance of the intervention team. At baseline, all participating ice hockey players will be screened for post-season injuries, e.g. back or lower extremity injuries during the last 6 weeks, using a medical baseline questionnaire. All players of the intervention team will be screened by the team physiotherapist for potential hip muscle strength deficits, i.e. muscle weakness. During the study period, one person from each team's medical staff, i.e. physiotherapist or massage therapist, will be responsible for the data collection of hip/groin overuse and traumatic injuries sustained by all participating ice hockey players.

Intervention

The following intervention is described according to the Consensus on Exercise Reporting Template (CERT).[29] The detailed description of the exercises and various intensity levels is shown in Table 1.

Execution: The hip/groin injury prevention program for ice hockey players will be performed in the training room/hallway of the ice hockey arena as a part of the regular warm-up before a training session or game using the minimum and most basic equipment, i.e. different elastic bands.

Dosage: The program will be performed at least 3 times per week during the preparatory phase as well as during the consecutive season.[16] In total, the warm-up will last 20-25 minutes, of which 10-15 minutes[17] will be devoted to hip/groin exercises and 5-10 minutes to endurance exercise, e.g. cycling. The prevention exercises contain three levels of intensity, of which the first level is for symptomatic players only. All players begin the program on the second level of intensity and progress to the third level. The program deliverer will adjust the exercise intensity as determined by the player's ability to complete 2-3 sets of 10-15 repetitions of an exercise with excellent movement quality and

technique.[30] Progression will be achieved by changing from simple to more hockey-specific complex exercises. For symptomatic players, the level of intensity can be adapted based on the level of pain assessed on a 0-10 visual analog scale (VAS), where 0 indicates 'no pain' and 10 'pain as bad as it could be'. Pain up to 2 on the VAS will be considered 'safe', i.e. green zone, allowing a progression to a higher level of intensity; pain up to 5 on the VAS will be considered 'acceptable', i.e. yellow zone, no progression of the level of intensity; and pain above 5 on the VAS will be considered 'high risk', i.e. red zone, first level of intensity with careful supervision of the physiotherapist.[30]

Assessments: Isometric maximal voluntary contraction (MVC) strength of specific hip muscles will be quantified at baseline and bimonthly in the case of one of the following deficits: (1) strength deficit greater than 10% compared to the contralateral side for any given measurement;[31] or (2) strength deficit greater than 10% compared to normative data of hip muscle strength in ice hockey players;[32] or (3) strength reduction of more than 15% compared to the previous strength assessment[33] as identified by the team physiotherapist who will instruct the player to ensure high-quality exercise performance.

MVC strength will be quantified with a stabilized dynamometer using external belt-fixation (Nicholas Manual Muscle Tester, Lafayette Inc., Lafayette, IN, USA)[34] in a randomized order for hip adductors, abductors, extensors, flexors, internal rotators and external rotators as well as for knee flexors. Hip adductor and abductor muscle strength will be assessed in the side lying position, hip extensor and knee flexor strength will be assessed in the prone position, and hip flexor strength as well as internal and external rotation muscle strength will be assessed in the sitting position with the hip in 90 degrees of hip flexion as described by Thorborg *et al*.[35] For all hip strength assessments, the participants will stabilize themselves by holding the sides of a treatment table with their hands.[34] No accessory movements of other body parts than the testing limb will be allowed.[34] For each muscle group, two submaximal contractions will be performed for warm-up and familiarization

purposes. Players will then perform 3-4 MVCs during which they will be asked to perform maximal efforts for 3-4 seconds with a gradual build-up of force. Rest time between trials will be 30-60 seconds. Verbal encouragement will consistently be provided by the physiotherapist. Only the highest MVC will be considered for analysis. Muscle strength assessments will last approximately 45 minutes per player.

Intervention exercises: The first part of the program consists of seven standardized exercises: the Copenhagen adduction exercise[36] as well as ice hockey-specific functional strength and balance exercises for the hip/groin. The isolated hip adductor exercise was included in the standardized part of the program because ice hockey players are particularly susceptible to adductor muscle strains.[6 11 37] Lower extremity strength is important for skating strides, acceleration, turning and stopping, and assists dynamic balance and stability that essentially protects players from injuries.[38] We therefore included functional hip strength exercises that are based on previously described strength and conditioning principles[38 39] as well as on rehabilitation programs for ice hockey players after adductor muscle strains[37] and femoroacetabular impingement (FAI) surgery.[40 41] Balance is critical to all ice hockey activities, but is often overlooked and not a main focus in training sessions.[39] To achieve balance, training of the accessory muscles around the pelvis and lower extremities are important.[39] We therefore included single-leg balance exercises with the focus on balancing while moving, which is vital in hockey.[39] The greatest risk factor for traumatic injuries has been identified as collisions with the opponent's body[1 2 42-46] hence we included a balance exercise with external perturbation to enhance stability.

Individualization: The second part of the program includes selected strength exercises for each hip muscle group. These exercises are less hockey-specific because the aim is to address a specific hip muscle group deficit. In the case of an identified hip muscle strength deficit, the player will perform additional exercise(s) according to the above described progression until muscle strength is either equal to or less than 10% compared to

contralateral strength or normative data or equal to or less than 15% compared to the previous assessment.

Training of program deliverer/end-users: Movement quality or technique has been described as one of the most critical aspects influencing the success of an injury prevention program.[16] Therefore, it is important to educate program deliverers and end-users to be confident in leading and performing injury prevention exercises and to provide proper feedback to end-users.[22] We will educate the program deliverer, i.e. athletic trainer, and program end-users, i.e. players, within a workshop held for approximately 3 hours, which has previously been described as having a positive effect on the execution of the program.[47] They will receive a detailed manual describing each of the standardized exercises and will be trained to perform the exercises correctly to enhance self-efficacy. Furthermore, it is important that the program deliverer is trained to provide motivation during exercise performance, which can influence the participants effort and force output.[29]

Training of person responsible for data collection and team physician: Each responsible person, i.e. physiotherapist or massage therapist, who will document traumatic hip/groin injury will be trained by the study coordinator (RB) to fill out the injury report form correctly before study initiation, since injuries in Swiss ice hockey teams are not documented on a regular basis. The final diagnosis of each reported traumatic injury will be made by the team physician, who will be trained on which diagnosed injuries surrounding the hip joint should be reported, e.g. inclusion of hamstring injuries. The person responsible for data collection will also be asked to gather information on the number of dryland and on-ice training sessions per week of each player.

Control group: The control group will perform a warm-up of 20-25 minutes, with 10-15 minutes of conventional strength exercises and 5-10 minutes of endurance exercise, e.g. cycling.

Table 1 Hip/groin injury prevention exercises program for ice hockey players

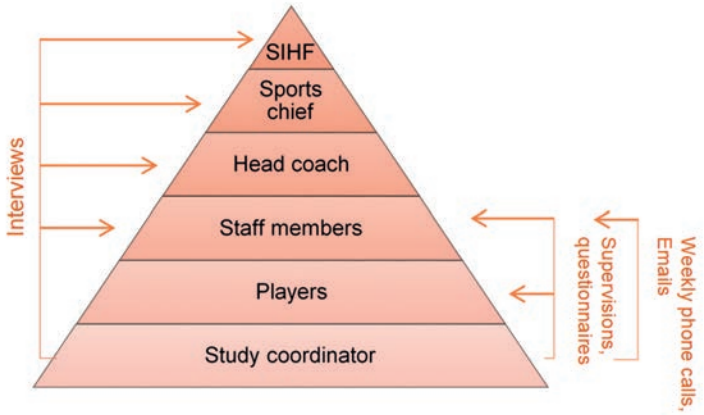
	Level I (for symptomatic players only)	Level II	Level III
Part I: Standardized exercises			
Specific hip muscle strength exercise	Copenhagen adduction exercise[36] (easy)	Copenhagen adduction exercise (moderate)	Copenhagen adduction exercise (hard)
Functional hip muscle strength exercises	Split squats	Reverse lunges with elastic band	Reverse lunges with harder elastic band + increased speed
	Single leg bridge	Hip thrust	Single leg hip thrust
	Side steps	Deep side steps with elastic band	Deep side steps with harder elastic band + increased speed
Balance exercises	Static single leg deadlift	Dynamic single leg deadlift	Single leg deadlift + pelvic rotation
	Dynamic single leg squats	Deep clock excursion exercise	Deep clock excursion exercise with elastic band
	Single leg squat + gentle external perturbation by teammate	Single leg squat + external perturbation by teammate	Deep single leg squat + external perturbation by teammate
Part II: Individual hip muscle strength exercises			
Hip flexors	Standing hip flexion with elastic band	Standing hip flexion with harder elastic band	Plank + hip flexion to right/left hand with elastic band
Hip abductors	*Side bench position:* abduction of the upper leg	*Side bench position:* abduction of the upper leg with elastic band	*Side bench position:* abduction of the upper leg with harder elastic band
Hip rotators	*Side laying position:* internal/external hip rotation with elastic band (clam shell)	*Sitting position:* internal/external hip rotation with elastic band	*Standing position:* internal/external hip rotation with elastic band
Hip extensors	Quadruped arm/lower extremity lift	Quadruped arm/lower extremity lift with elastic band	Quadruped arm/lower extremity lift with harder elastic band
Hamstrings	Nordic hamstring exercise[48] (easy)	Nordic hamstring exercise (moderate)	Nordic hamstring exercise (hard)

Primary study outcomes

Feasibility issues will be documented using a study diary filled out by the study coordinator (RB). Reasons for exclusion, dropouts, adverse events and costs of all aspects of the intervention, e.g. intervention material, time, will be recorded.

Responsiveness: One of the primary feasibility outcome measures of all included stakeholders indicates responsiveness, which is defined as the extent to which the stakeholders are engaged with the program, i.e. satisfaction, appreciation and acceptability of the program.[49] Responsiveness will be assessed using a semi-structured interview[50 51] conducted by the study coordinator (RB) with the corresponding person of the SIHF, the sports chief, team head or assistant coach, physiotherapists and the program deliverer. Open questions will be provided evaluating the provision of the program and intervention information; stakeholders' beliefs, expectations, preferences and experiences of the intervention; and the biweekly Oslo Sports Trauma Research Centre (OSTRC) questionnaire use as well as any needs for program improvement. A self-reported questionnaire will be used for the remainder of the staff members and all players of the intervention team. Responsiveness will be assessed after the preparatory phase. In the case of contrasting attitudes, program adaptions will be proposed and evaluated again at the end of the consecutive season. The communication process of the study coordinator (RB) and all included stakeholders during the study period is provided in Figure 1.

Figure 1. Communication process of all included stakeholders



Abbreviation: Swiss International Ice Hockey Federation, SIHF

Program use and adherence: Program use and adherence will be assessed based on the utilization frequency, i.e. number of sessions completed each week compared to the study protocol; utilization fidelity, i.e. number of exercises completed from the total possible per session; and cumulative utilization, i.e. number of sessions completed during the study period from the total possible sessions[52] using an exercise diary smartphone application filled out by the athletic trainer and by each player. The study coordinator (RB) will supervise the team without advance notification to validate team adherence.

Exercise dosage: The dosage of exercises, i.e. intensity, frequency and duration, will be documented using an exercise diary on the smartphone filled out by each player.

Protocol fidelity: To ensure adherence to the study protocol during the study period, the study coordinator (RB) will provide weekly phone calls to the athletic trainer and supervise the team bimonthly without advance notification.

The regular warm-up of the control and intervention teams will be documented by the athletic trainers.

Secondary study outcomes

Traumatic hip/groin injuries: The incidence of traumatic hip/groin injuries will be assessed using a standardized injury report form.[44] To ensure adherence, the responsible person will be asked to send the data collected to the study coordinator (RB) on a weekly basis. When incorrect completion of the injury report form or missing data arise, the person responsible for data collection will immediately be contacted by the study coordinator (RB) for clarification. For each player, the total time-on-ice during the season will be extracted from the individual statistics page of the SIHF website (www.sihf.ch/de/game-center/national-league/#/mashup/players/playerTimeOnIce/timeOnIce/desc/page/0/2017/2158).

Overuse hip/groin injuries: All players will be asked to fill out the OSTRC overuse injury questionnaire[53] biweekly during the study period to collect information regarding overuse injuries of the hip/groin. The OSTRC questionnaire contains four multiple-choice questions about: (a) the difficulties participating in normal training and competition during the last two weeks, (b) the amount of training volume reduction, (c) the extent of performance impairment and (d) the degree of pain related to ice hockey. The responses to each of the four questions will be allocated a numerical value from 0 (no problems/limitations) to 25 (maximum problems/limitations) and will subsequently be summed to calculate a severity score from 0 to 100.[53]

Self-reported hip/groin disability: All players will be asked to fill out the Copenhagen Hip And Groin Outcome Score (HAGOS) questionnaire at baseline, after the preparatory phase and at the end of the consecutive season. The HAGOS has six subscales: (a) pain, (b) symptoms, (c) activities of daily living, (d) sport and recreational activities, (e) participation in physical activity and (f) quality of life.[54] Each subscale is scored from 0 to 100, where higher scores indicate better hip and groin health.[54]

All study outcomes and other assessments are outlined in Table 2.

Table 2. Study outcomes and assessments

	Preparatory phase				Consecutive season								
Months	05	06	07	08	09	10	11	12	01	02	03	04	
Primary outcomes:	INTERVENTION												**Responsible person:**
Responsiveness													Study coordinator
Program use and adherence													Staff members, players
Exercise dosage (intensity, frequency and duration)													Staff members, players
Protocol fidelity													Study coordinator
Secondary outcomes:													
Incidence of traumatic hip/groin injuries													Staff member
Prevalence of overuse hip/groin injuries													Staff member
Self-reported hip/groin disability													Study coordinator
Other assessments:													
Medical baseline questionnaire													Team medical doctor
Hip muscle strength													Physiotherapist

Feasibility criteria

Success of feasibility will be defined as a program participation rate of at least 80%, i.e. at the individual player level, and a maximum dropout rate of 15% during the study period.[47] The risk level for severe musculoskeletal adverse events, e.g. muscle/ligament tear, should not be greater than 1% of all healthy participants.[55 56] High responsiveness of all stakeholders must be reached, i.e. no requirements for program improvement, to ascertain success of feasibility. Success of program use and adherence will be defined when 70% of utilization frequency, utilization fidelity and cumulative utilization are achieved.

Sample size calculation

Since the study aim involves the evaluation of feasibility of a hip/groin intervention, a formal sample size calculation is not applicable. However, a minimum of 12 players per team is recommended for feasibility studies.[57] Due to the cluster randomization in this feasibility trial and to account for possible dropouts, we doubled the sample size to 24 players including one ice hockey team per group.

Data analysis

Descriptive statistics will be used to present the rates of participation, dropout, occurrence of adverse events as well as frequencies and proportions of any recorded traumatic injury and the HAGOS score. The overall incidence of traumatic injuries will be calculated as the number of injuries per 1,000 game or training hours during the season. Qualitative data analysis will be performed to explore the answers of the semi-structured interviews and open questions of the questionnaire. The study coordinator (RB) will systematically assign codes and analyze the answers to identify themes using techniques of constant comparison.[50 51] Individuals displaying contrasting attitudes, e.g.

negative cases, will be studied in detail to understand the underlying reasons and to gain a deeper understanding of the data and findings. Two members of the research team will analyze approximately 10% of the qualitative data independently to compare coding and enhance dependability of findings. The findings will be presented descriptively and if necessary, improvements will be proposed.

Program use and adherence will be validated based on the agreement between the reports of the players and program deliverer regarding the number of sessions and exercises of the program. Data will be presented as proportions of agreement on the micro level.

The prevalence of overuse hip/groin injuries will be calculated as the number of players who reported overuse problems, identified by a score greater than 0 on any of the four questions or substantial overuse problems, divided by the total number of respondents.[53] Substantial hip/groin overuse problems will include only those leading to moderate or severe reductions in training volume or performance, or an inability to participate in normal training/competition.[58] The cumulative severity score will also be calculated by summing the severity scores of the respective body part for all players over the study period divided by the number of respondents within the 2-week interval.[53]

DISCUSSION

This protocol defines a plan for evaluating the feasibility of a hip/groin injury prevention program for ice hockey players in order to conduct a prospective study on a larger scale. Program responsiveness is expected to be high in players and staff members because both groups recognized a high perceived benefit of an injury prevention program as well as the relevance of injury prevention in ice hockey in our previous investigation.[17] High responsiveness of the SIHF is also expected because injury prevention should be one of their primary interests.

Success of program participation as well as use and adherence during the study period are expected to be achieved because players and staff members previously acknowledged the feasibility of a prevention program in the form of a warm-up of 15 minutes at least 4 times per week.[17] Surprisingly, time was not considered as a barrier for program adherence.[17]

Our proposed hip/groin injury prevention program includes standardized and individualized exercises, where the latter were identified as an important facilitator for program uptake and adherence.[17] However, this makes the program more difficult to promote as an end-product to ice hockey teams because the individual exercises differ from player to player and the program might last longer for some of them. On the other hand, ice hockey teams have access to their own physiotherapists and also have the appropriate setting to conduct standardized hip muscle strength assessments, which supports the practicality for program individualization. We therefore expect a high responsiveness of the individualized part by the team physiotherapists and players. If the standardized exercises are dictated by the athletic trainer, it is expected that the program will be performed regularly in a team setting. It is therefore important to attain a high responsiveness of the program deliverer in order to increase program adherence of the players. This is expected because most of the staff members clearly saw a benefit of a prevention program in preparing the body for training[17], and this aspect will be included in the development process of the program.

We only proposed the inclusion of strength and balance exercise elements for the hip/groin in this program without additional exercise elements, e.g. agility, stretching, plyometrics. This decision is based on our previous umbrella review, which showed that muscle strength and balance exercises should be prioritized in lower extremity injury prevention programs for team-sport athletes because these elements were most effective in preventing these injuries.[23] Furthermore, the program needs to be quick and

easy to perform with little additional equipment,[16] which is difficult to apply for agility and plyometric exercises. Agility training usually needs a long hallway often set up with additional equipment such as cones; and plyometric exercises require different jump heights usually created with boxes. Agility and plyometrics are nonetheless included in regular ice hockey training sessions (Brunner et al. 2018, unpublished data). Another reason for focusing on strength and balance for injury prevention is that these elements form the basis of every activity on the ice such as shooting, skating, and checking.[39]

There is no increase in the risk of adverse events when all athletes perform the prevention program compared to only those screened as high-risk candidates.[14] Neither severe nor moderate, e.g. muscle strain/pull, musculoskeletal adverse events are expected. Only minor musculoskeletal adverse events related to the testing of hip muscle strength (involving maximal-intensity contractions) might occur, e.g. muscle soreness. In this case, the symptoms will not last more than 2 to 3 days and will not affect the general physical condition of the players. Although a long-term follow-up has not been planned for the feasibility study, a 6-month follow-up should be planned to evaluate the long-term effectiveness of the intervention if the study is conducted on a larger scale.

Adherence to completing the OSTRC questionnaire over a long study period is expected to be challenging as experienced in our previous investigation.[6] However, the questionnaire will be filled out for the feasibility study by smartphone application targeting only the hip/groin area to increase long-term adherence.

By applying the proposed injury prevention program to youth ice hockey players, traumatic and overuse injuries of the hip/groin are expected to decrease, although traumatic injuries during games are difficult to address because of the environmental conditions. To prevent injuries, a player needs to be best prepared physically, especially the specific muscles that are prone to injuries, e.g. hip adductors, which is vital for a

high-speed, high-collision sport such as ice hockey.[38] Overuse injuries are expected to decrease especially in youth ice hockey players who have less or not yet occurring degenerative changes; the results are nonetheless expected to lack any statistical significance due to the relatively small sample size. Calculations based upon these approximations would lead to an underestimation of results.[59]

Limitations

One limitation of the feasibility study might be the risk of contamination bias stemming from the control team, since this group receives the same study information as that of the intervention team prior to randomization.[60] The athletic trainer might therefore need to consider placing the focus on prevention exercises to also target the specific area. This issue will be addressed by applying attention control to the participants, i.e. the study coordinator (RB) will provide general information about different injury prevention strategies, e.g. sleep, recreation, training, that can be analyzed.

There is also a risk of recall and reporting bias,[60] as underreporting of traumatic hip/groin injuries may arise due to only one person being responsible for data gathering. However, the study coordinator (RB) will be in close contact with the person responsible for data collection and provide weekly reminders by e-mails/phone. A final limitation is the lack of detailed diagnostic information derived from the OSTRC questionnaire[53] and in the case of program effectiveness, the classification of overuse hip/groin problems will therefore remain unknown.

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Chapter 6

Discussion and Conclusion

Picture taken by Tommaso Franceschini [September 8, 2017].

The purpose of this scientific work was to develop a protocol for a cluster-randomized feasibility study to evaluate an evidence-based injury prevention program for ice hockey players, addressing the most common overuse and traumatic injuries to the lower extremity. The project consisted of several steps: the first step was an umbrella review to evaluate the effectiveness of multicomponent lower extremity injury prevention programs in team-sport athletes (Chapter 2); the second step was to assess epidemiological injury data in Swiss professional male ice hockey players (Chapter 3); the third step was to identify barriers and facilitators among players and staff members for adhering to an injury prevention program in professional male ice hockey teams (Chapter 4); and the fourth step was to develop an evidence-based injury prevention program for the hip/groin for ice hockey players and to plan the evaluation of its feasibility in a real-world setting (Chapter 5). In this final chapter, the main findings and conclusions are critically reviewed, and some practical implications of this thesis are provided. Finally, suggestions for further research in this field are outlined.

6.1 Key findings

The first study of this thesis demonstrated the effectiveness of multicomponent exercise interventions in reducing the injury incidence/rate of general lower extremity, knee, ACL and ankle injuries in team-sport athletes. However, we did not find any effective multicomponent exercise prevention program for the hip/groin area. Together, the results demonstrated that the most frequent elements of an injury prevention program aimed at reducing lower extremity, knee, ACL and ankle injury incidence/rate were a combination of strength and balance exercises compared to the less frequent exercise components such as stretching, agility, plyometrics and technique. This study provided a foundation for the injury prevention program including the two most frequent elements to effectively prevent injuries to the lower extremity.

The second study demonstrated the significance of hip/groin problems in Swiss ice hockey by identifying a reported incidence of 23% for traumatic injuries and 16% for overuse injuries. In addition, the most common injury risk factors for traumatic injuries were collisions with the opponent's body (31%), hits by a puck (16%) and collisions with the board (13%). Furthermore, the highest game-related injuries were reported for the right forward position and the lowest for goalkeepers. Overall, the results demonstrated a generally high incidence of traumatic injuries and prevalence of overuse injuries with hip/groin problems predominating. These findings highlight a significant medical concern of hip/groin problems in ice hockey athletes and were therefore addressed within the design of the injury prevention program.

The most prevalent facilitators for players and staff members about injury prevention identified in the third study were knowledge, perceived benefit and relevance of injury prevention as well as awareness of the high risk of injuries in ice hockey. Players and staff members positively rated the perception of a benefit of such a program, which can be considered an important facilitator towards the uptake and adherence of an injury prevention program in ice hockey teams. Program individualization was rated as highly important by players and staff members and was therefore considered an important facilitator for program adherence. The highly-rated benefit of an injury prevention program in preparing the body for training by the staff members, facilitates adherence to preventive exercises, e.g. warming-up before each training session. This study also found that an injury prevention program should be offered to and implemented in players of all ages, levels of education and experience in NL, irrespective of previous injuries. Together, the barriers and facilitators identified in this study were addressed in the development of the prevention program.

The protocol describes the rationale for a cluster-randomized feasibility study to evaluate the hip/groin injury prevention program for ice hockey players based on the outcomes of studies I–III and the available literature. The prevention program

comprises the Copenhagen adduction exercise[1]—because ice hockey players are particularly susceptible to adductor muscle strains[2-4]—as well as ice hockey-specific functional strength and balance exercises. Each player will additionally perform individual strength exercises for each hip muscle group in the case of an identified hip muscle strength deficit. High participation and low dropout rates, high program use and adherence as well as high responsiveness of players and staff members are expected because both groups clearly perceived a benefit of an injury prevention program and highly rated the relevance of injury prevention in ice hockey in study III.

The main findings of each study are summarized in Figure 4 contributing to the protocol for a cluster-randomized feasibility study.

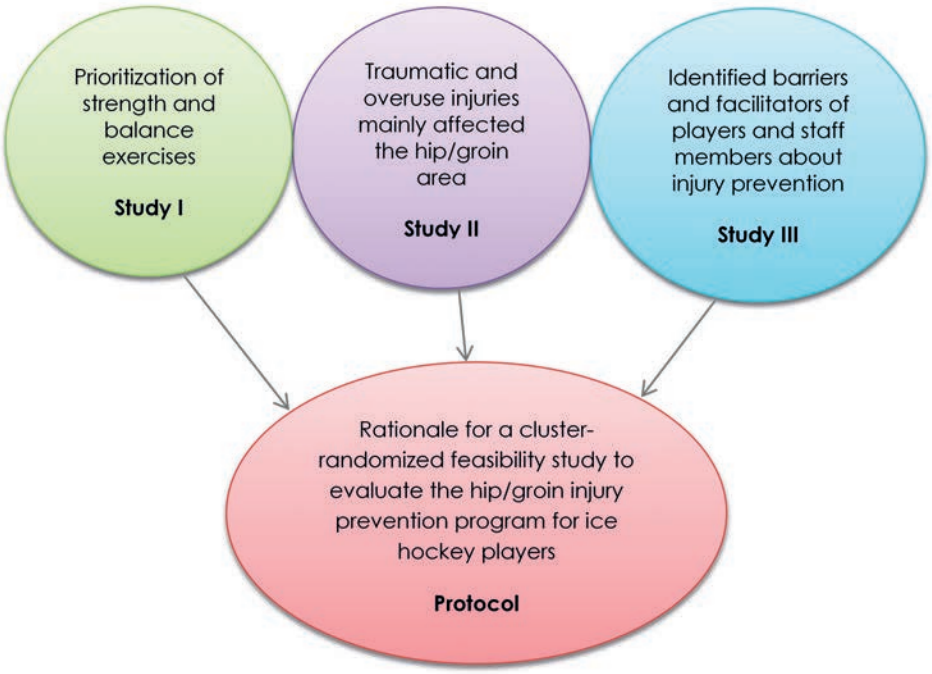

Figure 4: Main findings of each study contributing to the protocol for a cluster-randomized feasibility study.

Practical considerations when designing an injury prevention program for ice hockey players

Based on the outcomes of studies I-III, an injury prevention program for ice hockey players should take into consideration the following points:

- Strength and balance exercises should be prioritized besides other exercise components;
- The most common traumatic and overuse injuries in Swiss ice hockey mainly affected the hip/groin area;
- An injury prevention program can best be applied as a part of the warm-up program to enhance program adherence;
- Prevention exercises can be applied to all ice hockey players regardless of their characteristics, e.g. age, nationality, previous injuries;
- At least part of the prevention program should be individualized to enhance program adherence;
- Program deliverers and program end-users should be informed about the goal of preventive exercises and should be trained to perform the exercises correctly.

6.2 Strength and limitations

A strength of this thesis is that players and staff members were and will be integrated in the development process of the injury prevention program as well as the subsequent implementation process, which is an important aspect for increasing the chance of long-term program adherence.[5,6]

The effectiveness of multicomponent lower extremity injury prevention programs in team-sport athletes

A strength of the umbrella review is the high-level synthesis of evidence that identified the most frequent exercise combinations for lower extremity injury prevention. The major limitation was, however, the heterogeneity of methodological procedures in the reviews, which did not permit drawing conclusions about the specific intervention(s) for each exercise category as well as the frequency and intensity of such a program. In addition, we did not find any effective exercise element combination for the hip/groin area. One reason is that most of the original studies used a time-loss definition to assess groin injuries,[7] which possibly accounted for only about one-third of all hip/groin problems.[1 8] Hip/groin injuries often present as longstanding overuse problems that do not necessarily lead to time loss.[9] Another reason explaining the low incidence of hip/groin injuries is the lack of a standardized diagnostic protocol; these injuries are challenging to diagnose due to the different pathologies and overlapping symptoms.[7] Because of this aspect of low incidence, a high sample size would be needed to eventually detect any significant difference.[8] The fundamental element of poorly-reported program adherence outlined in the original studies might furthermore lead to non-significant results.[7] Nevertheless, high adherence to the intervention is necessary, as it has previously been shown to result in significant injury risk reduction.[1 10]

Epidemiology of traumatic and overuse injuries in Swiss professional male ice hockey players

The evaluation of ice hockey injuries is a milestone for Swiss ice hockey, since it is the first epidemiological study including five NL teams. For practical reasons, the epidemiological data was assessed in professional ice hockey players. However, we believe that the program should be implemented in youth ice hockey players to

ensure that they learn to correctly perform preventive exercises already at an early age; these exercises should be included in their training routine to eventually decrease the risk of hip/groin problems during growth. Furthermore, lower levels of sport-specific training are associated with increased risk of injuries in sport.[11] One of the study limitations was the duration of only one year, including the preparatory phase and competitive season. Another limitation was the sample size restricted to German speaking teams. A nationwide evaluation of ice hockey injury patterns would, however, only be possible if dictated from the top, e.g. by the Swiss Ice Hockey Federation (SIHF). Only one person from each team's medical staff was responsible for active data collection for traumatic injuries and reporting of training hours per week of each player, which was very time-consuming. A limitation of the OSTRC overuse injury questionnaire is that it focuses only on predefined injury regions and does not allow more specific injuries, e.g. FAIS, to be classified.[12] Nevertheless, this was the first study assessing overuse injuries in Swiss professional ice hockey players, which are highly relevant to address, especially for the previously neglected hip/groin area.

Perceived barriers and facilitators towards an injury prevention program among professional male ice hockey players and staff members

This was the first study assessing barriers and facilitators to program adherence among professional ice hockey players and staff members, which are important to consider for future program implementation in different ice hockey teams. A strength of this study was the inclusion of players and different staff members. Previous investigations examining the barriers and facilitators to implement injury prevention programs in athletes have typically focused on athletes and/or coaches separately.[13-15] The major limitation of our study is the low number of staff members, which leads to a limited generalizability of the results. However, this issue can only be addressed by increasing the total number of teams, which was not possible due to the restriction of teams to

the German speaking part of Switzerland. Another limitation is that the questionnaire was only face and content validated. However, the purpose of the questionnaire was not to apply it on a regular basis, but only once to the included teams.

Rationale for a hip/groin injury prevention program for ice hockey players

The main limitation is that we did not evaluate the feasibility of the hip/groin program, hence it only resulted in a protocol. Nevertheless, it is important to carefully plan the evaluation of the feasibility of an injury prevention program in a real-world setting to eventually improve the chances of success in conducting a high-quality, cluster RCT.[16] One of the key elements for ensuring future program implementation and adherence is to actively involve different stakeholders in the development process through to planning for implementation and conducting evaluation.[5 6 17] We will therefore involve medical staff members and team captains in the development process of the program in order to reach program agreement and enhance program adherence for future implementation in their teams.[17-19]

6.3 Practical implications

The knowledge gained from this thesis could lead to a significant impact on injury prevention in ice hockey. The findings provided a basis for designing an injury prevention program for ice hockey players, which is fundamental for a cluster RCT and future implementation in different ice hockey teams.

Impact on Swiss ice hockey

Results from this thesis have been presented to the participating ice hockey teams as well as regularly at the Annual Swiss Ice Hockey Medical Day, where staff members, e.g. physiotherapists, medical doctors, of different ice hockey teams are invited. Moreover, the results were presented to the Zurich Insurance Company to enhance the awareness towards injury prevention in Swiss ice hockey. Finally, a newspaper

article will be published in the Neue Zürcher Zeitung (NZZ) to present the results of this thesis and increase the focus of the general population on the severity of ice hockey injuries and how they might best be addressed.

6.4 Suggestion for further research

The feasibility study will help to determine whether an injury prevention program as part of a routine warm-up is realistic in the setting of an ice hockey team. If this aim is achieved, the effectiveness of the program needs to be tested further in the form of a cluster RCT, which would be a milestone in the prevention of hip/groin injuries in ice hockey. It is very important to conduct RCTs due to the lack of primary studies and the excessive publication of systematic reviews and meta-analyses on the topic of injury prevention in athletes. In addition, the nationwide regularly assessment of ice hockey injuries is crucial to evaluate injuries on a long term. Based on that, other specific prevention programs can be developed to decrease the risk of injuries and associated costs. However, this is only possible if dictated from the top, e.g. by the SIHF or accident insurances, due to the time-consuming data collection. Once demonstrated the effectiveness of an exercise program does not, however, automatically lead to program implementation in teams; failure to plan a program implementation can result in poor adherence and lack of success.[20] The translation into a real-world setting is therefore crucial.[21 22] To do so, it is important to describe, in detail, how to implement an injury prevention program and develop stakeholder-specific implementation activities for program adherence and maintenance in ice hockey teams. Future studies should no longer focus on traumatic injuries only, but rather include the assessment of overuse problems to capture the true number of injuries sustained by athletes, especially for the often-neglected hip/groin area.

6.5 Conclusion

This doctoral thesis builds a foundation for injury prevention research in ice hockey. Hip/groin injuries were found to be a major problem for ice hockey players and should therefore be addressed by implementing preventive exercise programs as a part of the team warm-up. The feasibility and effectiveness of such an exercise program in a real-world setting should be evaluated in form of a cluster RCT. This will, in turn, help to develop future implementation strategies.

6.6 References

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Supplementary material, Chapter 2

e-Supplement 1

Characteristics of the included systematic reviews and meta-analyses.

Reference	Year	Methodological quality (AMSTAR)	Evidence (GRADE)	Number of studies/participants	Combination of exercise elements								Heterogeneity	Results / Findings / Authors' conclusion
					Strength	Agility	Plyometrics	Balance	Stretching	Technique	Warm-up	Functional Activity		
Soligard, Steffen, Gatterer, van Beijsterveldt, Grooms, Hammes, Owoeye included in study of **Al Attar et al**	2016	4	high	9 / 5,481	x	x	x	x			x		NR	Pooled results from 9 studies: IRR 0.77, 95%CI = 0.65 to 0.91 (overall injury rate ratio) and IRR 0.76, 95% CI = 0.62 to 0.94 (lower extremity injury rate ratio); FIFA 11+ injury prevention program decreases the risk of injuries among soccer players
Grooms included in study of **Alentorn-Geli et al**	2014	5	high	7 / 641	x	x	x	x			x		NR	No quantitative pooling: effectiveness of prevention programs to reduce ACL injuries in male athletes are scarce and inconclusive
Engebretsen, Gilchrist, Pasanen, Holmich included in study of **Andrew et al**	2013	5	high	47 / NR	x		x	x	x		x		NR	No quantitative pooling: a program involving a combination of balance and control exercises, eccentric hamstring, plyometric and strength exercises could be efficacious in preventing all lower limb injuries
					x			x		x	x			
					x			x	x					
					x	x	x		x		x			
Barengo et al	2014	3	no evidence from systematic reviews	NA				NA					NA	NA
van Beijsterveldt, Engebretsen, Holmich, Steffen, Wederkopp included in study of **Esteve et al**	2015	8	low	7 / 4,191	x	x	x	x			x		I^2 = 7%	Pooled results from 7 studies: RR 0.81, 95% CI = 0.60 to 1.09; no statistical significant reduction in sport-related groin injuries was documented
					x			x		x	x			
					x			x	x					
								x				x		
Bixler, Wederkopp, Olsen included in study of **Fradkin et al**	2006	5	high	5 / 3,774 + 5 teams	x	x		x			x		due to the heterogeneity of the studies reviewed → no MA	No quantitative pooling: definitive conclusions cannot be drawn as to the role of warm-up for reducing the risk of exercise-related injury
									x		x			
								x				x		
Frisch et al	2009	1	no evidence from systematic reviews	NA				NA						NA
Gilchrist, Heidt, Hewett, Kiani, Mandelbaum, Myklebust, Olsen, Pasanen, Petersen, Pfeiffer, Steffen included in study of **Gagnier et al**	2013	7	high	15 / 18,502	x	x	x	x			x			Pooled results from 14 studies: IRR 0.46, 95%CI = 0.36 to 0.60 (fixed-effects model) and IRR 0.49, 95%CI = 0.30 to 0.79 (random-effects model); protective effect on risk of ACL injuries of approximately 50%, not possible to determine which components are most or least effective
					x	x			x		x			
					x		x	x	x		x			
					x	x		x		x				
					x			x	x	x				
						x	x							
							x	x						

Engebretsen, Gilchrist, Soligard, Steffen, Emery & Meeuwisse, van Beijsterveldt, Walden included in study of **Grimm et al**	2015	7	high	9 / 11,562	x	x	x	x			x	I^2 = 50.2%	Pooled results (based on 9 studies): RR 0.74, 95% CI = 0.55 to 0.98; support of injury prevention programs for preventing overall knee injuries
					x	x		x	x	x			
					x	x	x		x		x		
					x			x		x	x		
Emery & Meeuwisse, Engebretsen, Heidt, Soligard, van Beijsterveldt included in study of **Grimm et al**	2016	6	high	9 / 4,121	x	x		x	x	x		I^2 = 65.2%	Pooled results (based on 10 studies): RR 0.60, 95% CI = 0.40 to 0.92; significant reduction in risk of ankle injuries
					x			x		x	x		
					x	x	x		x		x		
					x	x	x	x			x		
Hewett, Myklebust, Mandelbaum, Petersen, Olsen included in study of **Grindstaff et al**	2006	5	moderate	5 / 11,026	x	x	x		x		x	NR	Pooled results (based on six studies): RRR 70%, 95% CI = 54% to 80%; NMT programs to prevent non-contact ACL injuries in females are likely to reduce injuries; NMT program should consist of plyometric, balance and agility exercises
					x	x		x			x		
					x		x	x			x		
					x		x		x	x			
							x	x					
Mandelbaum, Pfeiffer, Gilchrist, Kiani, LaBella, Soligard, Steffen included in study of **Herman et al**	2012	6	high	9 / 13,503	x	x	x	x			x	limited homogeneity between prevention strategies and method of recording of injuries → no MA	No quantitative pooling: training program should include stretching, strengthening, balance, agility drill, landing techniques for more than 3 consecutive months
					x	x	x	x					
					x	x	x		x		x		
					x			x		x	x		
						x	x						
Hewett et al	2005	2	no evidence from systematic reviews	NA				NA				NA	NA
Hewett et al	2006	1	no evidence from systematic reviews	NA				NA				NA	NA
Emery, Gilchrist, Olsen, Pasanen, Steffen included in study of **Hübscher et al**	2010	7	high	7 / 7,548	x	x	x	x			x	I^2 = 43%	Pooled results (based on 2 studies): RR 0.61, 95% CI = 0.49 to 0.77; evidence that balance training or multifaceted training programs might be effective in preventing lower limb injuries
					x		x	x	x		x		
					x	x		x			x		
								x	x		x		
					x	x	x		x		x		
Kirkendall et	2010	1	no evidence from systematic reviews	NA				NA				NA	NA
van Beijsterveldt, Emery, Emery & Meeuwisse, Gilchrist, Heidt, Holmich, LaBella, Longo, Olsen, Pasanen, Soligar, Steffen, Walden, Wederkopp included in study of **Lauersen et al**	2014	9	high	25 / 26,610	x	x	x	x			x	I^2 = 70%	Pooled results (based on 25 studies): RR 0.63, 95% CI = 0.53 to 0.75; stretching proved no beneficial effect, whereas multiple exposure programs, proprioception training, and strength training, in that order, showed a tendency towards increasing effect
					x		x	x	x		x		
					x	x		x	x	x			
					x	x	x	x					
								x	x		x		
									x		x		
					x			x	x				
					x	x		x			x		
					x	x	x		x		x		
					x			x		x	x		
Michaelidis et al	2014	2	moderate	NA	NA							NA	NA
Hewett, Heidt, Myklebust, Mandelbaum, Olsen, Petersen, Pfeiffer, Steffen, Gilchrist, Pasanen, Kiani, LaBella, Walden included in study of **Myer et al**	2013	6	high	14 / not consistently reported	x	x	x	x			x	assumed effect size of each study is different → random effects model	Pooled results (based on 14 studies): OR 0.54, 95% CI = 0.35 to 0.83; significantly greater knee injury reduction in female athletes in preventive NMT group; more pronounced prophylactic
					x	x	x		x		x		
					x		x	x	x		x		
					x	x	x	x					
					x	x		x			x		
					x		x	x			x		
					x		x		x	x			
						x	x						
							x	x					

Noyes et al	2012	3	no evidence from systematic reviews	NA					NA						NA	NA
Noyes et al	2014	3	no evidence from systematic reviews	NA					NA						NA	NA
Engebretsen, Holmich, van Beijsterveldt included in study of **Porter et al**	2015	9	very low	8 / 3,355	x				x			x	x		due to the heterogeneity of the studies reviewed → no MA	No quantitative pooling: no clear conclusion possible due to low quality of primary studies
					x				x	x						
					x	x	x		x				x			
Emery, Heidt, Hewett, Kiani, LaBella, Longo, Mandelbaum, Olsen, Pfeiffer, Soligard, Steffen, Walden, Wederkopp included in study of **Rössler et al**	2014	8	high	21 / 27,561	x	x	x		x				x		I^2 = 71%	Pooled results (based on 21 studies): RR 0.54 95%, CI = 0.45 to 0.67; significant beneficial prevention effects for minor, moderate and severe injuries; multimodal programs including jumping/plyometric exercises can be recommended
					x	x			x	x	x					
					x	x	x		x							
					x	x			x				x			
									x	x			x			
										x			x			
					x				x			x	x			
					x	x	x			x			x			
					x					x	x					
					x				x			x	x			
						x	x									
Gilchrist, Heidt, Hewett, Mandelbaum, Petersen, Pfeiffer included in study of **Sadoghi et al**	2012	6	low	8 / 10,618	x	x	x			x			x		I^2 = 64%	Pooled results (based on 8 studies): RR 0.38 95%, CI = 0.20 to 0.72; significant effect of ACL injury prevention programs; 52% reduction in females and 85% reduction in males
					x		x			x	x					
						x	x									
							x		x							
Wederkopp, Olsen, Emery, Soligard, Steffen, Longo, Owoeye included in study of **Soomro et al**	2015	6	high	10 / 8,513	x	x	x		x				x		I^2 = 80%	Pooled results (based on 10 studies): RR 0.60, 95% CI = 0.48 to 0.75; 40% reduction of injuries based on injury prevention programs
					x	x			x	x	x					
					x	x			x				x			
									x	x			x			
										x			x			
Hewett, Heidt, Myklebust, Mandelbaum, Petersen, Pfeiffer, Gilchrist, Steffen, Kiani included in study of **Stevenson et al**	2015	4	low	10 / 12,760	x	x	x		x				x		NR	No quantitative pooling: trend toward reduction in ACL injuries using neuromuscular training but not statistically significant evidence; plyometric is an important component of neuromuscular training programs
					x	x	x			x			x			
					x		x		x				x			
					x		x			x	x					
					x				x			x	x			
						x	x									
							x		x							
Gilchrist, Pfeiffer, Mandelbaum, Hewett, Myklebust, Petersen, Heidt included in study of **Stojanovic et al**	2012	5	moderate	9 / 13,884	x	x	x			x			x		not sufficient homogeneous and comparable → no MA	No quantitative pooling: moderate evidence that multifaceted training programs might be effective in preventing ACL injuries among female athletes engaged in team sports
					x		x		x				x			
					x		x			x	x					
						x	x									
							x		x							
Hewett, Heidt, Myklebust, Mandelbaum, Olsen, Petersen, Pfeiffer, Gilchrist, Steffen, Kiani, LaBella included in study of **Sugimoto et al**	2012	5	high	12 / 18,604	x	x	x		x				x		NR	No quantitative pooling: 73.4% risk reduction for noncontact ACL injuries, 43.8% for overall contact ACL injuries; NMT may reduce noncontact ACL injury risk and overall ACL injury risk
					x	x	x			x			x			
					x	x	x		x							
					x	x			x				x			
					x		x		x				x			
					x		x			x	x					
						x	x									
							x		x							

Hewett, Heidt, Myklebust, Mandelbaum, Olsen, Petersen, Pfeiffer, Gilchrist, Steffen, Pasanen, Kiani, LaBella, Walden included in study of **Sugimoto et al**	2015	6	high	14 / NR in detail	x x x x x x x	x x x x	x x x x x x	 x x x	x x x 	 x x 	x x x x x 	NR for overall effect (refers to study of Myer et al 2013)	<u>Pooled results (based on 14 studies):</u> OR 0.54, 95% CI = 0.35 to 0.83; neuromuscular training with strengthening and proximal control exercises significantly reduced ACL injury incidences
Gilchrist, Heidt, Hewett, Kiani, LaBella, Mandelbaum, Myklebust, Olsen, Petersen, Pfeiffer, Steffen, Walden included in study of **Taylor et al**	2015	7	high	13 / 24,188	x x x x x x x	x x x x x 	x x x x x x	x x x x	 x x 	 x x 	x x x x 	I^2 = 0% - 28%	<u>Pooled results (based on 10 studies):</u> OR 0.61, 95% CI = 0.44 to 0.85; ACL prevention programs effectively reduce ACL injury risk but best composition of programs is unclear
Emery, Heidt, Soligard, Steffen included in study of **van Beijsterveldt et al**	2013	5	high	6 / 6,099	x x	x x	x x	x x x	 x x	 	x 	NR	<u>No quantitative pooling:</u> The mean overall reduction in injury rate was 19%; conflicting evidence for the effectiveness of exercise based programs to prevent soccer injuries
Hewett, Heidt, Myklebust, Mandelbaum, Peterson, Pfeiffer included in study of **Yoo et al**	2010	5	no evidence from systematic reviews	7 / 10,618	x x x	x x	x x x x	 x x	x x 	 	x x 	x^2 = 12.55; p = 0.051	<u>Pooled results (based on 7 studies):</u> OR 0.40, 95% CI = 0.27 to 0.60 (fixed-effects model), OR 0.49, 95% CI = 0.24 to 1.02 (random-effects model); pooled result demonstrated the effectiveness of preventive training; plyometric and strengthening exercises were found to be essential components, whereas

NR = not reported
IRR = incidence rate ratio
CI = confidence interval
NA = not assessed
MA = meta-analysis
RR = relative risk
RRR = relative risk reduction
OR = odds ratio
NMT = neuromuscular training

List of publications

Publications resulting from this doctoral thesis

- Brunner R, Friesenbichler B, Casartelli NC, Bizzini M, Maffiuletti NA, Niedermann K. Effectiveness of multicomponent lower extremity injury prevention programmes in team-sport athletes: an umbrella review. *Br J Sports Med* 2019;535:282-88.
- Brunner R, Bizzini M, Niedermann K, Maffiuletti NA. Epidemiology of traumatic and overuse injuries in Swiss professional male ice hockey players. *Orthop J Sports Med* 2020;810:2325967120964720.
- Brunner R, Bizzini M, Maffiuletti NA, Niedermann K. (2021). Perceived barriers to and facilitators of an injury prevention program among professional male ice hockey players and staff members. *J Sport Rehabil.* Advance online publication. https://doi.org/10.1123/jsr.2020-0410.
- Brunner R, Niedermann K, Bizzini M, Maffiuletti NA. Rationale for a hip/groin injury prevention program for ice hockey players: a randomized feasibility study protocol. *University of Lucerne* 2020. DOI: 10.5281/zenodo.408452.

Infographic resulting from umbrella review

- Valenzuela PL, Brunner R, Castillo-García A, Friesenbichler B, Casartelli NC, Morales JS, Maffiuletti NA, Bizzini M, Niedermann K. Infographic. Effectiveness of multicomponent lower extremity injury prevention programmes in team-sport athletes: an umbrella review. *Br J Sports Med* 2020;54:815-816.

Other articles published

- Oliveras R, Bizzini M, Brunner R, Maffiuletti NA. Field-based evaluation of hip adductor and abductor strength in professional male ice hockey players: Reference values and influencing factors. *Phys Ther Sport* 2020;43:204-09.
- Casartelli NC, Maffiuletti NA, Brunner R, Büchi M, Sutter R, Pfirrmann CW, Naal FD, Leunig M, Bizzini M. Clinical rating of movement pattern quality in patients with

femoroacetabular impingement syndrome: a methodological study. *J Orthop Sports Phys Ther* 2018;48:260-9.

- Casartelli NC, Brunner R, Maffiuletti NA, Bizzini M, Leunig M, Pfirrmann CW, Sutter R. The FADIR test accuracy for screening cam and pincer morphology in youth ice hockey players. *J Sci Med Sport* 2018;21:134-8.
- Brunner R, Maffiuletti NA, Casartelli NC, Bizzini M, Sutter R, Pfirrmann CW, Leunig M. Prevalence and functional consequences of femoroacetabular impingement in young male ice hockey players. *Am J Sports Med* 2016;44:46-53.

Conferences - Oral Presentations

- Brunner R, Bizzini M, Maffiuletti NA, Niedermann K. (postponed to 2021) Perceived barriers and facilitators towards an injury prevention program among professional male ice hockey players and staff member. IOC World Conference on Prevention of Illness & Injury in Sport, Monaco. https://ioc-preventionconference.org/?page_id=2347.
- Maffiuletti NA, Brunner R, Bizzini M, Niedermann K. (September 2020) Prévention des blessures en hockey sur glace...et ça marche! 13e congrès SFMES SFTS, Vichy, France. https://www.congres-sfmes-fts.com/_2/upload/programme/programme.pdf.
- Sacherer P, Brunner R, Brunner U. (November 2017) Die Hüfte im Eishockey. 3rd Medical Talk Kloten, Zürich, Switzerland.
- Brunner R. (April 2018) Verletzungsprävention im Eishockey. Swiss Medical Day, Langenthal, Switzerland.
- Brunner R. (April 2016) Dissertationsarbeit: Verletzungsprävention im Eishockey. Swiss Medical Day, Biel, Switzerland.
- Brunner R. (April 2015) Femoroazetabuläres Impingement (FAI) im Eishockeysport. Swiss Medical Day, Biel, Switzerland.

Conferences - Poster Presentations

- Brunner R, Friesenbichler B, Casartelli NC, Bizzini M, Maffiuletti NA, Niedermann K. (November 2018) Effectiveness of multicomponent lower extremity injury prevention programmes in team-sport athletes: an umbrella review. 1st Sportfisio and Swiss Sports Med Conference, Bern, Switzerland.
- Brunner R, Maffiuletti NA, Casartelli NC, Bizzini M, Sutter R, Pfirrmann CW, Leunig M. (November 2015) Prevalence and functional consequences of femoroacetabular impingement in young male ice hockey players. 1st World Sports Physical Therapy Congress, Bern, Switzerland.