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FEASIBILITY, ADHERENCE AND PERCEPTION OF A PREVENTATIVE GROIN INJURY EXERCISE IN YOUTH ICE HOCKEY

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Groin injury rehabilitation and prevention exercise programs have some support from the prevailing literature. Recently, the Copenhagen Adductor Exercise has demonstrated its ability to increase adductor strength and reduce the risk of groin problems. Measuring adherence to therapeutic exercise is challenging however it is important as a link has been found between improved outcomes and higher adherence. Variable adherence/engagement potentially driven by poor knowledge is highlighted as a weakness of injury prevention programs. An increased focus has been placed on implementation planning to address this.

Youth ice hockey players (n=18) were recruited to complete a 10-week adjusted Copenhagen Adductor Exercise intervention. An initial education package was delivered directly to the players. Suitable levels of the exercise were prescribed at 0 and 5 weeks. Hip adduction/abduction strength was measured at 0 and 10 weeks. Qualitative surveys regarding injury prevention exercise were completed at 0 and 10 weeks. Adherence rates were measured via retrospective self-report and a mobile phone workout log.

The study showed initial support for the use of this exercise in youth ice hockey with a median adherence of >60%. An education package directed at players was consistently supported as a meaningful facilitator of engagement/adherence. The strength results were not conclusive. We could not conclude if the changes in strength were due to our intervention or some other factor outside the study intervention as change in strength was not correlated with adherence reports. The benefits of utilizing measurement of strength change toward estimating adherence were not demonstrated in this study.

CONTENTS

1 INTRODUCTION

There is evidence supporting the use of therapeutic exercise in both sport injury prevention and rehabilitation from acute musculoskeletal injury (Lauersen, Bertelsen & Andersen 2014, 871; Kristensen & Franklyn-Miller 2012, 719). Adherence rates are a major factor in demonstrating the efficacy of exercise interventions and hence the applicability of available evidence to the real-world setting. Studies have reported a link between higher levels of adherence and improved injury prevention outcomes. (van Reijen, Vriend, van Mechelen, Finch & Verhagen 2016, 1125).

Injury prevention research has identified and highlighted a need to focus on implementation factors as a method for increasing adherence (Emery, Roy, Whittaker, Neterl-Aguirre, & van Mechelen 2015, 865-867; O'Brien & Finch 2014, 357-360). Most injury prevention exercise programs have been implemented within team training sessions. Training, education and subsequent delivery of these programs has largely been directed at coaching staff (O'Brien & Finch 2014, 357-360). This is despite qualitative feedback from players and coaches that players themselves are also responsible for injury prevention activities (McKay, Steffen, Romiti, Finch & Emery 2014a, 1281-1283).

When reviewing qualitative perspectives on injury prevention programs, knowledge gaps and lack of engagement are two key issues identified. It is hypothesized that interventions combating these barriers to adherence could improve program adoption and outcomes. (McKay et al. 2014a, 1281-1284; Zech & Wellman 2017, 6-7; Martinez et al. 2017, 146-147; Donaldson et al. 2018, 5-7; Soligard et al. 2010, 787-790; O'Brien & Finch 2016, 1-3; Kilding, Tunstall & Kuzmic 2008, 320-322).

Limited muscle injury prevention research has been conducted within ice hockey vs. football and very limited information is available regarding the perceptions of youth ice hockey players on the prevention of non-contact injuries. The most common non-contact muscle injuries in ice hockey are hip adductor injuries (Hyvönen &

Törmänen, 2018, 13-15; Tyler, Silvers, Gerhardt & Nicholas, 2010, 231-236; McKay, Tufts, Shaffer & Meeuwisse, 2014b, 57-60) and the strength of the adductor muscle complex has been identified as an associated risk factor for injury (Engebretsen, Mykelbust, Holme, Engebretsen & Bahr 2010, 2051-2056). Injury prevention and rehabilitation of groin injuries using therapeutic exercise has been supported in the literature (Hölmich et al. 1999, 439-441; Tyler, Nicholas, Campbell, Donellan & McHugh, 2002, 680-682). Some of these programs are extensive and time consuming and recently evidence supporting strength gains and injury prevention from a single exercise approach, The Copenhagen Adductor Exercise, has been presented (Harøy et al. 2018, 1-7; Ishøi et al. 2015, 1334-1340). The Copenhagen Adductor Exercise is yet to be studied in ice hockey to our knowledge. However, the eccentric strengthening nature of the exercise is well linked with the hypothesized common mechanism of adductor injuries in ice hockey (eccentric adductor force required to decelerate hip abduction and extension during skating stride) (Tyler, Nicholas, Campbell & McHugh, 2001, 124-126).

2 ADHERENCE TO THERAPEUTIC EXERCISE INTERVENTIONS

2.1 Sport injury prevention and musculoskeletal rehabilitation exercise

Lauersen, Bertelsen & Andersen's (2014, 871-875) systematic review and meta-analysis supports the effectiveness of exercise interventions in the prevention of sports injury. The statistically significant relative risk reduction for all interventions included was 0.632 vs. controls. The meta-analysis included 4 different subgroup intervention estimates (strength training, proprioceptive exercises, multimodal programs and stretching). Stretching was the only group that didn't show a significant reduction in risk of injury independently. The authors reported that strength training, proprioceptive exercises and multimodal programs including all 3 elements reduced injuries significantly. It was shown that both overuse and acute injury rates could be reduced by physical activity exercise interventions.

Exercise therapy in various forms is used in musculoskeletal rehabilitation. It has been shown that resistance training can improve muscle strength, reduce pain and improve functional ability in conditions such as chronic lower back pain and knee osteoarthritis (Kristensen & Franklyn-Miller 2012, 719-722). Similarly, rehabilitation from acute sports injury often includes prescription of therapeutic exercise (strengthening, early mobilization, proprioceptive exercises and sports specific exercises). The goals of exercise therapy in rehabilitation from acute sport injuries are return to pre-injury playing level as fast as possible whilst reducing re-injury risk. This includes considerations such as speed of return to play and re-injury rates and as such extends beyond the goals in more traditional musculoskeletal physiotherapy. The evidence supporting the ability of therapeutic exercise to achieve these extended rehabilitation goals is not conclusive.

In relation to hamstring injuries a meta-analysis supported the use of lengthening exercises in improving return to play time but did not find conclusive evidence regarding reducing re-injury risks (Pas et al. 2015, 1197). Reviews indicate that after ACL revision and subsequent rehabilitative exercise, 53-65% of players return to pre-injury level competitive play (Grassi et al. 2015, 1295-1296; van Melick et al. 2016, 1506-1507). In relation to groin pain, adductor related exercises have been shown to increase strength (Harøy et al. 2017, 3052; Ishøi et al. 2015, 1334), reduce injury risk (Harøy et al. 2018, 1-7) and there is some support that rehabilitation programs including specific focus on this muscle group can improve outcomes in relation to return to play (Hölmich et al. 1999, 439-443; Weir et al. 2010, 148).

2.2 Adherence / Compliance definition

The main output of the health care community is the prescription of medication and behavior change advice. The health care industry has variably defined behaviors consistent with this advice most commonly using the terms adherence and compliance. Some argue that adherence is a more appropriate term to use as compliance implies a clinician centered, dependent relationship which excludes the concepts of a partnership between the professionals and the free will/choice of the patient or client (Gould & Mitty 2010, 291). The World Health Organization (WHO) describe adherence as:

“The extent to which a person’s behavior – taking medications, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider” (Website of World Health Organization 2003). Whilst we appreciate the subtle nuances of compliance and adherence the terms are often used interchangeably within literature and for consistency, we will use the term adherence throughout this document.

Adherence is an important part of rehabilitation and injury prevention. Increased adherence rates have been positively correlated with improved treatment outcomes (Jack, Mclean, Moffett & Gardiner 2010, 220-228). However, within the context of therapeutic exercise there is no clear consensus regarding the definition of adherence especially when considering the parameters of frequency, duration, intensity and accuracy (Bailey et al. 2018, 1-3).

2.3 Measurement of adherence in therapeutic exercise

To understand the impact of adherence on the efficacy of therapeutic exercise we must measure the concept. Analysis of the measurement of therapeutic exercise within the setting of musculoskeletal pain demonstrates that a wide variety of measurement tools have been used including clinician focused methods (observing attendance/exercise intensity) and more patient focused methods (questionnaires/diaries) (McLean et al. 2017, 426-430). Bailey et al. (2018, 1-3) reported that that "measurement methods and parameters used to represent adherence were inconsistent". Examples of the parameters measured historically include exercise frequency, session attendance, intensity and accuracy of completion. However, even within the most common grouped parameter (exercise frequency) the definition of frequency varied when considering elements such as repetitions, sets, frequency per week/month and duration. Methods used to measure adherence also varied including self-report diaries, class registers, subjective questionnaires and objective measures. (Bailey et al. 2018, 1-5).

Bailey et al. (2018, 1-3) also reported that values for satisfactory adherence rates also varied materially. Half of the studies did not provide information about what they considered satisfactory and three quarters of the studies that did provide a position gave a wide range from 60-100%. Predetermined target levels of adherence were not common thus creating a large range of “satisfactory” adherence levels relative to participant performance within each study. The conclusion from the review indicated that 80% might be a reasonable threshold for satisfactory adherence to target in the future. (Bailey et al. 2018, 1-5).

Reliability and validity for the use of adherence measures for home-based exercise was reviewed by Frost, Levati, McClurg, Brady & Williams (2017, 1241-1250). There was some support for the use of home-based diaries to measure adherence. The use of retrospective adherence questionnaires was challenged due to a lack of reliability and validity support. The use of some objective measures of adherence (e.g. pedometer) were also supported. (Frost, Levati, McClurg, Brady & Williams 2017, 1241-1250).

It is apparent that there is no current consensus of the best way to measure adherence to therapeutic exercise. Further consideration also needs to be given to the accuracy of various measures of adherence. Observational measures such as monitors are arguably more accurate however the volume of high-quality evidence of the replicability and practicability of these measures is still being generated. (Peek, Sanson-Fisher, Mackenzie & Carey 2015, 535-539).

van Reijen et al. (2016, 1125-1130) conducted a review of the consistency with which sports injury prevention RCTs measured and reported adherence with interventions (e.g. neuromuscular strength training, equipment). They found that there was significant heterogeneity of measurement and reporting of adherence rates. Just over half of the studies reviewed provided adherence related data and only 20% of these studies measured the impact of adherence on an intervention's effectiveness at preventing injury. The measurement of adherence varied significantly including number of sessions completed, retrospective recall of the coaches, number of exercises completed, number of players attending and mixed methods of the above. The definition of satisfactory adherence was also highly variable. Several examples of arbitrary cut offs were presented to define high/medium/low adherence based on relative performance study participants. (van Reijen et al. 2016, 1125-1133).

Real world adherence rates to therapeutic exercise interventions are challenging to estimate partially due to the above-mentioned measurement limitations within registered studies. Adherence to home exercise and self-management exercise plans are in the range of 30-40% with some indication that when only considering home exercise programs this could be even lower (Jack et al. 2010, 220; Peek et al. 2015, 535-540).

When reviewing adherence to sport injury prevention interventions similar conclusions are drawn. A lack of consistency regarding measurement in studies limits estimation of real-world adherence rates. In a systematic review of sport injury prevention studies, a very wide range of adherence rates was reported (26-100%). (van Reijen et al. 2016, 1131-1135). For examples of the wide range of reported rates and measurement approaches see the table in Appendix 5.

2.4 Adherence and its impact on outcomes

Adherence to prescribed therapeutic exercise interventions in musculoskeletal studies are considered a key part of the success of exercise programs with increased adherence enhancing effectiveness of these programs (Holden, Haywood, Potia, Gee & McLean 2014, 2). Randomized controlled trials still report that effect sizes using various physiotherapy modalities remains low and these low effect sizes could be related to lack of adherence towards the treatment process (Jack et al. 2010, 220-222).

A similar finding is present within the prevention of sports injury literature. A key aspect in clinical trials that potentially impacts the reporting of an intervention's effectiveness is intention to treat analysis which excludes consideration of post randomisation adherence rates. Analyses including consideration of post randomisation adherence, such as per protocol analysis or group analysis based on levels of adherence, may improve accuracy of measuring an intervention's effectiveness (van Reijen et al. 2016, 1125-1136). The review by van Reijen et al. (2016, 1125-1136) reported several trials which carried out adjusted analysis that showed a further reduced risk of injury in participants with greater adherence to the intervention vs. original intention to treat analyses. Goode et al. (2015, 349-350) indicated that adherence is influential in understanding the true effect of eccentric hamstring exercise protocols. Another study retrospectively analysed a neuromuscular ankle rehabilitation program and found that the original significant reduction in re-injury risk using an intention to treat analysis was 3 times larger using per protocol analyses based on patient reporting of adherence (Verhagen, Hupperets, Finch & van Mechelen 2011, 290).

However, completing subsequent analyses such as per protocol analyses did not show a statistically significant improved risk reduction in all cases discussed in the review by van Reijen et al. (2016, 1125-1136). This methodology also has weaknesses such as the potential to increase the risk of bias as compliers may have a different baseline risk to non-adherers. (Goode et al. 2015, 349; Marshall, Donovan-Hall & Ryall 2012, 18-22). Furthermore, some argue that when quantifying the effect size, we should report conservatively (Verhagen et al. 2011, 287-290). When considering the applicability of RCTs to the real world an intention to treat analysis is confirmed by the CONSORT statement as the most appropriate (Schulz, Altman & Moher 2010, 5). The variability of adherence rates in studies indicate that to have truly applicable intention to treat results, exercise programs should include a focus on interventions designed to increase adherence (Verhagen et al. 2011, 291).

3 PSYCHOLOGY OF ADHERENCE

To influence levels of adherence to injury prevention and rehabilitation programs, we need to understand the factors that affect adherence. Some of the psychological models that can help contextualize adoption of behaviors include the Health Belief Model and the Theory of Planned Behavior (Glanz, Rimer & Viswanath 2008, 45-51).

When reviewing the literature for the use of behavioral theories incorporated into sport injury prevention research a McGlashan & Finch review (2010, 841-843) indicated that only 11% of the papers explicitly mentioned theories within their study. The most commonly used were variations around the Health Belief Model and the Theory of Planned Behavior. The most common use of these theories was guiding implementation and program design. They believed this represented a missed opportunity given the broader application of theoretical models in other domains of health behavior change initiatives. Application of these theories is considered beneficial in the design process in order to impact intention to complete injury prevention exercise.

3.1 Health Belief Model and Theory of planned behavior

The Health Belief Model (HBM) developed over the past 70 years encapsulates the concepts that if an individual believes they are at risk for a health condition and its associated consequences and there is an action or behavior which may reduce the risk of that condition and or reduce the severity of the consequences then the individual may adopt the behavior. The main factors involved in this model are described in table 1 (Glanz, Rimer & Viswanath 2008, 45-51).

Table 1. Factors of the Health belief model

Factor	Description
Perceived susceptibility	How likely to individual considers that the risk will occur to them
Perceived severity	What will be the consequences of the risk factor
Perceived benefit	How big will the benefits and what is the likelihood of achieving these benefits
Perceived barriers	What are the psychological and physical costs/efforts required to potentially deliver the benefits
Cues to action	What are the internal and external cues that might restrict or facilitate completion of the action
Self-efficacy	One’s belief in competence to achieve

The Theory of Planned Behavior (TPB) states that behavioral intentions are driven by individual’s attitudes, the surrounding subjective norms and their perceived control (self-efficacy) (Glanz et al. 2008, 45-51). Similarly, to the HBM the “attitudes” of the individual with respect to their beliefs about what outcomes might occur from undertaking a behavior will affect one’s likelihood of undertaking that behavior. The TPB also indicates the importance of surrounding “subjective norms” with respect to understanding of societal impact of referent individuals, their perspectives regarding the behaviors and subsequently the motivation of the participant to meet the expectations of these referent individuals. The model's 3rd factor driving intention is the individual's "perceived control" or self-efficacy with respect to their perception of their power to control barriers/facilitators to desired behaviors (Glanz et al. 2008 45-51).

Within the concept of sport's injury prevention/rehabilitation exercise, the perceived likelihood to develop a condition and the severity of its subsequent consequences coupled with the amount of effort required to overcomes the barriers associated with completing the exercise may influence adherence rates (Glanz et al. 2008 45-51).

3.2 Facilitators and barriers to adherence

To understand why people don't adhere to rehabilitation programs that they have been prescribed, we need to understand the factors that affect adherence. Identifying those barriers in patients, could help clinicians identify the patients at risk of non-adherence and help patients overcome/reduce these barriers thus maximizing adherence (Jack et al. 2010, 222).

Jack et al. (2010, 222-228) systematic review about barriers to treatment adherence in physiotherapy outpatient clinics, showed evidence that low physical activity at the baseline or a few weeks before treatment, low self-efficacy (belief in one's own ability to achieve), depression, anxiety, helplessness, poor social support or activity, greater perceived numbers of barriers to exercise and increased levels of pain during the exercise were found to be barriers that predict poor treatment adherence. Within our research we felt that levels of pain during or after exercise was of importance and thus considered this in our study design.

Marshall et al. (2012, 18-23) indicated that there are multifactorial reasons driving adherence to rehabilitative physiotherapy from an athlete's perspective via qualitative analysis. A key theme highlighted the importance of being given a rationale for the rehabilitation prescribed including a clear explanation of the injury. The distinction between intrinsic motivation vs. extrinsic motivation was confirmed by the participants as a determinant for adherence. Some highlighted the importance of an extrinsic driving force and others indicated that personality traits were more likely to be a determining factor in their adherence. Memory impairment was highlighted as an additional reason for lack of adherence and athletes mentioned the positive impact of additional materials over and above verbal instruction as being beneficial in aiding adherence.

A further systematic review indicated that the strongest evidence supported self-motivation, self-efficacy, previous adherence and social support as major factors in prediction of adherence to home-based exercise programs. There were also some mixed findings associated with perceived susceptibility potentially being a factor in adherence. (Essery, Geraghty, Kirby & Yardley 2016, 519-525).

3.3 Qualitative attitudes toward injury prevention

There is a material amount of qualitative literature generated to analyze the attitudes of implementers and participants in injury prevention programs. When reviewing attitudes toward injury prevention and injury rehabilitation programs several themes emerge. The themes we will discuss are education gaps, engagement and responsibility for completion. (McKay et al. 2014a, 1281-1284; Orr et al. 2011, 271-276; Saunders et al. 2010, 1128-1130; Joy et al. 2013, 2263-2267; Finch et al. 2014, 702-705).

3.3.1 Education gaps

Despite wide ranging efforts at disseminating and implementing injury prevention exercise programs the link between best available evidence and real-world perspectives is consistently poor.

Players, parents and management staff consistently indicate a varied knowledge on the ability of exercise to prevent injury. McKay et al. (2014a, 1281-1284) research reported that less than 50% of youth football players/coaches believed that muscular injuries were preventable. Another study in a similar setting confirmed similar rates of belief of ability to prevent injury of 50% or lower in player’s and parents and only slightly over 60% in coaching staff (Orr et al. 2011, 271-276). Adherence with injury prevention strategies is immediately challenged if a large proportion of the implementers and participants are unaware of the potential efficacy of the programs.

Furthermore, there is considerable discordance between player, parent and coaching staff perspectives of the most commonly mentioned methods to reduce injury risk. Many qualitative studies completed reflect the highly prevalent belief in the real world that stretching reduces injury risk (Martinez et al. 2017, 146-147; McKay et al. 2014a, 1281-1284; Orr et al. 2011, 275; Zech & Wellman 2017, 6-7). This is despite there being limited evidence supporting stretching as an effective method of injury prevention (Behm, Blazevick, Kay & McHugh 2016, 1-8).

When considering the best available evidence supports strengthening/neuromuscular exercise as the most effective interventions in avoiding injury it is surprising that player, parent and coaching knowledge of this factor remains low (Orr et al. 2011, 271-276). Some studies show that less than 10% of individuals believe strengthening can reduce injury risk (McKay et al. 2014a, 1281-1284). Two separate studies indicated the figure to be around 30% of players that believe strengthening activities would reduce the risk injury (Orr et al. 2011, 275; Zech & Wellman 2017, 1-7). These perspectives indicate a lack of knowledge regarding an important aspect included in most effective injury prevention programs, strength and neuromuscular training. A further challenge is present when use of injury prevention programs over a season, including strength and neuromuscular training, didn’t materially change perspectives toward what activities are most effective (McKay et al. 2014a, 1281-1283).

Within ice hockey a large proportion of education related to injury prevention programs have focused on contact injuries such as concussion, neck related injuries due to checking rather than neuromuscular training to reduce muscular injury. It is considered possible that there is an inherent knowledge gap of this player population in relation non-contact injury prevention. (Popkin, Schulz, Park, Bottiglieri & Lynch, 2016, 167-170). Our study will aim to investigate if this knowledge gap is prevalent.

Within a study of an Australian rules football injury prevention program player concern regarding muscular soreness post strength training was cited as an additional education gap impacting adherence (Donaldson et al. 2016, 337-340). Whilst we haven't seen this mentioned extensively within the qualitative literature, pain during exercise has been highlighted as a barrier to exercise adherence within musculoskeletal rehabilitation (Jack et al. 2010, 222-228) and prevalence of delayed onset muscle soreness (DOMS) could negatively affect adherence to a program due to fear that it is actually indicative of injury.

The causal link between a lack of knowledge and athlete support/engagement in sports injury prevention program has not been shown in the literature to our knowledge. However, in one qualitative study some of the coaches reporting a lack of athlete support for the program had proactively pursued education efforts regarding injury prevention to increase engagement (Joy et al. 2013, 2263-2267).

3.3.2 Engagement/prioritization

Logically linked with lack of knowledge about the main purpose of injury prevention programs is low engagement with the programs. Initial perspectives indicate that if evidence is strong engagement should be achievable. In a study of female adolescent athlete's 70% of participants indicated they would be willing to perform an injury prevention program if data showed it reduced risk factors of injury, reduced lower limb injuries or reduced likelihood of ACL injury (Martinez et al. 2017, 146-147).

However, barriers to adherence to these programs consistently mention a lack of engagement/boredom associated with the programs and a lack of time where they can prioritize these activities. We believe these aspects are intrinsically linked as a lack of engagement will result in prioritization of time spent in activities other than the injury prevention programs.

A qualitative analysis completed by Donaldson et al. (2018, 1-5) indicated that "lack of player enjoyment and engagement" and "lack of time at training" were two key barriers to implementation. Soligard et al. (2010, 787-790) reported that the probability of low compliance with an injury prevention program was 87% higher if the coach believed the program was too time consuming. They also indicated that teams with high adherence were more likely to have a coach perception that their players held a high motivation to complete the program vs. low compliant teams.

Long term maintenance of team-based injury prevention programs has been highlighted as a key issue. When long term maintenance was followed in female youth soccer, despite high rates of continued use of aspects of the implemented program, modifications related to the frequency with which it was performed and the content retained placed into question the ability to achieve the benefits associated with the original program (Lindblom, Waldén, Carlfjord and Hägglund 2014, 1425-1427).

In younger football players c. 10-11 years old a similar perception of boredom at the repetitiveness of a structured injury prevention program was reported (Kilding et al. 2008, 320-324). Three other studies from various settings further reinforced this theme of a boredom/lack of engagement from athletes and supporting adults during implementation (Saunders et al. 2010, 1128-1130; Joy et al. 2013, 2263-2267; Finch et al. 2014, 702-705).

The barrier of time to implement or length of the injury prevention program has been consistently linked to engagement within the literature even though injury prevention initiatives have mostly aimed for 20-25 minutes as a standard length. Feedback from netball, Australian rules football and soccer has commonly indicated the length of the program as a suboptimal aspect (Donaldson et al. 2016, 337-340; Finch et al. 2014, 702-705; Joy et al. 2013, 2263-2267; Saunders et al. 2010, 1128-1130).

Whilst suggested improvements to the player engagement barrier includes incorporating the activities into fun drill related activities it could be suggested that an increased player knowledge of the benefits of injury prevention programs may change the lack of interest and as such make implementation easier. Netball coaches' perspectives on delivery of a landing focused injury prevention program placed improvement in athletic attributes and injury risk reduction at equal levels with regards to the benefits of the program (Saunders et al. 2010, 1128-1130). A cohort of “best practice" youth football coaches who had implemented ACL injury prevention programs indicated performance improvement benefits should also be highlighted over and above injury prevention (Hägglund, Atroshi, Wagner & Walden 2013a, 974-977). Performance benefits of injury prevention programs have been presented as an additional benefit including better strength ratios, improved balance/neuromuscular control etc. (Bizzini & Dvorak 2015, 577-579). Where engagement with the main aim of injury prevention measures fails consideration of increasing the volume of benefits presented to participants including performance benefits may be of use. For example, individual performance benefits on agility, strength or dynamic balance (Neto et al. 2017, 651-653) could be presented. Alternatively, team performance benefits from a lower overall injury rate increasing overall performance of the team could be presented (Hägglund et al. 2013b, 738-739).

3.3.3 Responsibility for completion

When considering who was responsible for injury prevention in youth football McKay et al. (2014a, 1281-1284) work indicated that baseline beliefs of over 90% of players and coaches indicated players were responsible for this initiative with more than 75% of both groups also indicating coaches were responsible. In general injury prevention exercise programs have focused their implementation on the coaches/support staff not the players which is interesting given players clearly view themselves as responsible.

When investigating the perception of coaching and support staff in "professional youth soccer" 89% of respondents indicated that exercises to prevent lower limb injury should be performed both as a part of training and separate from team training. Perception of who bears the responsibility of injury prevention was shared amongst the relevant stakeholders (fitness coaches, players, head coaches) with most saying that all parties were responsible. However, when asked who bears the "ultimate" responsibility there was no consensus (head coach 35%, player 24%, fitness coach 24%). There is clearly a perception within some of this community that player's bear the ultimate responsibility to complete at least some injury prevention exercise and that at least some of this could take place outside the team trainings. (O’Brien & Finch 2016, 1-7).

3.4 Implications for interventions targeting adherence and implementation

O’Brien & Finch (2014, 357-363) concluded that focus on the core implementation aspects in sports injury prevention exercise programs in ball sports was inadequate. They reviewed injury prevention programs and reported that the interventions tended to focus solely on the injury prevention exercise program (83% of the trials) with no mention of any additional aspects of the intervention (e.g. education/training). In the remaining 17% explicit mention of the use some form of education and instruction intervention targeted at coaches, players and parents was prevalent. It was reported that in many studies it was challenging to identify the specific intervention as either the exercise program, the education about the exercise program or both combined. It was also challenging to identify the specific intervention target as the players, coaches, athletic trainers or multiple targets. Furthermore, it was reported that a clear approach to the delivery agent of programs was not identified. They believed having a clear strategy toward educating/supporting delivery agents (e.g. coaches or captains) were a key aspect of successful outcomes.

Emery et al.’s (2015, 865-868) systematic review in sports injury prevention research concluded that evidence exists showing program uptake and maintenance is a problem and further highlighted that implementation factors needed to be addressed. Suggestions included focus on making programs sport specific, increasing level of coach education (as this had been linked with improved adherence) and highlighting the performance benefits as a side effect to injury prevention exercise programs. This review also highlighted a need to address the deficiency in “coach, player and parent knowledge” regarding these programs. (Emery et al. 2015, 865-868).

Interventions designed to increase adherence to physical activity recommendations have been studied in patients suffering from chronic musculoskeletal pain. The review found that where programs specifically address adherence the frequency/duration and attendance at sessions is increased. Additional findings indicated supervised exercise is more effective than unsupervised exercise and graded activity is effective in improving adherence. (Jordan, Holden, Mason & Foster 2010, 1-13).

A range of interventions have been developed to increase adherence in general to physical activity. These include but are not limited to the use of mobile applications, increased materials for consumers (videos, paper materials), increased supervision (Jordan et al. 2010, 1-13). These interventions vary regarding the quality of evidence available regarding their effectiveness and firm conclusions from the research community are not yet available. Similar approaches have been trialed within sports injury prevention research including additional education targeted at varying audiences (more player/coach focused) and additional supervision with some promising initial results regarding increasing adherence rates (O'Brien and Finch 2016, 1-6).

4 GROIN INJURY PREVENTION AND REHABILITATION

Limited amounts of injury prevention randomized controlled studies have been conducted in ice hockey with far more research being conducted in the football setting. Furthermore, research discussing the perception of youth ice hockey players to injury prevention interventions is limited (Popkin et al. 2016, 167-170). Groin injuries are a common injury in ice hockey and often occur in non-contact situations (Hyvönen & Törmänen, 2018, 13-15; Tyler, Silvers, Gerhardt & Nicholas, 2010, 231-236; McKay, Tufts, Shaffer & Meeuwisse, 2014b, 57-60). Our study focusses on the implementation and adherence toward an injury prevention intervention within the scope of groin injuries in youth ice hockey players.

4.1 Groin injuries epidemiology in ice hockey

Ice hockey is a fast-paced sport which includes quick changes of direction and high-speed contact with ice, boards and other players putting players at a high risk of getting an injury during play (Hyvönen & Törmänen, 2018, 2). The Pelvic girdle area, of which the hip/groin are a part, keeps the body's center of gravity in the midline.

Therefore, it is in constant stress as almost every athletic movement/force production goes through the pelvic girdle. The pelvic girdle muscles/structures need to stabilize the area against these forces. For example, jogging has been found to cause 8-times higher stress than body weight on the pelvic girdle area and high pace sports like ice hockey or football cause even higher amounts of stress to this area (Dalton et al. 2016 1-3). The excessive force created during the acceleration and deceleration phases of skating have been considered as the cause of the increased risk of ice hockey players sustaining adductor strains. During the skating stride, the hip extensors and abductors are the prime movers and the hip adductors and flexors are working as stabilizers to decelerate the leg. The eccentric force/load absorbed by the adductors while decelerating the hip movement has been proposed to be the reason for adductor strain. The muscle strength imbalance of the stabilizing muscles and propulsive muscles is considered to be the mechanism of the injury. (Tyler et al. 2001, 124-127).

Groin strain injuries have been reported to represent 4-10% of all injuries in ice hockey and the amount of injuries varies by the level and league played (Tyler et al. 2010, 231-236; McKay et al. 2014b, 57-60). The most common body parts injured in ice hockey are the head and neck (15%), upper-limbs (34%), body and back (14%) and lower-limbs (34%) (Hyvönen & Törmänen, 2018, 19). From all ice hockey injuries, 85% of the total amount of injuries were caused by contact situation and 15% were non-contact injuries. Given groin strains are 4-10% of the all injuries in ice hockey and occur 90% of the time in non-contact situations, as such they can be considered as the most common non-contact injury in ice hockey. (Hyvönen & Törmänen, 2018, 13-15; Tyler et al. 2010, 231-236; McKay et al. 2014b, 57-60). Groin injuries have been found to occur as overuse/gradual injuries in ice hockey (Kerbel, Smith, Prodromo, Nzeogu & Mulcahey, 2018, 1-6). Given groin injuries mostly occur in non-contact situations, it tells us that players physical abilities and intrinsic factors are more linked in the incidence of groin injuries in ice hockey, rather than the impact of contact situations.

Groin strain injury rates have been reported to be 3.2 strains per 1000 player-game exposures in one NHL team and the injury rates have been reported to be higher in games versus practice. These figures might still be below the real amount of groin strains in ice hockey, since some may be left unreported with players often playing even if minor groin pain is present. (Tyler et al. 2010, 231-236; Dalton et al. 2016, 1-6). In a similar study about groin strains in ice hockey in the National Collegiate Athletic Association (NCAA), 50% of the groin strains were reported as non-time loss injuries, which often are not reported in other studies because they are not causing any missed playing or training for the player. Still reporting these non-time loss injuries should be as important, since they are a risk factor for injury/re-injury, which can result in a longer absence from the sport. **(**Dalton et al. 2016, 1-6; Tyler et al. 2010, 231-236).

The extent of how different injuries are affecting a team, or a player can be measured by the time they need to return to sport. A prospective study done in North America and European ice hockey leagues found out that injuries causing most absence time from the games were knee (40%), shoulder (20%), groin area (15%) and back (10%) injuries (Hyvönen & Törmänen, 2018, 19).

In the NHL hip/groin injuries were found to cause significant time-loss ranging from 10-58 Man-game-lost per season. (McKay et al. 2014b, 57-60). Whilst groin injuries are not the most common injury in ice hockey it is still a cause of high absent time volumes, with the grade of the strain being a major factor in determining the speed of return to play. (Website of American Medical Society for Sport Medicine, 2018).

4.2 Groin pain and grading of the injury

The groin area is a complex area of different muscular and tendinous structures which makes the location of the exact area of the groin injury difficult. The terminology historically used of different groin symptoms and pathologies has varied greatly and more precise definitions for groin pain have been formed to attempt to avoid different interpretations of same term used by clinicians (Weir et al. 2015, 768-772). A classification system for acute groin injuries was made in the Doha agreement by Weir et al (2015, 768-772) and they were: Defined clinical entities for groin pain, Hip-related groin pain and other causes for groin pain in athletes. It was considered that assessment of the history of the patient, clinical examination including palpation, stretching and resistance testing should be included to ensure a thorough examination allowing a specific clinical entity to be identified for groin pain (Weir et al. 2015, 768-772)

Defined clinical entities of groin pain are divided into; Adductor-related groin pain, iliopsoas-related groin pain, inguinal-related groin pain and pubic-related groin pain. Since groin pain can involve many different structures in the groin, the following screening procedures were created to examine the groin. (Weir et al. 2015, 768-772)

Adductor-related groin pain is occurring when there is a tenderness and pain on resisted adduction testing. Iliopsoas-related groin pain occurs when there is tenderness in iliopsoas or pain in resisted hip flexion and/or pain when stretching the hip flexors. Inguinal-related groin pain refers to the pain located in the inguinal canal region with concurrent tenderness of the inguinal canal and no palpable inguinal hernia is present. Groin pain is more likely inguinal related if resisted abdominal testing aggravates the pain or pain is occurring during Valsalva, cough or sneeze. Pubic-related groin pain is occurring as local tenderness on the pubic symphysis and the bony structures next to it. For pubic-related groin pain, there were no resistance test found to be used together with palpation that would provoke the symptoms of pubic-related groin pain. These terms are useful to categorize different groin pain by their anatomical location in the groin area and therefore to make more accurate diagnosis of groin pain (Weir et al. 2015, 768-772).

Hip-related groin pain is always a possible reason for groin pain, since the pain from the hip can be felt as pain in groin area and hip-related groin pain may be difficult to separate from other possible causes for groin pain, since there might be other coexisting factors for groin pain. In diagnosing hip-related groin pain, the passive range of motion tests and hip special tests like FABER (flexion-abduction-external rotation) and FADIR (Flexion-adduction-internal rotation) were recommended by Weir et al (2015, 768-772) to be used in examination for every case of groin pain. Special clinical tests for hip-related groin pain seems to have good sensitivity but low specificity, which means that they could be used in clinical practice to exclude the hip-related groin pain. Since the hip has so many possible aspects which could be cause groin pain, the clinical specials tests are not always enough to confirm existing pathology and therefore are not always useful in clinical work (Weir et al. 2015, 772-773).

The third classification criteria were other causes that can possibly cause groin pain in athletes. Since the possibilities of these causes are numerous, clinicians should be alert if the groin pain classification doesn't fit in usual patterns of groin pain. The main categories of other factors for groin pain are orthopedic, neurological, rheumatological, urological, gastrointestinal, dermatological, oncological and surgical. (Weir et al. 2015, 772).

Adductor strains are a common cause of athletes' groin pain. The symptoms that occur in adductor strain are defined as an injury in the muscle tendon unit which is causing pain when the tendons or the insertions are palpated near the pubic bone with or without pain during resisted adduction (Tyler et al. 2010, 231-236). Adductor strain grading is a 3-level grading system. First degree strain is if there is pain, but only a little loss of strength and restriction of movement is minimal. Second degree strain includes tissue damage that results in loss of strength in the muscle, but the muscle doesn't lose its full function/strength. Third degree strains are total detachment of the muscle tendon and loss of muscle function. (Tyler et al. 2010, 231-236). Recovery time from the groin strain injury varies depending on the grade of the injury and the treatment of the injury. Estimated recovery time is 1-4 weeks in grade 1 strain, 3-8 weeks in grade 2 strain and 8-12 weeks or longer in grade 3 adductor strain (Website of American Medical Society for Sport Medicine, 2018).

The topic of this thesis focuses on the feasibility of actions players can take in order to prevent groin pain and adductor injuries. These are a common finding in sports such as football and particularly in ice hockey it is the most common non-contact injury. (Hyvönen & Törmänen, 2018, 13-15; Tyler et al. 2010, 231-236; McKay et al. 2014b, 57-60).

4.3 Groin injury risk factors

Previous adductor injury (Tak et al. 2017, 12), hip adductor strength deficits (Esteve, Rathleff, Bagur-Calafat, Urrutia & Thorborg, 2015, 785-786) and previous injury in other parts of the body are found to be risk-factors for having an adductor injury (Tak et al. 2017, 12). Groin injuries are approximately 5-10% of all sports injuries (Esteve et al. 2015, 785-787). The adductors of the hip are the most commonly injured aspect when considering groin injuries related to sports. Given previous injury is a major risk factor new groin injury, primary prevention of groin injury is a major priority when considering overall prevention (Esteve et al. 2015, 785-790).

Tyler et al. (2002, 124-127) showed that in ice hockey, players at risk of an adductor injury can be screened by strength testing to assess the ratio between adductor- and abductor muscle strength of the hip. Players who had adductor strength less than 80% of abductor strength had a 17-times higher risk for an adductor injury. This study also showed that completion of a preseason exercise program including concentric, eccentric & functional hip adductor exercises by the at risk players decreased the incidence of the adductor injuries during the following seasons from 3.2 strains per 1000 player-game exposures to 0.71 strains per 1000 player-game exposures ($P < 0.05$) (Tyler et al. 2002, 124-127).

Some evidence has been presented indicating weak adductor strength as a significant risk factor of adductor injury among football players (Engebretsen et al. 2010, 2051-2056). Hölmich et al. randomized trial (1999, 439-442) about long-standing adductor-related groin pain in athletes found out that an active strengthening therapeutic program was effective in treating the long-lasting groin pain. The effects of the intervention were also found to be long lasting, which suggests a possible secondary, re-injury prevention effect of this exercise program (Esteve et al. 2015, 785-791).

Thorborg et al. (2014, 1-3) studied adductor strength as a predictor for groin pain/injury. They found eccentric strength to be significantly lower in symptomatic players with groin pain vs. asymptomatic controls on the dominant side only. No other differences were found between symptomatic and non-symptomatic players on the non-dominant side nor during isometric testing. Engebretsen et al. (2010, 2051-2057) found weak isometric strength of hip adductors as a risk factor for injury in football players. Players with weak hip adductor muscles had a 4-times higher risk for injury.

Results of the predictive value of strength testing on injury risk/symptoms are not always consistent across research. However existing research does tend to support the inclusion of specific exercises aimed at improving hip adductor strength (particularly in an eccentric manner) with the aim of injury/re-injury prevention.

4.4 Injury prevention programs for groin injuries

The current evidence surrounding the impact of preventive strength training programs is mixed. A meta-analysis demonstrated a potentially clinically meaningful risk reduction of 19% but no statistically significant results were found. Adherence to some of the studies included in this meta-analysis were poor, opening the question of whether these programs can be effective in reducing risk where adherence levels are sufficiently high (Esteve et al. 2015, 787-789). A new study published in 2018 looking at an eccentric strength program to prevent groin injury has however shown statistically significant results and will be discussed below.

Different exercises for hip adductor prevention or rehabilitation programs and their intensity have been studied to find suitable exercises for teams to use. The Serner et al. (2014, 1108-1112) study found that the Copenhagen Adductor Exercise, hip adduction with elastic band and the hip adduction on a machine are most relevant to injury prevention, since they include eccentric contractions in the movement with high intensity muscle activation. High intensity, dynamic eccentric exercises have been found to be preventive exercises for muscle injury. It is hypothesized that this is because they create strength in a similar position/action to the situations where most muscles strains are proposed to occur (eccentric force production). That way, they can prevent another muscle-tendinous injury by strengthening the muscle eccentrically and prepare it better for requirements of these movements in sports like ice hockey or football. (Serner et al. 2014, 1108-1112).

FIFA 11+ is a complete warm-up and neuromuscular strength program developed for youth and amateur football players and there is evidence supporting its preventive effect on injuries among football players. Randomized controlled trials have been researching FIFA 11+ and the results are mixed about its ability to prevent groin injuries. The FIFA 11+ doesn’t have a specific exercise to target adductor strength, a possible limitation, even though groin injuries are one of the most common injuries in football and adductor strength deficits are found to be risk factors for adductor injury. (Harøy et al. 2017, 3052-3056).

Nordic Hamstring curl is a high intensity eccentric exercise and it has been found to have preventive effects in decreasing hamstring strains. It has been found to be effective when used as part of a warm-up/neuromuscular training routine or as an isolated exercise and it is already included in FIFA 11+ program. Since the Copenhagen Adductor Exercise has a similar type of high intensity eccentric loading, it has been suggested to have similar preventive effects for adductor related groin injuries (Harøy et al. 2017, 3052-3053).

Harøy et al. (2017, 3052-3057) made an 8-week randomized controlled trial, using a FIFA 11+ on under 19-years old players. 45 players included in the study were randomized in two groups, where the intervention group did FIFA 11+, but replaced the Nordic hamstring curl with the Copenhagen Adductor Exercise, with the control group performing the standard FIFA 11+ program. The results showed an 8% average increase in hip adduction strength. When between group comparisons were undertaken there was a significant between group difference in strength gains indicating that the difference was driven by the inclusion of the Copenhagen Adductor Exercise (Harøy et al. 2017, 3055-3057).

Even higher results have been achieved in adductor strength adaptation by using the Copenhagen Adductor Exercise. Ishøi et al. (2015, 1334-1340) made a study with under 19 football players and an 8-week progressive training program using the Copenhagen Adductor Exercise whilst the control group continued normal training. Results were significantly higher, after 8-weeks in favor of the intervention group. Eccentric hip adduction strength increase was 35.7% (2.71 ± 0.48 to 3.67 ± 0.38 Nm/kg, $P < 0.001$) in the intervention group. In the control group the results were a non-significant strength increase of 0.4% (2.91 ± 0.34 to 2.92 ± 0.37 Nm/kg, P = 0.909) vs. starting point. Also, they had significant results in increasing eccentric hip abduction strength of the intervention group by a mean difference of 20.3% (2.27 ± 0.41 to 2.74 ± 0.41 Nm/kg, P< 0.001) where control groups results were a non-significant increase of 1.6% (2.40 ± 0.27 to 2.44 ± 0.29 Nm/kg, P= 0.335). Increase in hip abduction strength has been hypothesized to be due to the Copenhagen Adductor Exercise, since it has shown to have nEMG activation in hip abductors of 48% vs. max isometric voluntary contraction. Therefore, if the eccentric hip abduction strength increase is due to the Copenhagen Adductor Exercise, it would mean that the exercise is beneficial for the abductor muscle group also (Ishøi et al. 2015, 1334-1340; Serner et al. 2014, 1112). However, the Ishøi et al. (2015, 1334-1340) study could not conclude the increase of abductor strength was solely due to the Copenhagen Adductor Exercise or to some other exercise that the team was doing during that time.

Ishøi et al. (2015, 1334-1340) had much higher results (35.7% increase) than the Harøy et al. (2017, 3052-3055) 8%, even though the procedures of testing and the training were similar. Harøy et al. (2017, 3052-3057) addresses this and suggests the reason for the difference between the results could be that Ishøi et al. (2015, 1334-1340) was using higher amounts of repetitions in total during the intervention period (Harøy et al. 2017, 3055-3057).

Results of the Copenhagen Adductor Exercise in increasing eccentric strength levels of hip adduction and having preventive effect on groin strain injuries among football players have been demonstrated (Harøy et al. 2017, 3052-3055; Ishøi et al. 2015, 1334-1340; Harøy et al. 2018, 1-6). **T**here are no studies found using Copenhagen Adductor Exercise to prevent injury in ice hockey specifically to our knowledge. In ice hockey (similar to football) groin strains most commonly occur in non-contact situations (Hyvönen & Törmänen, 2018, 15). This highlights the intrinsic factors of the players as a major causal factor and as such supports the hypothesis that perhaps these factors could be addressed by an injury prevention program (Hyvönen & Törmänen, 2018, 15). In ice hockey the strength ratio of the hip adduction and abduction strength lower than 80% has been found to be a predictive factor for groin injuries for the players in the following season (Tyler et al. 2002, 681-683). Evidence of preventive effects have been demonstrated by using a pre-season preventive exercise program designed to get the ratio closer to 1 (Tyler et al. 2002, 681-683). Given the Copenhagen Adductor Exercise has not been studied in ice hockey to our knowledge, we would like to test its initial suitability to this sport and assess if it is feasible to complete during season for the players as a groin injury prevention exercise to fit into their normal training. This may lead to a more sustainable practical injury prevention solution vs. having longer specialized prevention programs as detailed in some of the literature to date.

4.5 Rehabilitation programs for groin injuries

Adductor injury rehabilitation programs have included both active therapy (e.g. exercise programs) and passive modalities (e.g. manual therapy programs). One of the aims of studies has been to investigate the most effective and time efficient rehabilitation options. Exercise therapy has been suggested as the best option for rehabilitation of groin pain (Hölmich et al. 1999, 439-442), still there are some inconsistent results of how passive manual modalities can impact groin pain rehabilitation and some evidence exists which might support their use (Weir et al. 2010, 150-153).

Hölmich et al. (1999, 439-442) studied the effect of active physical training on long standing adductor related groin pain in athletes. Results were that 79% of the athletes who participated in the active physical training program returned to sports on their previous level without any symptoms with a median return to play time of 18.5 weeks. Only 14% of the control group (intervention consisted of massage, stretching, laser treatment and TENS) returned to previous level of play (Hölmich et al. 1999, 439-442).

A follow up study was completed 8 to 12 years after the original study of Hölmich et al. (1999, 439-442) and the available study subjects were re-assessed (Hölmich, Nyvold & Larsen, 2011, 2448-2450). The follow-up study showed significant difference in favor of active therapy where long-term reduction of groin pain still existed ($p=0.047$) and the effect was even higher when measured in only the sub-group of football players ($p=0.012$) (Hölmich et al. 2011, 2448-2450).

Different results have been found in the study of Weir et al. (2010, 148-154), where they compared exercise therapy vs. multi-modal treatment on long-lasting adductor-related groin pain. The multimodal group focused on heat, a specific manual therapy technique and stretching followed by an active return to running program. The control group had a home-based exercise therapy followed by a return to running program. There was some support from this study that perhaps manual therapy might result in a faster return to play (12.8 weeks vs. 17.3 weeks, p=0.043). However, there was no statistically significant difference in proportion of athletes who returned to sport nor pain follow up. (Weir et al. 2010, 148-154). Whilst there may be some support from this study for inclusion of a manual component to a physiotherapeutic rehabilitation program from long standing groin pain the overall body of evidence on injury rehabilitation and prevention supports the prioritization of an inclusion of an active exercise component. When considering long-term effects of the rehabilitation, the Hölmich et al. (1999, 439-442) exercise therapy demonstrated also a long-term preventive effect for groin pain even after 8 to 12 years and as such strongly supports the use of exercise therapy as a rehabilitation method in long standing groin pain (Hölmich et al. 2011, 2449).

5 PURPOSE

We will investigate the feasibility of an adjusted version of the Copenhagen Adductor Exercise in youth ice hockey players delivered directly to players rather than coaching staff. We aim to use an education package, strength measurements and adherence tracking to maximize player engagement toward the injury prevention exercise and demonstrate evidence of how these may help optimize implementation and adherence in the real world.

We hypothesize that:

- Players will demonstrate (through subjective opinion and median adherence levels of >60%) that it is feasible to complete the program during the season

- Initially player’s will not rate neuromuscular strength training highly as a method of injury risk reduction. This perception will be modified via the delivery of the education package.
- The education package content will be rated as a stronger motivator toward completing the exercise program over other extrinsic motivators (e.g. adherence review)
- Players will demonstrate an average >7.5% (Harøy et al. 2018, 1-7) average increase in adduction strength. There will be a correlation between strength gains and reported adherence thus giving an indication this change was due to the exercise and giving support for the use of measurement as a proxy for adherence

Study questions:

- How will the players perceive the overall intervention?
- How will players adhere to the exercise?
- What will players view as the biggest facilitators/barriers to adherence?
- What support might strength change measurements provide toward estimation of adherence to the exercise?

6 METHODS

We conducted a mixed methods single arm study to assess the feasibility of the adjusted Copenhagen Adductor Exercise. We reviewed player’s perspectives, self-report adherence rates, application data adherence rates and objective measures of strength gains. We qualitatively analyzed the major drivers/barriers toward adherence from the players perspectives to aid future research.

6.1 Study design and participants

The study participants were male junior ice hockey players from 14-21 years of age, and they were screened for inclusion from the Porin Ässät A1, B1 and C1 junior teams. Consent was obtained from the team leader, coaches, individuals and parents where individuals were under 18 years. Screening is represented in figure 4.

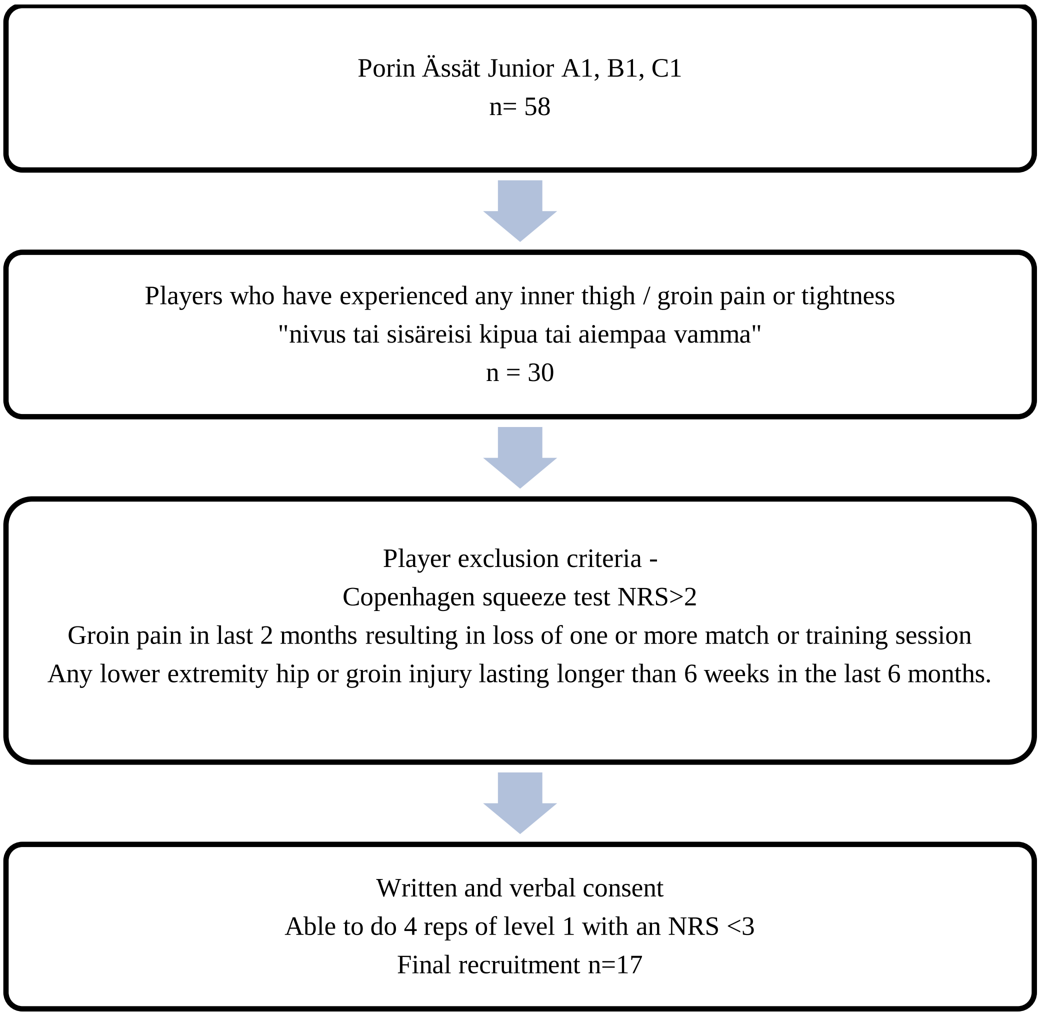

Figure 4. Recruitment flow chart

Initial screening for study inclusion was the question "Have you ever experienced any groin or inner thigh pain/injury/tightness at present or in the past". We have selected these aspects as potentially indicative of some past injury as prior groin injury has been identified as a risk factor for future groin injury (Tak et al. 2017, 12).

All individuals with past or present groin pain were further screened using the Copenhagen five-second squeeze test as described by Thorborg, Branci, Nielsen, Langelund and Hölmich (2017, 5-10). Any players scoring higher than a 2 out of 10 on a Numerical Rating Scale (NRS) of pain were excluded from the study due to suggestions that players above an NRS 3 are potentially in need of medical assessment regarding their groin symptoms (Thorborg et al. 2017, 5-10). Players were further screened and excluded if they have had groin pain resulting in the loss of one or more match/training session within the last 2 months prior to study initiation. They were excluded if they had suffered any lower extremity hip or groin injury lasting longer than 6 weeks in the prior 6 months. (Ishøi et al. 2015, 1334-1340). The inability to undertake 4 reps of the easiest level of the exercise initiative at the first meeting without an NRS <3 resulted in exclusion from the study similar to the approach used in Harøy et al. (2018, 1-7).

We provided players with verbal and written information regarding study purpose and procedures. Target recruitment was 15-20 players.

6.2 Qualitative questionnaire

A pre-intervention qualitative questionnaire was completed by 58 players before screening for study inclusion took place and before any information had been provided about the purpose of the study. The purpose of the pre-intervention questionnaire was to gather youth player perspectives regarding sporting injuries within ice hockey, injury prevention methods and facilitators/barriers to adherence. A post-intervention qualitative questionnaire was completed by 17 players after the intervention. The purpose of the post-intervention questionnaire was to collect any change in perception regarding injury prevention methods, to assess the participants perception regarding the actual facilitators/barriers to adherence during the process and finally their perception toward the feasibility of the program.

We reviewed various prior studies' surveys on perceptions of injury and injury prevention in detail and used their survey question and study findings in the construction of our questionnaires (Martinez 2015, 117-130; McKay et al. 2014a, 1281-1286; Orr et al. 2011, 271-277; Saunders et al. 2010, 1128-1132; Joy et al. 2013, 2263-2267; Finch et al. 2014, 702-705; Zech & Wellman 2017, 6-7). We also used our analysis of the pre-intervention questionnaire to change the structure of some of the repeated questions in the post-intervention questionnaire in order to clarify some open text responses originally provided.

Copies of the questionnaire are provided in Appendix 1 & 2.

If participants reported pain during or after the exercise either during a follow up meeting or in the post-intervention survey, we sought additional detail associated with the type, location and duration of pain through unstructured verbal interview.

6.3 Adherence measurement

When communicating with participants about adherence we used number of sets completed as the definition of adherence rather than repetitions or number of days they did the exercise. Adherence rate ranges were asked to be provided both prospectively and retrospectively in the questionnaires.

We also asked them to record adherence through a diary application each time they did the exercise by entering the sets and repetitions into an application that was loaded onto their phones (WORKIT – Gym Log, Workout Tracker). All levels of the exercise were created within their phone and included a link to a YouTube video where we explained the exercise. We asked them about their use of the application at the interim meeting and reminded them to continue or restart using it.

6.4 Pre- and post-intervention strength measurements

Testing of eccentric hip adduction and abduction strength were done by using a hand-held dynamometer (Microfet 2) and all the tests were done in individual meetings on two examination tables placed next to each other using the protocol described below. Both legs were tested for hip adduction and abduction from all participants and the right leg was tested first from each participant. To measure peak eccentric force, the test was a break test where the peak force occurs due to the limb’s motion during eccentric strength testing (Thorborg, Couppé, Petersen, Magnusson & Hölmich, 2011, 15). Testing was scheduled on non-match days. Every participant went through a 6 min standardized warm-up protocol before testing, which included jogging, squatting and activation movements for hip adductors and abductors.

The testing position was as described in Thorborg et al. (2011, 15). The participant lay over on an examination table in side-lying position and the leg not being tested was in 90-degree flexion of the knee and hip. The participant was asked to take support from the examination table with their hands during testing. The examiner applied resistance in a fixed position to the leg with the hand-held dynamometer, 8cm proximal from the most prominent point of lateral malleoli. The participant lifted the leg above horizontal for the abductor test and 20-30cm off the examination table for the adduction test. The participant applied a 3-5 second maximum isometric contraction to the device before the tester broke the contraction by pressing the leg down thus providing an eccentric strength measurement. The tester stabilized the hip/pelvis area during testing. All the participants were introduced to the testing procedure and had 1 practice trial before the actual test. Test was done 3 times the highest result and the mean value of the 2 highest results analyzed. There was 45 seconds rest between each trial to avoid decline in strength during the trials due to fatigue (Sisto & Dyson-Hudson 2007, 123-128). The tester used standardized commands on each test, which were “Go ahead-push-push-push-push-push” and commands were given in Finnish language during the testing. Leg length/lever length was measured from each client in supine, from the most prominent point of anterior superior iliac spine to 8 cm proximal from the most prominent point of the lateral malleoli. Lever length was used to calculate the torque and all the force values were reported as weight adjusted torque figures (Nm/kg).

A single examiner completed the measurements. Hand-held dynamometer strength testing has been shown to be reliable in both athlete and non-athlete populations (Sisto & Dyson-Hudson, 2007, 123-130; Fulcher, Hanna & Raina Elley, 2010, 80-82). Thorborg et al. (2011, 15) reported intra-class correlation coefficient (ICC) and standard error for measurement (SEM) for hip adduction ICC=0.91 (0.70-0.98) SEM=6,3% and for hip abduction ICC=0.86 (0.53-0.96) SEM=5,1%, which showed minimal absolute measurement variation of this procedure.

6.5 Intervention

Intervention sessions began in November 2018 and lasted for 10 weeks and the content is highlighted in table 2.

Table 2. Intervention plan

Meeting type	Meeting content	Time commitment / Location
Initial meeting Group	Survey completion, group screening and individual screening based on adductor injury history and Copenhagen squeeze test, explanation of study content and distribution of consent forms	30 minutes Before team training at Ässät Astora Areena / Isomäki arena
Individual meeting 1 Week 1	Adductor injury education package delivery, strength measurements, exercise education/prescription, adherence diary application use and adherence/strength gain goal setting	60 minutes – SAMK campus
Individual training	Participants undertake exercise programme for 10 weeks	Approx. 20 minutes per week. Location was up to the player, home or off-ice training facilities
Group meeting Week 5	Progression criteria review/advice, safety discussion, review of exercise technique	Before team training at Ässät Astora Areena / Isomäki arena
Individual meeting 2 Week 11	Questionnaire, strength measurements, collection of adherence diary, future advice, compensation massage (if desired)	60 minutes – SAMK

6.5.1 Initial meeting / goal setting and education package

The participants attended individual sessions. Strength measurements were completed as described above. An education package was delivered regarding adductor injury risk and prevention (see Appendix 2). A goal setting discussion was completed with participants centered around the concept of >80% adherence to the prescribed number of sets resulting in a potential >10% strength improvement in the adductor complex. We then taught the exercise program as described below with the varying levels of progression.

6.5.2 Adjusted Copenhagen Adductor Exercise prescription

The exercise was an adjustment on the partner-based Copenhagen Adductor Exercise as described in Harøy et al. (2018, 1-7) which has been demonstrated to be effective increasing in adductor eccentric strength and having preventative effect for groin problems (Harøy et al. 2018, 1-7; Ishøi et al. 2015, 1334-1340; Harøy et al. 2017, 3052-3056). The adjustments were made to enable the activity to take place alone thus allowing a transfer of the responsibility of injury prevention directly to the player.

Level 1 (the least loading) – the knee is supported on a pillow on a chair or table approximately 45cm off the ground. In the start/end position (Figure 5) the lower leg is placed through the chair's legs and the hips are raised with the goal a straight line between the upper knee, upper hip and upper shoulder. The unsupported leg is maximally adducted as far as possible. The hips are lowered toward the ground and the supported leg is maximally abducted toward the ground in a controlled manner thus creating an eccentric contraction of the supported leg's adductor muscles (Figure 6). The lower leg and hips are then raised to the start/end position and this is one repetition.

Figure 5. Level 1 start/end position (Copyright Heikki Laaksonen)

Figure 6. Level 1 midpoint position (Copyright Heikki Laaksonen)

Level 2 (medium loading) – the ankle is supported on a pillow on a chair or table approximately 45cm off the ground. In the start/end position (Figure 7) the lower leg is placed through the chair's legs and the hips are raised with the goal a straight line between the upper ankle, upper knee, upper hip and upper shoulder. The unsupported leg is maximally adducted as far as possible. The hips are lowered toward the ground and supported leg is maximally adducted toward the ground thus creating an eccentric contraction of the supported leg's adductor complex (Figure 8). The lower leg and hips are then raised to the starting position and this is one repetition.

Figure 7. Level 2 start/end position (Copyright Heikki Laaksonen)

Figure 8. Level 2 midpoint position (Copyright Heikki Laaksonen)

Level 3 (most loading) – the ankle is supported on a pillow on a table approximately 75cm off the ground. All other aspects of level 3 are identical to level 2 except that the range of movement is greater due to the higher support point at the ankle. See Figure 9 and 10 for start/end and midpoint position.

Figure 9. Level 3 start/end position (Copyright Heikki Laaksonen)

Figure 10. Level 3 midpoint position (Copyright Heikki Laaksonen)

The players were instructed in the appropriate level for them as determined below. They were given access to a YouTube video explaining the exercise and its levels (See Appendix 3 for links).

Within a study of an Australian rules football injury prevention program player concern regarding increasing the risk of muscular injury or muscular soreness as an indicator of damage was mentioned (Donaldson et al. 2016, 337-340). As such we were mindful about grading the exposure of the exercise to minimize excessive DOMS in the early stages. In order to achieve this, we adopted the resistance exercise specific rating of perceived exertion as demonstrated in table 3 (Zourdos et al. 2016, 267-270) to determine the appropriate starting level for participants.

Table 3. Description of perceived exertion based on 0-10 rating of perceived exertion

Numerical rating of perceived exertion (RPE)	Description at that point in time
10	Maximum effort – no more repetitions could be completed
9	1 repetition remaining
8	2 repetition remaining
7	3 repetitions remaining
5-6	4-6 repetitions remaining
3-4	Light effort
1-2	Little to no effort

The target by the end of week 5 (the midpoint) was two sets completed twice per week with 8-10 repetitions of the exercise resulting in a target RPE of 7-9 at the end of the second set (e.g. less than 3 repetitions remaining). To assign the appropriate level to each individual we had the participants complete 5 repetitions of level 1 followed by asking the question "how many more repetitions do you think you can do". If the participant answered 4 or more, they had a corresponding RPE at a level that indicates they were already at the 5-week target. As such, we progressed them immediately to level 2 and repeated the process asking them to do 5 repetitions and again asking them "how many more repetitions do you think you can do". If the participant answered 4 or more, they were progressed to level 3.

Anyone experiencing an NRS of 3 or more out of 10 on level 1 before reaching 4 repetitions (the minimum starting level) would have been excluded from the study (however this didn't occur). If anyone had an NRS of 3 or more on level 2 or 3 they were returned to level 1 and this was their starting level. An NRS of 3 or more has been chosen based on prior research that this is an indicator of acute injury that should be rested/seek medical attention (Harøy et al. 2018, 1-5).

The target at the end of week 10 was 2 times per week 2 sets per side and 10-15 repetitions per side of the prescribed exercise level determined at the week 5 meeting. As such at the week 5 meeting the participant was asked to complete 8 repetitions of the existing level they were on and we asked how many more repetitions they could complete. If they could complete 4 or more, they were progressed to the next level. The guidance sets/reps for the 10-week training period are shown in table 4a and 4b.

Table 4a. Training protocol if the level of the exercise did not change at 5 weeks

Week	Weekly sessions	Sets per side	Repetitions per side
1 & 2	2	2	4-6
3, 4	2	2	6-8
Group meeting in beginning of week 5			
5-6	2	2	8-10
7-8	2	2	10-15
9-10	2	2	10-15

Table 4b. Training protocol if the level of exercise changed after 5 weeks

Week	Weekly sessions	Sets per side	Repetitions per side
1 & 2	2	2	4-6
3, 4 & 5	2	2	6-8
Group meeting in the beginning of the week 5 for progression			
5-6	2	2	6-8
7-8	2	2	8-10
9-10	2	2	10-15

We discussed the use of the workout log application to track their exercise and explicitly mentioned that we would collect this data at the end of the study. We also mentioned that we would re-measure their strength at the end of the study.

Finally, we gave them written instructions of the exercise at both the initial and midpoint meetings detailing their exercise level, number of recommended sets/reps etc. Examples of the written instructions provided to participants are presented in Appendix 4.

6.5.3 Follow up meetings

After 10 weeks of the exercise program we invited the participants back for a follow up session. We had them complete a questionnaire regarding perception of injury prevention, their perceived adherence and the factors that influenced this. We extracted the adherence data from the workout log application and we repeated the measurements of adductor and abductor strength according to same protocol. We presented the strength results to the participants and had an informal discussion of these results in relation to their reported adherence. We gave advice on any continuation of the exercise after the study period and offered a 30-minute massage as compensation for their participation in the study.

6.6 Survey and adherence data analysis

The survey results were translated into English for those completed in Finnish and then qualitatively and quantitatively analyzed by the study administrators. Open text answers were analyzed and grouped into categories and subsequently numerically analyzed. For questions where motivators for completion of the exercise were ranked from greatest to least, we created a scoring system to allow graphical representation (3 points for most motivating, 2 points for 2nd motivator, 1 point for 3rd motivator and 0 points for least motivating). We grouped responses regarding pain during or after the exercise by location (groin/non-groin area), type (DOMS or non-DOMS). We used professional judgement and open-ended discussion with participants to make this assessment. We also used professional judgement to categorize any additional detail provided (e.g. if a concurrent unrelated injury may have caused the pain).

We collected diary application data by extracting the output file from phone applications. This data was compiled to give a figure of total sets completed vs. intended total sets as this was one of our methods of measurement of adherence %. The number of repetitions were also collected but not used for analysis.

6.7 Strength measurement data analysis

Force in newtons as measured with the dynamometer was converted to Torque (Nm) using length of the lever arm and standardize for the different weight of participants (Nm/kg). Strength change was calculated by comparing initial measurements vs. final measurements of each participant. Statistical analysis was completed with Tixel software to undertake one sample average tests and one-way analyses of variance for subgroup analyses. We grouped the participants for further sub-analysis based on age (A/B juniors vs. C juniors, over and under 17 years of age) and post-intervention survey adherence estimates (over and under 60%). We also averaged the changes in left and right sides to give a pooled estimate of total average change of adduction and abduction in each player.

By grouping the players on adherence rates and analyzing the difference in strength change between higher and lower adherers we aimed to show how objective changes in strength of a muscle group might be an additional indicator of adherence to a specific exercise.

7 RESULTS

7.1 Recruitment process

Separate recruitment meetings were conducted with three teams in October 2018 with 58 players in attendance. When screened for prior groin/inner thigh pain 21 out of 58 players responded positively and an additional 12 players indicated interest in taken part in the study despite not having experienced prior groin pain/injury. We then conducted exclusion criteria screening (see methods) and 8 players were excluded leaving 25 recruited players who were invited to individual meetings at SAMK during October and November 2018. The first meeting invitations were attended by 18 out of 25 players and at these meetings the education package was delivered, strength measurements were completed, and the appropriate starting level of the exercise was prescribed. Baseline characteristics of the 18 players that took part in the study are presented in table 5.

Table 5. Baseline characteristics of 18 study participants.

	Mean
Age	16.83
Weight (kg)	80.39
Right leg length (cm)	89.47
Left leg length (cm)	89.69

7.2 Qualitative questionnaire before and after the intervention

A pre-intervention questionnaire was given to 58 ice hockey players who were unaware of the subject matter of the study. All players, ranging from 14-21 years of age, completed the questionnaire electronically on their own mobile phones via a web browser. The pre-intervention survey was completed in Finnish by 55 players and in English by 3 players. A post-intervention questionnaire was given to all players who were participating until the end of the study before final strength measurements were taken. There were 17 players ranging from 14-21 years of age who completed the post-intervention questionnaire. The survey was completed in Finnish by 16 players and in English by 1 player.

7.2.1 Perception toward injury prevention

Figure 11 reflects the initial player perceptions of the single main purpose of currently completed off ice conditioning training. Most responses by players were Increased strength (33%), Increased speed (26%) and Increased mobility/agility (22%). After these was Increased Stamina (16%). Only 3% mentioned reduction in injury risk.

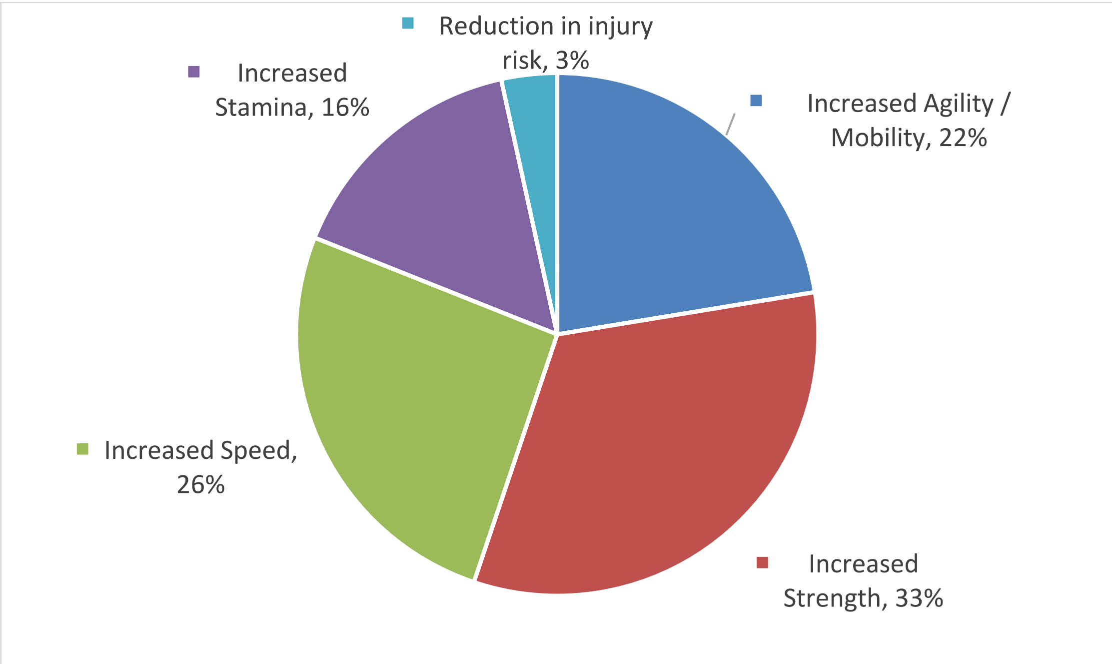

Figure 11. Player perception of the main purpose of current off ice conditioning training (%, n=58). Pre-intervention questionnaire.

Player perception of the body areas most commonly injured in non-contact situations were Groin/Inner thigh (45%), Knee joint (14%) and Back muscles (14%) (Figure 12). Lack of flexibility/stretching (83% of players) and poor warm up (81% of players) were the most common perceived causes of non-contact injuries (Table 6). This was followed by poor muscle strength (28%) and lack of fitness/training (16%) (Table 6).

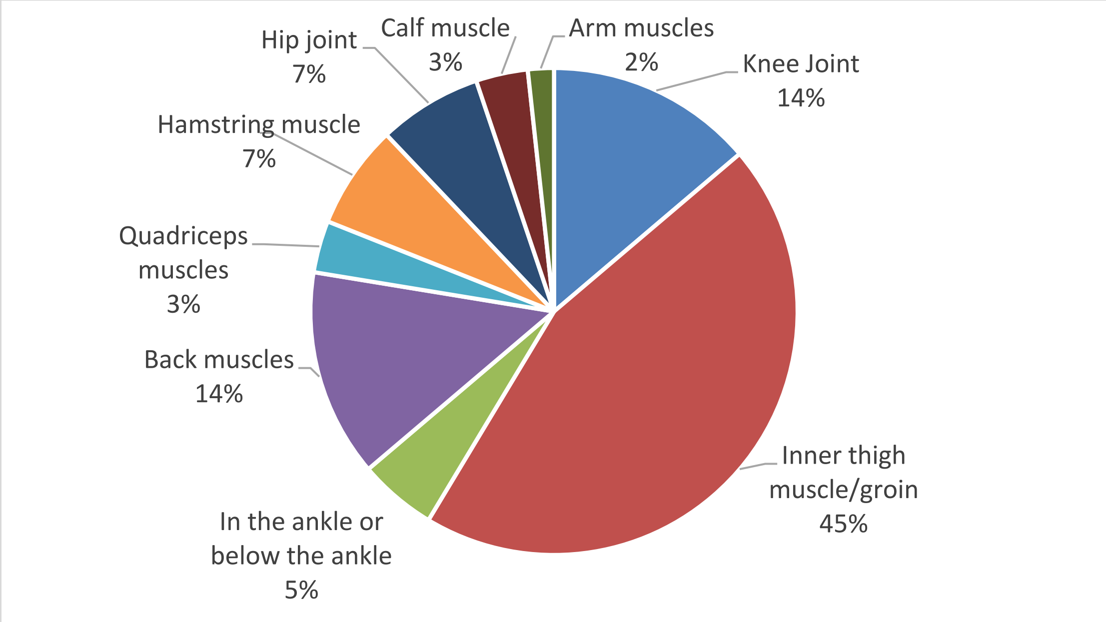

Figure 12. Player perception of most commonly injured areas in non-contact ice hockey injuries (%, n=58). Pre-intervention survey.

Table 6. Player perception of the causes of non-contact ice hockey injuries. *Up to 3 responses could be selected. Pre-intervention questionnaire.

Causes of non-contact injuries*	Responses	% of all survey participants (n=58)
Lack of stretching/flexibility	48	83%
Inadequate warm up	47	81%
Poor muscle strength	16	28%
Lack of fitness or training	9	16%
Poor equipment/Ice	8	14%
Lack of skill/technique	7	12%
Player’s genetic background	3	5%

In the pre-intervention questionnaire, players broadly believed that some non-contact injuries are preventable with 86% responding positively, 12% indicating they didn’t know and 2% or one player answering negatively. The most common response of non-contact injury types that could be prevented were muscle strains/tears (92% of respondents) and joint injury (15%) (Table 7).

Table 7. Player perception of types of non-contact ice hockey injuries that can be prevented and what actions could achieve this. Free text answers grouped by study co-ordinators. Pre-intervention survey. N.B. 19/58 players gave no answer to this question.

Types of non-contact injuries that could be prevented	Responses	% of all respondents to this question (n=39)
Muscle strain/tear	36	92%
Joint injury	6	15%
Other	2	5%
Overuse & Stress fracture	2	5%
Total responses	46	

In the pre-intervention survey players indicated the actions they believed that would reduce their injury risk were completing a proper warm up (88%), stretching muscles (78%), focusing on technique (43%), ensuring adequate rest (41%) and strengthening muscles (19%) (Table 8).

Table 8. Player perception of actions they can take to reduce non-contact injury risk. *Up to 3 responses could be selected. Pre-intervention survey.

Actions players can take to reduce non-contact injury risk	Responses (167 from 58 players)	% of all survey participants (n=58)
Complete a proper warm up	51	88%
Stretch muscles	45	78%
Focus on technique	25	43%
Ensure adequate recovery/rest	24	41%
Strengthen muscles	11	19%
Eat Healthy	9	16%
Ensure I have good stamina	2	3%

Table 9 shows the results of the post-intervention perceptions of the actions a player can take to reduce non-contact injury risk. The most common actions were Warm up (82%), Stretching (65%) and Adequate rest/recovery (65%). Strengthening muscles was only chosen as part of the top 3 actions by 24% of the players (Table 9). When only considering players, who participated in the intervention and received the education package, 2/17 pre-intervention and 4/17 post-intervention mentioned strengthen muscles as one of the top 3 methods of reducing injury risk.

Table 9. Player perception of actions they can take to reduce non-contact injury risk. *Up to 3 responses could be selected. Post-intervention survey.

Actions player can take to reduce non-contact injury risk	Responses (51 from 17 players)	% of all survey participants (n=17)
Complete a proper warm up	14	82%
Stretch muscles regularly	11	65%
Ensure adequate recovery/rest	11	65%
Focus on correct technique	8	47%
Strengthen muscles	4	24%
Eat Healthy	1	6%
Ensure I have good stamina	2	12%

In the pre-intervention questionnaire, all players confirmed that they themselves were responsible for prevention of non-contact injuries (100%) (Table 10). Other common answers included the Coaching staff (52%) and Physiotherapists (24%) (Table 10).

Table 10. Player perception of who is responsible for preventing risks of sustaining a non-contact injury. *Up to 3 responses could be selected. Pre-intervention survey.

Parties responsible for prevention of injury	Responses	% of all survey participants (n=58)
Players themselves	58	100%
Coaching staff	30	52%
Physiotherapists	14	24%
Parents	5	9%
Doctors	3	5%
Other medical professionals	2	3%
Administration of sport	2	3%
Total responses	112	

Player’s perception regarding completing one additional strength and conditioning exercise designed to reduced injury risk was broadly positive. On a Likert scale of 1 to 7 where 1 was extremely bad and 7 was extremely good the average response was 5.5.

Player’s belief regarding the likelihood that they would suffer a non-contact injury at some point in the next 12 months that would result in missed training or match was mixed. On a Likert scale of 1 to 7 where 1 was extremely unlikely and 7 was extremely likely the average response was 2.8 (slightly lower than likely).

7.2.2 Adherence estimates, facilitators and barriers

In the pre-intervention survey the most commonly mentioned free text responses regarding the biggest barriers/facilitators to completing this exercise were time/private life (36%), motivation (28%), the exercise facilitating ability to play/train (33%) and education/demonstration of the benefits of the exercise (16%) (Table 11).

Table 11. Player's free text answers on any barriers / facilitators for completing the exercise, answers grouped by study coordinators. Pre-intervention survey

Barriers / facilitators	Grouped responses	% of all survey participants (n=58)
Time / private life	21	36%
Ability to play/train (injury prevention)	19	33%
Motivation	16	28%
Education / demonstration of benefits	9	16%
Exercise too loading	5	9%
Other	5	9%
Total	75	

Player self-reported adherence estimates post-intervention were mixed (Table 12a). Player estimates of what the diary application data would reflect were mixed (Table 12a). Median values of the retrospective adherence estimate were 60-80% in the post-intervention survey. Median values of the workout log application adherence rates were 40-60% with a mean of 41% (Table 12b). Player estimates of the pre-intervention adherence rates trended toward being higher than player estimates of post-intervention adherence rates (Table 12a). Workout log application adherence rates trended toward a lower rate than retrospective self-reported adherence estimates from the survey (Table 12a). Only 24% of participants had a self-report estimate that matched their application data and 2 of these 4 people did less than 20% of the exercises (e.g. if you estimate you did nothing and did nothing/didn't use the app then congruence is automatic). There was a clear trend in the reported data and qualitative comments from participants that use of the application diary was not consistent. Where there were discrepancies between post-intervention self-report and workout log application data the application data was lower in 11/13 (85%) of these cases.

Table 12a. Exercise adherence rate ranges n=17. Figures presented include estimate before intervention, survey estimate after intervention, workout log application data post-intervention.

Adherence range	Pre-intervention survey estimate	Post-intervention survey estimate	Post-intervention workout log	Post-intervention log data matched survey estimate
0-20%	0%	12%	29%	2 cases
20-40%	0%	12%	18%	0 cases
40-60%	12%	18%	24%	1 case
60-80%	35%	29%	18%	0 cases
80-100%	53%	29%	12%	1 case
Median	80-100%	60-80%	40-60%	
Total	100%	100%	100%	4 cases / 24%

Table 12b. Player adherence rate medians and means by age group.

Adherence rates	Median			
	Overall	A/B	C	
Post-intervention survey estimates	60-80%	60-80%	40-60%	
	Mean			
	Overall	A/B	C	
Post-intervention workout log data	41%	48%	31%	p>0.05

The most common post implementation reason given for lack of adherence to the exercise was Memory (47%), Sickness (35%), Pain during or after exercise discouraging completion (35%) and injury that stopped participation (18%) (Table 13a). A free text answer was also provided from one player (6%) that the exercise was highly loading given the game schedule at the time (Table 13a).

Pain during or after the exercise and a “high loading” exercise is of relevance to the feasibility of this process. Additional qualitative feedback was sought on the kind of pain that was experienced from the 7 players that had provided such feedback (Table 13b). The player who dropped out of the study at the interim 5-week meeting cited undefined groin pain which was categorized as DOMS. The qualitative feedback confirmed that most of the pain experienced (4 out of 7 players) was DOMS like pain. The rest of the relevant feedback included two cases of knee pain, one of hip flexor pain and one without pain but that they experienced the exercise to be highly loading.

Table 13a. Player responses for reasons why the exercise wasn't completed.

Reasons for not completing exercise	Reponses	% of all survey participants (n=17)
Memory	7	41%
Sickness	6	35%
Pain during or after exercise	6	35%
Injury that stopped participation	3	18%
Time	2	12%
Lack of motivation due to laziness	2	12%
Lack of motivation due to insufficient benefits of exercise	1	6%
Exercise had a high loading given game schedule	1	6%
Total	28	

Table 13b. Additional qualitative feedback given about the type of pain during or after the exercise that was experienced

Response	Groin/Inner thigh "DOMS"	Other details
Pain during or after exercise	Yes	Mainly when rep level was high
Pain during or after exercise	Yes	No additional detail
Pain during or after exercise	Yes	Bilateral when progressing from Level 1 to Level 2. Player reported low levels of adherence before progression to level 2
Pain during or after exercise	Yes	Groin pain and unilateral posterior knee pain when moving to level 2.
Pain during or after exercise	No	Unilateral knee pain on level 2, jumper's knee medical diagnosis on same side
Pain during or after exercise	No	Unilateral hip flexor pain stopped exercise for 2 weeks
Exercise had a high loading given game schedule	No	No DOMS or pain just considered the exercise was highly loading

The most common reasons for completing the exercise were Motivated by injury reduction risks (65%), Motivated to achieve strength increase goal (29%) and they Enjoyed the exercise (29%) (Table 14).

Table 14. Player responses for reasons why the exercise was completed.

Reasons for completing exercise	Responses	% of all survey participants (n=17)
Motivated by injury risk reduction	11	65%
Motivated to achieve strength goals	5	29%
Enjoyed the exercise	5	29%
Knew that application data would be reviewed	2	12%
Wanted to help the research	1	6%
Total	24	

When asked to rank the aspects of the intervention that were most motivating toward completing the exercise the “Education Package” was the biggest motivator (38 points, 37% of total), followed by the “Personal motivation to achieve the strength gain goals” (32 points, 31%), followed by “Being told that completion would be reviewed by re-measurement of strength gains” (27 points, 26%). The smallest motivator was clearly “Being told that completion would be reviewed in the application data” (5 points 5%). (Figure 13).

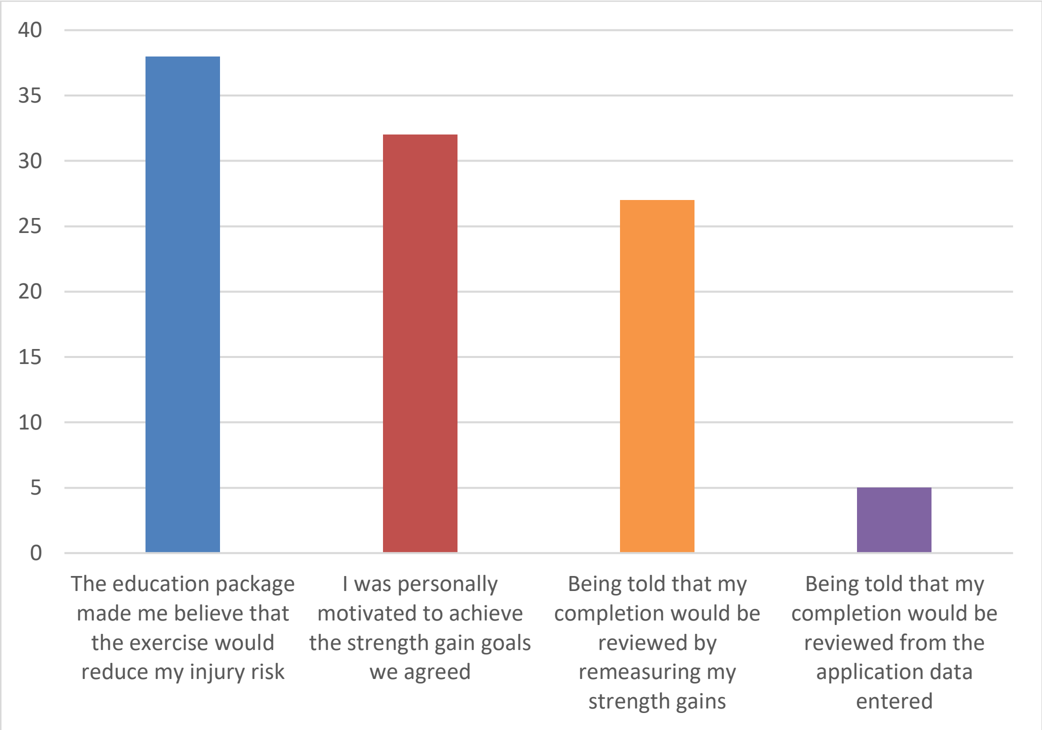

Figure 13. Cumulative points score resulting from ranking the aspects of the intervention package from most motivating to least motivating. Biggest motivator 3 points, second biggest 2 points, third biggest 1 point, smallest 0 point.

All players indicated that they thought that the exercise was feasible (possible and practical) to complete including consideration of their other commitments (Figure 14).

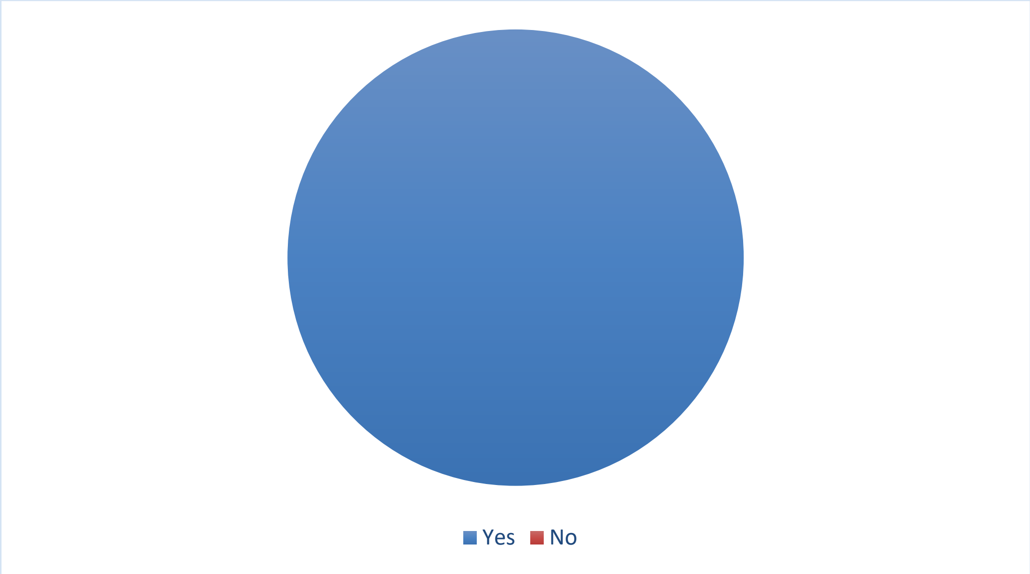

Figure 14. Player's perception of if the exercise was feasible to complete during the season.

7.3 Exercise progression

Starting levels were determined as described in the methods section and 61% started on level 1, 33% on level 2 and 6% or 1 player on level 3. There was one drop out at the interim meeting due to groin pain categorized as DOMS. After the interim meeting at 5 weeks the appropriate exercise level was recalibrated as described in the method section and ten players (56%) progressed to a higher level, seven from level 1 to level 2 and three from level 2 to level 3. This left 18% of players on level 1, 59% of players on level 2 and 24% of players on level 3 for the final 5 weeks. A player moved away and as such the interim review was completed electronically to determine if progression was appropriate. See table 15 for additional detail.

Table 15. Adjusted Copenhagen Adductor Exercise starting level and subsequent progression at 5 weeks where applicable

Level of Exercise	Participants starting level n (%)	Continued at same level after 5 weeks n (%)	Progressed after 5 weeks n (%)	Dropped out at 5 weeks n (%)
1	11 (61%)	3 (18%)	7 (64%)	1 (9%)
2	6 (33%)	10 (59%)	3 (50%)	0 (0%)
3	1 (6%)	4 (24%)	0 (0%)	0 (0%)
Total	18 (100%)	17 (94%)	10 (56%)	1 (6%)

7.4 Strength measurement results

Table 16 shows the average strength measurements and the difference between final measurements and initial measurements. All strength measurements were significantly higher after the intervention when analyzed using a one sample average test two tailed p value (p<0.05). The mean change was an increase of 0.3Nm/kg or 19%.

Table 16. Final vs. Initial average % strength change. R prefix = right, L prefix = left, Ab = abduction, Ad = adduction, Max = maximum result, Av2 = average of the highest two results. *=statistically significant (p<0.05)

	Subjects (n)	Initial mean Nm/kg	SD	Final mean Nm/kg	SD	Mean absolute change	SD	p value	Mean % change
RAd Max	16	2.20	0.52	2.61	0.60	0.41	0.30	p<0.05*	20%
RAd Av2	16	1.91	0.55	2.28	0.62	0.38	0.24	p<0.05*	21%
LAd Max	16	2.11	0.50	2.45	0.47	0.34	0.28	p<0.05*	18%
LAd Av2	16	1.83	0.54	2.13	0.49	0.30	0.23	p<0.05*	19%
RAb Max	16	1.65	0.33	1.91	0.34	0.27	0.26	p<0.05*	18%
RAb Av2	16	1.44	0.37	1.67	0.37	0.23	0.26	p<0.05*	19%
LAb Max	16	1.62	0.32	1.89	0.35	0.27	0.24	p<0.05*	19%
LAb Av2	16	1.40	0.36	1.64	0.38	0.24	0.21	p<0.05*	20%

The results of abduction and adduction were pooled by taking an average of the left and right side for each player. A one-way analysis of variance average test shows that there was no difference in the change between adduction and abduction (p>0.05) (Table 17).

Table 17. Pooled (left and right average) strength change in Adduction (Ad) vs. Abduction (Ab). Max = maximum result, Av2 = average of the highest two results. *=statistically significant (p<0.05)

Variable	Subjects (n)	Mean change	SD	% change	Variable	Mean change	SD	% change	p value
Ad Max Change	16	0.37	0.21	19%	Ab Max change	0.27	0.20	18%	p>0.05
Ad Av2 change	16	0.34	0.17	20%	Ab Av2 change	0.24	0.18	19%	p>0.05

The initial strength measurements when grouped by A/B juniors vs. C juniors show that there were some initial differences in strength based on age. The results showed an initial difference in favor of the older group A/B juniors. Right abduction was significantly higher for the older group of players when analyzed by both maximum and average of highest 2 results. Left abduction was statistically significant higher when reviewed by average of the highest 2 results but not by maximum result. Right adduction was statistically significantly higher when reviewed by average of the top two results but not by maximum result. Left adduction was statistically significantly higher when reviewed by the average of the top two results but not by maximum result. (Table 18a).

There were no statistically significant differences in % strength changes pre- vs. post-intervention in any of the measurements when the players were compared by age (A/B juniors vs. C juniors) (Table 18b).

Table 18a. Initial mean strength measurements by age grouping. A/B = A and B juniors – 17 years and over. C = C juniors 16 years or younger. *=statistically significant (p<0.05)

Age grouping	Variable	Subjects (n)	Initial mean Nm/kg	SD	Average test
A/B	RAd Max	9	2.36	0.56	p >0.05
C	RAd Max	7	1.99	0.39	
A/B	RAd Av2	9	2.19	0.55	p = 0.013*
C	RAd Av2	7	1.54	0.28	
A/B	LAd Max	9	2.32	0.47	p >0.05
C	LAd Max	7	1.84	0.42	
A/B	LAd Av2	9	2.11	0.46	p = 0.013*
C	LAd Av2	7	1.48	0.42	
A/B	RAb Max	9	1.81	0.28	p = 0.017*
C	RAb Max	7	1.44	0.27	
A/B	RAb Av2	9	1.68	0.28	p = 0.001*
C	RAb Av2	7	1.14	0.22	
A/B	LAb Max	9	1.74	0.30	p >0.05
C	LAb Max	7	1.45	0.27	
A/B	LAb Av2	9	1.62	0.29	p = 0.002*
C	LAb Av2	7	1.12	0.23	

Table 18b. Mean % change in strength initial vs. final by age grouping. *=statistically significant (p<0.05)

Age grouping	Variable	Subjects (n)	Mean change %	SD	Average test
A/B	RAd max	9	23%	15%	p>0.05
C	RAd max	7	16%	18%	
A/B	RAd A2	9	23%	15%	p>0.05
C	RAd A2	7	18%	20%	
A/B	LAd max	9	11%	12%	p>0.05
C	LAd max	7	27%	17%	
A/B	LAd A2	9	12%	12%	p>0.05
C	LAd A2	7	29%	19%	
A/B	RAb max	9	12%	16%	p>0.05
C	RAb max	7	26%	17%	
A/B	RAb A2	9	12%	19%	p>0.05
C	RAb A2	7	28%	17%	
A/B	LAb max	9	16%	15%	p>0.05
C	LAb max	7	22%	21%	
A/B	LAb A2	9	15%	13%	p>0.05
C	LAb A2	7	26%	25%	

There was a statistically significant difference in initial mean strength measurements on all aspects (bar right adduction maximum) when the players were grouped based on their final survey adherence estimate (over/under 60%). Those who reported completing less than 60% of the exercise had lower initial strength starting points than those who reported completing more than 60% of the exercise (Table 19a).

The players who reported having completed less than 60% of the exercise had a statistically significant higher increase in mean % change for all left side measurements. There was no statistically significant difference on the right side although the trend was in the same direction as the left side. (Table 19b).

Table 19a. Initial mean strength measurements grouped by post-intervention estimate of adherence. <60% self-reported adherence of less than 60%, 60.01-100% = self-reported adherence of greater than 60%. *=statistically significant (p<0.05)

Post-intervention adherence estimate grouping	Variable	Subjects (n)	Initial Mean Nm/kg	SD	Average test
<60%	RAd Max	7	1.95	0.41	p>0.05
60.01-100%	RAd Max	9	2.40	0.52	
<60%	RAd Av2	7	1.60	0.30	p=0.044*
60.01-100%	RAd Av2	9	2.14	0.59	
<60%	LAd Max	7	1.84	0.39	p=0.048*
60.01-100%	LAd Max	9	2.33	0.49	
<60%	LAd Av2	7	1.52	0.40	p=0.035*
60.01-100%	LAd Av2	9	2.08	0.52	
<60%	RAb Max	7	1.44	0.26	p=0.019*
60.01-100%	RAb Max	9	1.81	0.29	
<60%	RAb Av2	7	1.21	0.28	p=0.021*
60.01-100%	RAb Av2	9	1.62	0.34	
<60%	LAb Max	7	1.37	0.26	p=0.002*
60.01-100%	LAb Max	9	1.81	0.20	
<60%	LAb Av2	7	1.14	0.26	p=0.006*
60.01-100%	LAb Av2	9	1.60	0.29	

Table 19b. Mean % change in strength measurements initial vs. final grouped by self-reported final adherence estimate over/under 60%. *=statistically significant (p<0.05)

Post-intervention adherence estimate grouping	Variable	Subjects (n)	Mean change %	SD	Average test
<60%	RAd Max	7	26%	22%	
60.01-100%	RAd Max	9	15%	8%	p>0.05
<60%	RAd Av2	7	28%	23%	
60.01-100%	RAd Av2	9	15%	6%	p>0.05
<60%	LAd Max	7	29%	15%	
60.01-100%	LAd Max	9	10%	12%	p=0.015*
<60%	LAd Av2	7	32%	16%	
60.01-100%	LAd Av2	9	10%	10%	p=0.005*
<60%	RAb Max	7	22%	15%	
60.01-100%	RAb Max	9	15%	20%	p>0.05
<60%	RAb Av2	7	25%	17%	
60.01-100%	RAb Av2	9	14%	21%	p>0.05
<60%	LAb Max	7	29%	18%	
60.01-100%	LAb Max	9	11%	14%	p=0.043*
<60%	LAb Av2	7	32%	20%	
60.01-100%	LAb Av2	9	10%	13%	p=0.018*

8 CONCLUSIONS

Players concluded that they felt the exercise was feasible to complete during the season. The adherence level reported by the player group was reasonable for a pilot study of an independently completed injury prevention exercise when compared to other programs reviewed.

Player perceptions confirmed prior research of poor knowledge regarding the risk reduction benefits of neuromuscular strength training. Our education package and also education about benefits were consistently reported as a strong motivator/facilitator. Despite listing the education package as the strongest motivator, it failed to materially change player’s first choices of potential injury prevention activities (strength training continued to be ranked lower warm up and stretching). Players indicated strongly that they felt responsible for injury prevention activities. This study logically supports existing literature conclusions that additional education around the benefits of injury prevention activities directed at players themselves is an area that can be targeted to increase engagement and as such adherence.

The results of the strength measurements were not conclusive. Many players found the concept of gaining strength a motivator toward completion of the exercise. We cannot conclude that strength changes realized in the players were due to our intervention. Increases in strength were not correlated with reports of adherence and we hypothesize that exercise outside of our intervention impacted the results of the study. In order to ascertain if tracking strength change could provide benefits toward adherence estimation control groups would be required.

This study provides support for the use of an adjusted version of the Copenhagen Adductor Exercise within ice hockey. It further supports the use of education packages directed at players as a method of optimizing implementation of injury prevention interventions.

9 DISCUSSION

9.1 Player perspective and analysis of feasibility of the exercise

Feasibility of the exercise during the season was the main purpose of this study and the player's qualitative perspective was clear with 100% of those who completed the final questionnaire indicating it was feasible to practically and conveniently complete this in the ice hockey setting (Figure 14). Despite this unanimous qualitative opinion there was one player who dropped out of the study due to pain in the groin after doing the exercise and other players did report pain that reduced their adherence to the exercise. When more thoroughly investigated most of the pain experienced was in or around the groin complex and most of it was categorized as delayed onset muscle soreness (DOMS) (Table 13b). Two players experienced knee pain when completing straight leg versions (level 2) of the exercise where knee valgus stress is raised. It is possible that this could have been related to aspects of our adjusted Copenhagen Adductor Exercise where the knee isn't supported vs. the original where the knee is supported. Both instances of knee pain were unilateral and one of these players also had an existing medical diagnosis of quadriceps tendinopathy on the same side as the pain. As such, our conclusion is that the knee pain was related to intrinsic player factors rather than the exercise in the adjusted form being too loading for the knee.

9.2 Impact of DOMS on adherence

In the previous study by Ishøi et al. (2015, 1334-1340) players experienced DOMS during the study period and some individuals reported a high level of pain. We designed the exercise protocols to include graded exposure to the exercise with the intent of avoiding excessive DOMS. We also asked the players to inform us immediately if they experienced any pain during or after the exercise. We didn't get any contact during the intervention period from the players. It was only during the interim meeting and final meeting that the players reported pain/DOMS from the exercise. DOMS was the cause of the one drop out from our study and it has been shown in research that players can be concerned that this pain is an indicator of possible injury (Donaldson et al. 2016, 337-340) thus reducing adherence.

In comparison study protocols the exercise was supervised by physiotherapists and the level of DOMS, adherence and training load was registered. The study participants reported experiencing DOMS but there were no adverse effects reported. (Ishøi et al. 2015, 1334-1340; Harøy et al. 2017, 3055-3057). Whilst additional support is desirable, in a practical world injury prevention exercise programs cannot always be supervised by physiotherapists/physical trainers at all levels of sport. DOMS is a common necessity to strength adaptation that humans experience and despite it being a factor in adherence during our study and previous studies (Ishøi et al. 2015, 1334-1340; Harøy et al. 2017, 3055-3057; Donaldson et al. 2016, 337-340) we feel that the best solution is to adapt implementation education packages to include information about DOMS and how to identify/react to different sorts of pain.

9.3 Adherence rate estimates

During our adherence discussions with participants we tried to steer target adherence rates to over 80% of sets during the intervention period. The median adherence rate in the study was 60-80% (players retrospective survey answers) at the post-intervention meeting (Table 12a). We consider that a median adherence over 60% for an individual exercise prescription is a good initial sign that this exercise is feasible to complete independently in the youth ice hockey setting.

In study reviews concerning physiotherapy home-exercises programs, adherence rates range from 30-40% (Jack et al. 2010, 220; Peek et al. 2015, 535-540). In sport, injury prevention implementations have wide ranging adherence rates from 26%-100% (van Reijen et al. 2016, 1131-1135). In a review on adherence measurement for therapeutic exercise for musculoskeletal pain 76% of studies indicated 60-100% being a suitable range for acceptable adherence (Bailey et al. 2018, 1-5).

Adherence rates in the other studies concerning the Copenhagen Adductor Exercise completion vary. Ishøi et al. (2015, 1334-1340) reported adherence of 91.25%, although it is not immediately clear in their article if this is player adherence to sessions or sets within each session. This impressive adherence rate is likely to have been supported by training being undertaken during team training and supervised by 2 physiotherapists. Harøy et al. (2017, 3055-3057) did confirm that the number of sessions complied with was their measure of adherence. The reported adherence rate was 73% during pre-season and 70% during the season based on weekly self-report rates (Harøy et al. 2017, 3055-3057). Harøy et al. (2017, 3055-3057) set their predesignated rate of per protocol analysis at 67% adherence and Ishøi et al. (2015, 1334-1340) indicated the intention to remove anyone from the study with adherence of lower than 70%.

We believe that our median self-report rate of 60-80% compares moderately to reference literature and provides further support to the feasibility of this intervention.

The primary assessment of adherence was completed using final retrospective self-report by the players in the final survey. We also collected adherence data from the workout log phone application. In addition to hoping to use this as a measure of adherence we wanted to see the feasibility of using a phone application as an adherence measurement tool and to assess if it affected motivation.

The qualitative feedback provided by players was that the phone application was not consistently used. We assessed whether there was congruence between the player's self-report estimates and the application reports. The workout log data matched the same range self-report estimates in only 24% of cases (Table 12a) and half of these instances were in the 0-20% range. Furthermore, when reviewing the direction of incongruence between self-report and workout log data the workout log was lower 85% of the time. Support in the prevailing literature on using retrospective self-report as a measure of adherence is low due to its inherent bias (Frost et al. 2017, 1241-1252). Despite this, when considering the feedback provided from many of the participants that they did not use the application, we felt strongly that the more accurate representation adherence rates was the self-report figure. Players also didn't attribute a lot of value to the diary data consistently ranking the fact that we would review this data as a low motivator for exercise completion (Figure 13; Table 14).

There is no way of knowing the true adherence rate, nor which was more accurate and as discussed above there are many challenges facing measurement of adherence to exercise in studies and in the real world. We chose to use the self-report data as the primary measure of adherence and when completing per protocol analysis based on adherence estimates. Given that we have used two measures to assess adherence we can say with some clarity the actual adherence rate average is highly likely to have been above the estimate provided by the application data (mean 41% of sets) and it may have been as high as the self-report estimate range (median of 60-80%). Both results provide initial support for the feasibility of this exercise in this setting as adherence rates approached an acceptable level.

9.4 Exercise progression as a signal for exercise feasibility

There were 3 levels of the exercise designed to grade exposure in the early phase. When we look at the progression data 10/18 of (Table 15) participants met the progression criteria at the interim meeting including 7/10 of those who started on level 1 (leaving only 3 participants on the lowest level). This is a soft indication more than half of the players may have experienced some neuromuscular adaptation in the first

5 weeks allowing progression to a harder exercise level. This is a further indicator of the feasibility of the exercise in this setting.

9.5 Motivators to adherence

One of the main purposes of the education package was to show that we could impact player engagement in the overall process of injury prevention. In order to assess this, we gathered qualitative feedback in pre- and post-intervention questionnaires regarding barriers and facilitators toward adherence.

In the pre-intervention questionnaire, the players gave free text responses about facilitators/barriers that could affect their adherence during the intervention. From free text answers 36% of players listed time as a barrier and 28% listed motivation as a barrier/facilitator (Table 11). These two most common responses are in line with qualitative research of mainly coaching staff perspectives. The combination of time/lack of engagement and its impact on prioritizing the activity is a major barrier/facilitator to adherence. (Donaldson et al. 2018, 1-5; Soligard et al. 2010, 787-790; Finch et al. 2014, 702-705; Joy et al. 2013, 2263-2267; Saunders et al. 2010, 1128-1130). Our results regarding motivation are consistent with literature which indicates that self-motivation, self-efficacy and player motivation have been shown to be predictors of adherence towards exercise programs (Essery et al. 2016, 519-525; Soligard et al. 2010, 787-790). Another major facilitator/barrier to adherence mentioned by players was desire to train/play (e.g. be injury free) answered by 33% of individuals also in line with qualitative perspectives presented in literature (Essery et al. 2016, 519-525).

The combination of these factors directly links to our view that increasing education on the benefits of injury prevention activities could enable improved knowledge leading to increased engagement/motivation and as such reducing the "time/prioritization" barrier.

The results of the post-intervention questionnaire about why the players completed the exercise were that 65% of the players were motivated by injury risk reduction, 29% of players to achieve the strength goals and 29% that they enjoyed the exercise (Table 14). From the intervention package the players found the education package most motivating toward completing the exercise and second highest was achieving the strength goals agreed during the meetings (Figure 13). These results support earlier literature about self-motivation and self-efficacy as increasing factors toward home exercise program adherence (Essery et al. 2016, 519-525).

The biggest motivators of adherence were the education package and injury risk reduction benefits. These provide further reinforcement to existing literature that education about the benefits of injury risk reduction can increase engagement/adherence (Martinez et al. 2017, 146-147). Some researchers believe that education/knowledge regarding muscular injury prevention in ice hockey might be lacking (Popkin et al. 2016, 167-170) and education seems to be effective in increasing player motivation towards preventive exercise programs and therefore can be a useful tool when prescribing training programs for athletes. Where resource permits an individual approach toward engaging the player to the process including player education about the decreased risk of injury risk rather than just prescribing exercises could be a better approach to increase adherence rates.

In the post-intervention questionnaire, the barriers listed to exercise completion were Memory (41%), Sickness (35%), Pain during/after the exercise (35%) and Injury that stopped them doing the exercise (18%) (Table 13a). Memory is a challenging barrier to overcome without increased resource allocated to increase supervision however it is an aspect that has been highlighted in previous literature as a factor affecting adherence (Marshall et al. 2012, 18-22). As discussed above education in relation to DOMS pain could have an impact on increasing adherence. This aspect could also have been impacted by training load during the season which could be addressed by having a pre-season preparation training period as discussed below in the limitations section. Sickness and injuries which stopped them doing the exercise were outside impacts that had a negative impact on adherence results.

A change from the pre-intervention survey was that time was no longer listed as a barrier to completion (12% post-intervention vs. 36% pre-intervention). Given that players volunteered to be part of the study this could be a result of self-selection in that only those who felt they were available and able to complete the program chose to be part of the study.

9.6 Strength changes

We saw a consistent increase in abduction and adduction strength between the pre and post-intervention strength measurements (Table 16). The mean increase was 18-21% for all measurements. Relevant research placed our adduction strength gain expectations in the range of 8% (Harøy et al. 2017, 3055-3057) to 35% (Ishøi et al. 2015, 1334-1340). Our abduction strength results (mean 20%) were also in a similar range shown in the research by Ishøi et al. (2015, 1334-1340).

It was unexpected that we would see a similar strength gain for both abduction and adduction. There was no statistically significant difference between adduction and abduction strength gains (Table 17). Given that nEMG data indicates a greater activation on adductors vs. abductors for the Copenhagen Adductor Exercise (Serner et al. 2014, 1111-1112) we expected to see a larger gain in the adductor complex vs. the abductor complex. This opens the question as to whether the c. 20% strength change was solely due to this study's exercise intervention.

There were several strength measurements where there was an initial difference between age groups. Older players in the A/B age grouping were more likely to have a statistically significantly higher initial Nm/kg strength vs. younger players (Table 18a). Given that there was an initial difference we wanted to investigate whether a difference in training regimes might have impacted the overall strength results. However, there were no statistical difference in strength change between groups when analyzed by age (Table 18b). The median for self-reported adherence rates was lower for the C juniors than for the A/B juniors, 40-60% vs. 60-80% (Table 12b). The mean for the adherence application data was also lower 31% vs. 48%, however this difference was not statistically significant (Table 12b). Lower adherence rates for the younger group did not lead to lower strength change results.

When analyzing the strength changes based on the player's final survey self-reported adherence estimates we grouped participants into over and under 60%. There was an initial difference in strength when analyzed based on these groups. Those players who ended up reporting lower than 60% final survey adherence estimates had statistically significantly lower initial Nm/kg measurements vs. those whose final survey adherence estimates were over 60% (Table 19a). This is likely to have been partially driven by the prior mentioned initial strength difference by age as 57% of the low adherence group were C juniors and only 22% of the high adherence group were C juniors.

Contrary to our expectations, the mean change in left side strength was significantly higher for all measurements for the group with a self-reported adherence rate of less than 60% vs. over 60% (Table 19b). Similarly, the right-side measurements were higher for the group with lower adherence, but the difference was not significant. Similar trends were seen when completing the same analysis but grouping by application data adherence rates.

When reviewing the combination of results that were contradictory to our expectations, we cannot conclude that overall group strength changes were due to our intervention's exercise. Some members of the C juniors reported that this was the first year that they had started formal resistance training using weights as part of team training (vs. prior conditioning training using body weight as resistance). It is possible that the combination of the C juniors lower strength starting point, a change in their training regime and a lower adherence rate affected our analysis. That is to say that external factors to our intervention may have had a greater impact on the C junior's overall strength changes thus skewing the results. However, it is not possible to confirm with the data available if this was the case or if it is driven by an unknown factor. Limited benefits could be drawn from the addition of tracking strength changes to the estimation of adherence due to the lack of correlation between reported adherence and strength changes.

9.7 Player perception of activities that prevent injury.

Our research further supports available literature displaying a series of knowledge gaps in players particularly regarding strength training and its efficacy in injury prevention. Our research indicated a high rate of belief in the ability to prevent non-contact injury of 86%. This is consistent with the available literature which indicates that the proportion of players and coaches that believe all injuries are preventable is 50-60% (McKay et al. 2014a, 1281-1286; Orr et al. 2011, 273-276).

Muscle strain/tear (92% of responders to this question) and joint injuries (15%) were the most common free text responses of types of injuries that could be prevented. However, their views regarding what activities prevent these injuries were contrary to the best available evidence. Only 19% of players selected strengthening muscles as one of the top 3 ways to reduce non-contact injuries. Only 28% of players responded with poor muscle strength as a possible cause of non-contact injury. Only 3% chose injury prevention as the main purpose of off-ice strength training. These results are consistent with available qualitative literature where qualitative perspectives of players and coaches indicate that around 10-30% of respondents mentioned strengthening as a method to reduce injury risk (McKay et al. 2014a, 1281-1286; Orr et al. 2011, 275; Zech & Wellman 2017, 1-7). Consistent with the prevalent literature, warm up and stretching were the most commonly mentioned activities in our study that could reduce non-contact injury. (Martinez et al. 2017, 146-148; McKay et al. 2014a, 1281-1286; Orr et al. 2011, 275; Zech & Wellman 2017, 6-7).

It is clear from the pre-survey results that most players either do not think strengthening exercise reduces non-contact injury risk or they are not aware of these potential benefits. Furthermore, they more commonly mention other activities such as stretching, warm up, recovery and technique as effective in reducing non-contact injury risk over strengthening (5th ranked). This education gap was expected and was a focal point of our education package. Despite this aspect being a focal point of our education package, the post-intervention player perception persisted with strengthening exercise still ranked 5th of top three activities to reduce injury risk (24%). It is a clear challenge in the implementation of injury prevention neuromuscular strength programs that there is a prevailing real-world perspective that other activities either better prevent injuries or that people simply don’t know that getting stronger can help prevent injuries (Martinez et al. 2017, 146-147; McKay et al. 2014a, 1281-1286; Orr et al. 2011, 275; Zech & Wellman 2017, 6-7). It is a challenge for future research as it almost appears that in order to promote the evidence supporting neuromuscular strength training in its reduction of injury risk one might have to discredit an alternative activity e.g. stretching.

9.8 Responsibility

Our research further supported the literature that shows that players believe they share a portion of the responsibility for preventing risks of sustaining injuries (McKay et al. 2014a, 1281-1286; O’Brien & Finch 2016, 1-6). In our research 100% of players indicated they themselves were one of the responsible parties for this act. We believe that this is a clear signal that if players believe they are responsible for carrying out the activities then they should also be open to being educated regarding the reasons behind the injury prevention activities. Without understanding of the purpose of injury prevention exercises we believe player engagement (a common barrier) has the potential to be low and this has the potential to reduce likelihood of coach and player adherence to injury prevention programs. Furthermore, the results in this study showed quite a low rate of players stating that coaches are responsible (52% vs. 75%+ in the literature) (McKay et al. 2014a, 1281-1284). We believe this aspect of responsibility further indicates that injury prevention exercise can be completed outside of the team setting (e.g. individual prescription of injury prevention exercises before/after training or at home). Our study gives initial indications that at least in a certain portion of athletes this should be feasible. It also contributes to overcoming the barrier of lack of time during training to complete these programs, commonly mentioned in the literature (Donaldson et al. 2016, 337-340; Finch et al. 2014, 702-705; Joy et al. 2013, 2263-2267; Saunders et al. 2010, 1128-1130).

9.9 Limitations and further research

There are several limitations to our study. The lack of a prospectively randomized control group makes this a single arm study from which clear conclusions of the impact of the intervention difficult to make. Furthermore, the study is particularly small at only 17 participants and as such lacks statistical power to draw strong conclusions.

In relation to our adherence data there is a risk of bias when utilizing retrospective recall/self-report (Frost et al. 2017, 1241-1252) as we have done, and it is considered possible that the self-report adherence figures may have been overstated vs. reality. We tried to circumvent this bias by having real time recording of every set using a simple to use phone application. However, engagement in this aspect of the study was poor and as such based on the feedback from the players we believe this data understates reality. The use of these two methods gives us two end points between which we believe the reality lies.

The study measurer practiced using the dynamometers several times before completing the measurements and we used the same person for all measurements. However, it is fair to say that our measurer was not an experienced user of dynamometers. We did not observe in the data nor during the measurements that any technical errors/body positions may have impacted the results. All measurements were also supervised/watched by the other study administrator. Regardless it is possible that measurement errors may have occurred due to a lack of experience.

It is commonplace within injury prevention studies to begin high loading injury prevention programs in the off-season. This allows a lead in time without concurrent game schedules increasing the risk of adverse effects of the exercise (e.g. DOMS affecting game performance or drop out from study). We did not manage to implement our study with an off-season exercise period due to time constraints during the period leading up to the start of the study.

Furthermore, there were some clear initial differences in participants based on the age groups of the players. The younger group had a lower initial strength when adjusted for weight and also there were no players in the younger group who had the original intended injury/pain inclusion criteria. The older participants had higher initial strength when adjusted for weight and almost all the players had the initial injury/pain inclusion criteria. Initial heterogeneity in the study participants may have impacted strength and adherence results. Lack of prior pain/injury in the younger group may have impacted their belief of susceptibility to injury. This factor is prevalent in theoretical models of health behavior change (Glanz et al. 2008, 45-51) and there is some evidence that lower belief of susceptibility could reduce engagement and adherence (Essery et al. 2016, 519-525).

This was a small study aimed at testing the feasibility of an adjusted version of an exercise. This exercise has been moderately studied in football but not in ice hockey to our knowledge. It is our view that the research support for the use of this exercise in football to reduce groin pain/injury could be beneficial to ice hockey. A future randomized control study of the Copenhagen Adductor Exercise or our adjusted version in ice hockey that followed injury risk reduction through this intervention would be a useful piece of research.

Furthermore, we believe that we have shown an example of how engagement can be increased by including education of players in the implementation of injury prevention programs. Further study on the impact of directing implementation aspects directly at players, utilizing the fact that they believe they are also responsible for this activity, would be beneficial to addressing adherence issues seen in the real world.

Finally, our study replicates previous qualitative studies showing the conflict between evidence supporting neuromuscular strength training as an effective injury prevention intervention and player belief of stretching/warm up as the most effective interventions. Further study investigating an appropriate way to combat this knowledge gap is required to increase real world knowledge on the wide-ranging benefits of neuromuscular strength training.

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APPENDICES

Appendix 1. Questionnaire assessing injury prevention knowledge, adherence/intended adherence and attitudes towards injury prevention programs.

Youth Ice Hockey Player Perception Survey

This survey will study your initial perception to why Ice hockey players train. You have been provided with limited information initially as we would like to gain your current perception before telling you about the purpose of a larger study.

PLEASE ENTER FirstnameSecondname@fakemail.com in the email section as your identifier.

*Pakollinen

1. **Sähköpostiosoite** *

2. **1. What do you perceive as the main purposes of your current off ice conditioning training?** *

Merkitse vain yksi soikio.

- Increased Speed
- Reduction in injury risk
- Increased Strength
- Increased Agility / Mobility
- Increased Stamina
- Muu: ______

Contact or non-contact injuries

A Non-Contact injury is defined as an injury where contact with another player or a side barrier is not deemed to be the cause of the injury

3. **2. Since the start of the prior season (2017-2018) have you experienced a lower extremity injury from playing Ice Hockey that resulted in you not being able to participate in playing Ice Hockey for at least one week? Please select a combination of the location of the injury in the body and whether it was caused during a contact or non-contact situation? If you have not experienced an injury please continue to the next question.**

Valitse kaikki sopivat vaihtoehdot.

	Contact	Non-contact
Hip Joint		
Calf / Shin		
Quadriceps		
Inner thigh / groin		
Ankle or below		
Hamstrings		
Knee Joint		

1. **Of these injuries what was the longest period you were unable to participate in Ice Hockey?**
   Merkitse vain yksi soikio.

   - 1 to 2 weeks
   - 2 weeks to 1 month
   - 1 to 3 months
   - 3 to 6 months
   - 6 months or more

Siirry kysymykseen 4.

NON-CONTACT injury - player perception

A Non-Contact injury is defined as an injury where contact with another player or a side barrier is not deemed to be the cause of the injury

2. **3. In your opinion, what is the most common body area injured in NON-CONTACT Ice Hockey injuries** *
   Merkitse vain yksi soikio.

   - Shoulder joints
   - Elbow joint
   - Knee joint
   - Inner thigh muscle/groin
   - Arm muscles
   - Calf muscle
   - Quadriceps muscles
   - Wrist joint
   - Hamstring muscle
   - Abdominal muscles
   - Back muscles
   - In the ankle or below the ankle
   - Neck joints
   - Hip joint

3. **4. What are some of the factors that you think may contribute to an Ice Hockey player's risk of sustaining a NON-CONTACT injury? Select up to the 3 most important answers?** *
   Valitse kaikki sopivat vaihtoehdot.

   - [ ] Inadequate warm up
   - [ ] Lack of stretching/flexibility
   - [ ] Poor muscle strength
   - [ ] Lack of fitness or training
   - [ ] Player's genetic background
   - [ ] Lack of skill/technique
   - [ ] Poor equipment/Ice
   - [ ] Muu: ______________________

1. **5. Do you believe some NON-CONTACT Ice Hockey injuries are preventable?** *
Merkitse vain yksi soikio.

- ( ) No *Siirry kysymykseen 7.*
- ( ) Yes *Siirry kysymykseen 8.*
- ( ) Don't know *Siirry kysymykseen 9.*

5. Do you believe some NON-CONTACT Ice Hockey injuries are preventable?

8. **No...Please explain your answer** *

Siirry kysymykseen 10.

5. Do you believe some NON-CONTACT Ice Hockey injuries are preventable?

9. **Yes......what are the injuries that can be prevented and what are the actions that can help prevent each NON-CONTACT injury** *

Siirry kysymykseen 10.

5. Do you believe some NON-CONTACT Ice Hockey injuries are preventable?

10. **Don't know...please add an explanation if you have one**

10. 6. Who do you think are the people responsible for preventing Ice Hockey players' risks of sustaining a non-contact injury. Select up to 3 answers *

Valitse kaikki sopivat vaihtoehdot.

- [ ] Players themselves
- [ ] Physiotherapists
- [ ] Other medical professionals
- [ ] Doctors
- [ ] Coaching staff
- [ ] Administration of sport (national association)
- [ ] Parents
- [ ] Muu: ____________________

11. 7. What are some of the things you could do as a player to reduce the risk of sustaining a non-contact injury? Tick up to the most important 3 answers. *

Valitse kaikki sopivat vaihtoehdot.

- [ ] Complete a proper warm up
- [ ] Ensure I have good stamina
- [ ] Stretch muscles
- [ ] Strengthen muscles
- [ ] Ensure adequate recovery/rest
- [ ] Focus on technique
- [ ] Eat Healthy
- [ ] Muu: ____________________

Players' attitudes and Beliefs

12. 8. I expect that I will sustain a non-contact muscular injury at some point in the next 12 months that will result in me missing a training session or match? *

Pick a number along the scale that best matches your opinion

Merkitse vain yksi soikio.

	1	2	3	4	5	6	7	
Extremely unlikely	◯	◯	◯	◯	◯	◯	◯	Extremely likely

13. 9. Completing one additional strength and conditioning exercise designed to reduce my injury risk would be... *

Pick a number along the scale that best matches your opinion

Merkitse vain yksi soikio.

	1	2	3	4	5	6	7	
Extremely Bad	◯	◯	◯	◯	◯	◯	◯	Extremely Good

10. **10. If given one specific injury preventing strength exercise, 4 sets per week over a 10 week training period (40 sets in total) to complete independently either at home or during off ice training, on average what percentage of these 40 sets do you think you would complete? ***

Merkitse vain yksi soikio.

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

11. **11. If given one specific injury preventing strength exercise, 4 sets per week over a 10 week training period (40 sets in total) to complete independently either at home or during off ice training, what are the main barriers / facilitators to you adhering with the prescribed exercise package? ***

Youth Ice Hockey Player Perception Survey

PLEASE ENTER FirstnameSecondname@fakemail.com in the email section as your identifier. DONT WRITE YOUR OWN EMAIL.

*Pakollinen

1. **Sähköpostiosoite** *

2. **What are some of the things you could do as a player to reduce the risk of sustaining a non-contact injury? Tick up to the most important 3 answers.** *
Valitse kaikki sopivat vaihtoehdot.

- ☐ Complete a proper warm up
- ☐ Ensure I have good stamina
- ☐ Stretch muscles regularly
- ☐ Strengthen muscles
- ☐ Ensure adequate recovery/rest
- ☐ Focus on correct technique during training
- ☐ Eat Healthy
- ☐ Muu: ____________________

Adherence

3. **Do you think it was feasible (possible and practical to do conveniently) to complete this exercise as recommended during the season given all your other current commitments?**
Merkitse vain yksi soikio.

- ○ Yes
- ○ No

4. **What proportion of the prescribed sets of the Adjusted Copenhagen Adduction Exercise do you think you completed?** *
Merkitse vain yksi soikio.

- ○ 0-20%
- ○ 20-40%
- ○ 40-60%
- ○ 60-80%
- ○ 80-100%

1. **What proportion of the prescribed sets of the Adjusted Copenhagen Adduction Exercise do you think your exercise log will show you completed?** *
Merkitse vain yksi soikio.

- ( ) 0-20%
- ( ) 20-40%
- ( ) 40-60%
- ( ) 60-80%
- ( ) 80-100%

Did you get to 100%?

2. **When you didn't complete the exercise as recommended what were the main reasons for this?**
Select the main reasons that apply. If there were no reasons move onto the next question.
Valitse kaikki sopivat vaihtoehdot.

- [ ] Exercise was too difficult/complicated
- [ ] I wasn't motivated to do the exercise due to laziness
- [ ] Memory - I forgot to do it
- [ ] I got an injury which stopped me doing it
- [ ] Sickness
- [ ] I wasn't motivated enough by the benefits of the exercise to prioritize it
- [ ] Time - I needed to prioritize other activities over this exercise
- [ ] I experienced pain during or after doing the exercise that discouraged me from continuing
- [ ] Muu: ____________________

3. **When you did complete the exercise as recommended what were the main reasons for this?**
Select the main reasons that apply. If there were no reasons move onto the next question.
Valitse kaikki sopivat vaihtoehdot.

- [ ] I was motivated by reducing the risks of injury in the future
- [ ] I was motivated to achieve the strength gain goals discussed
- [ ] I knew that my completion of the exercise would be checked (application data and strength gains)
- [ ] I like working out and I enjoyed doing the exercise
- [ ] Muu: ____________________

Intervention motivating factors

1. **Please order the below factors in order of biggest to least motivation for you completing the exercise?** *

Please order these by selecting one option from each row and column

Merkitse vain yksi soikio riviä kohden.

	Biggest motivator	Second Biggest	Third Biggest	Smallest
The education package made me believe that the exercise would reduce my injury risk	⬭	⬭	⬭	⬭
Being told that my completion would be reviewed by remeasuring my strength gains	⬭	⬭	⬭	⬭
Being told that my completion would be reviewed from the application data entered	⬭	⬭	⬭	⬭
I was personally motivated to achieve the strength gain goals we agreed	⬭	⬭	⬭	⬭

2. **8. Is there any other feedback you'd like to give about any aspect of the process or the exercise specifically?**

Google Forms

Appendix 2. Education package regarding injury prevention and adductor injuries in Ice hockey players, English version.

PowerPoint slideshow including 3 slides:

Slide 1.

Groin injuries among ice hockey players:

-Groin injuries are approximately 10% from all injuries in ice hockey

-90% from all groin injuries in ice hockey occurs outside of contact situations, which indicates the impact of players intrinsic factors in origin of the groin injuries

Slide 2.

Injury mechanism, risk factors & prevention:

-Hip adductor weakness in comparison to hip abductor muscle strength has been proposed to be the injury mechanism.

-During the skating stride, the hip adductor muscle can't resist the strength made by abductor muscles in the kicking motion and therefore there is damage occurring in the adductor muscle

-Statistically ice hockey team of 20 players will face 3 or more adductor strains after 50 games played.

→ By implementing exercise programs, the prevalence of adductor strains has been decreased that only 1 player out of 20 player team would face the adductor strain after 50 games.

Slide 3

Preventive strength training:

-Many researches have shown eccentric strength training and neuromuscular training having strong evidence in injury prevention.

-Copenhagen adduction is high intensity exercise to increase eccentric strength in adductor muscles and therefore to prevent injuries. It strengthens the muscle in the same range of motion where the injury mechanism would occur.

-In football the groin problem rates have been managed to decrease even 41% by only using this one exercise with different difficulty levels

-By doing this exercise there have been managed to get 10-35% strength increase by doing 8- to 10-week exercise programs.

Appendix 3. Links for the exercise instruction videos

Links for the exercise instruction videos on Youtube provided to the players embedded in the workout log application

Level 1. Adjusted Copenhagen adduction exercise

https://www.youtube.com/watch?v=We_FLqOlqxI&t=2s

Level 2. Adjusted Copenhagen adduction exercise

https://www.youtube.com/watch?v=4IRMwyIVwWU

Level 3. Adjusted Copenhagen adduction exercise

https://www.youtube.com/watch?v=nqNhlyOOjYE

Appendix 4 Example Instruction sheets given for the players at initial meeting Finnish/English

1. Level 1 Adjusted Copenhagen Adductor Exercise

Start and end position

Middle position

Place you knee on a pillow on a chair, bed or surface that is approximately 50cm high. Raise your hips so that your body is in the starting position. Lower your bottom leg and hips down to the ground using a count to 3. Raise your lower leg and hips back to the starting position. Keep your knee, hip and shoulder in a straight line up the body trying not to bend at the hips or twist the chest.

Try and do the exercises on Monday and Wednesday each week. Remember to track what you do in the application. If you have any questions, pain or safety concerns, please message us on below numbers.

Week	Weekly sessions	Sets per side	Repetitions per side
1 & 2	2	2	4-6
3, 4 & 5	2	2	6-8
Group meeting at Ässät			

2. Level 2 Adjusted Copenhagen Adductor Exercise

Aloitus/loppu asento

Liikkeen puolivälin asento

Aseta kyynärpääsi suoraan linjaan olkapään alle tukikädessä. Aseta jalkateräsi/nilkkasi tyynylle, joka on tuolilla, sängyllä tai jollain muulla tasolla, joka on noin 50cm korkeudella. Nosta lantiotasi siten, että vartalosi on suorassa linjassa, kuten aloitusasennossa. Laske alempaa jalkaa ja lantiotasi alas kohti maata laskien samalla 3. Nosta alempi jalka ja lantio takaisin ylös aloitusasentoon. Pidä jalkaterä, polvi, lonkka ja olkapää samassa linjassa muodostaen suoran linjan vartalolla. Vältä lonkan koukistamista ja vartalon kiertymistä liikkeen aikana. Pidä 1min tauko sarjojen välissä.

Ajoita harjoitteen teko viikonalkuun, ja tee sitä joka maanantai ja keskiviikko tai vaihtoehtoisesti tiistaisin ja torstaisin. Vältä tekemästä harjoitetta peräkkäisinä päivinä tai päivää ennen peliä.

Jos on mitään kysyttävää, kipuja harjoituksen aikana tai harjoituksen turvallisuuteen liittyviä kysymyksiä, lähetä meille viestiä alla oleviin numeroihin.

Viikko	Viikottaiset harjoituskerrat	Sarjat per puoli	Toistot per Puoli
1 & 2	2	2	4-6
3, 4 & 5	2	2	6-8
Ryhmätapaamiset Ässien tiloissa			

3. Level 3 Adjusted Copenhagen Adductor Exercise

Start and end position

Middle position

Place your elbow under your shoulder. Place your foot/ankle on a pillow on a table, bed or surface that is approximately 75cm high. Raise your hips so that your body is in the starting position. Lower your bottom leg and hips down to the ground using a count to 3. Raise your lower leg and hips back to the starting position. Keep your foot knee, hip and shoulder in a straight line up the body trying not to bend at the hips or twist the chest.

Try and do the exercises on Monday and Wednesday each week. Remember to track what you do in the application. If you have any questions, pain or safety concerns, please message us on below numbers.

Week	Weekly sessions	Sets per side	Repetitions per side
1 & 2	2	2	4-6
3, 4 & 5	2	2	6-8
Group meeting at Ässät			

Appendix 5. Examples of adherence rates

As mentioned above there is considerable heterogeneity in consistency of reporting and methods of measurement of adherence to injury prevention interventions. Given the focus of this thesis is adherence to neuromuscular training interventions we have reviewed the relevant literature to extract adherence rates to specific programs as summarized in table 20.

Table 20. Adherence rates and methods of collection of neuromuscular training injury prevention RCTs

Author/s	Type of intervention	What sport / body part	Setting	Adherence rates	Adherence measurement
Bredeweg, Zijlstra, Bessem & Buist, 2012	Pre-conditioning for running – walking and hopping	Running related injuries	Individual home setting	72% defined as adherent (10 or more out of 12 sessions)	Self-report
Buist et al. 2008	Graded running program	Running, lower extremity or back	Individual unsupervised	65-70% adherence	Internet based, included in running log
Coppack, Etherington & Wills 2011	Neuromuscular strength/balance, flexibility	Army, overuse anterior knee pain	Physical trainer conducted all platoon trainings	>90% adherence	Adherence recorded using attendance records during sessions

Cumps et al. 2008	Neuromuscular strength, propriocep-tion and plyometric	Volleyball, ante-rior knee pain	Team training	78% didn't drop out, no report of number of sessions com-pleted	Self-report, unspecified if coach or athlete
Engebret-sen, Mykle-bust, Holme, Engebretsen & Bahr 2008	Neuromuscular strength and balance	Football, lower limb injuries	Unsupervised, individual spe-cific training	20-30% of players completed more than 83% of prescribed sessions. 45-50% completed less than 2/3rds of sessions.	Player reported
Gabbe, Branson & Bennell 2006	Neuromuscular training (Nordic hamstring exercise)	Amateur Austral-ian rules football, hamstring,	Study personnel visited and ran the session	5 sessions – 60% session 1 (S1), 35% S2, 30% S3, 10% S4, <5% S5. 30% failed to complete 1 session, 46.8% com-pleted at least 2 of the 5 sessions.	Adherence recorded by study personnel when they ran the session.

Gilchrist et al. 2008	Neuromuscular strength, flexibility, plyometrics and running	Football, ACL injury prevention	Team training	Average of 72% of team training sessions completed	Weekly adherence reported as part of larger participation form.
Hägglund, Waldén, Ekstrand 2007	Player education on return to play period after injury, progressive running exercises	Football, whole body	Individual adherence with recommendations as directed by coaching staff	68% compliant with length of return to play period recommendations. No data reported for completion of progressive running exercises.	Reported on forms submitted by athletes
Hägglund et al. 2013a	Neuromuscular training	Football, lower limb/core	Team training	79% team adherence	Team reported
Hupperets, Verhagen, van Mechelen 2009	Neuromuscular proprioceptive training	Football, ankle	Individual home training	23% fully compliant, 29% partially compliant, 35% non-compliant, 13% unknown	Athlete retrospective self-report of adherence

Jamtvedt et al. 2010	Stretching	Not sport specific, injury/bothersome soreness	Individual	38% frequency adherence (completed stretching on most or all occasions after exercise), 8% time compliant (>10 minutes per week).	Website self-report retrospectively at one point in time
Janssen, van Mechelen & Verhagen 2014	Bracing/neuromuscular training	General athletes, ankle sprains	Home based	45% fully compliant with neuromuscular training, 48% with bracing. Where full adherence was >75% of prescribed use	Monthly questionnaire self-report
Kiani, Hellquist, Ahlqvist, Gedeborg & Byberg 2010	Neuromuscular activation, balance, strength, core stability	Football, knee injury prevention	Team training	>75%, only 3 of 48 teams reported less than 75% adherence	Coaches provided an estimation within 4 ranges <50%, 50-75%, 75-100%, 100%

Longo et al. 2012	Neuromuscular training	Basketball, lower limb/core	Team training	100% team adherence but adherence was not defined	Unspecified
McGuine & Keene 2006	Progressive balance exercises	Football and basketball, ankle	Team training before or after	339/373 >90% deemed compliant based on not missing more than 4 sessions in a row. However actual adherence with recommendations of 3-5 times per week not reported.	Athletic trainer record – frequency of data collection not specified
Myklebust et al. 2003	Neuromuscular, proprioception	Handball, ACL injury prevention	Team training	Adherence with target was 26% and 29% across 2 seasons for teams. Target was 3 times per week over 5-7	Weekly reports from physical therapists.

				weeks. Adherence required 75% player participation in 15 sessions over the 5-7 weeks.	
Olsen, Myklebust, Engebretsen, Holme & Bahr 2005	Strength, balance, warm up	Handball, ankle/ knee injury	Team training	87% of teams continued some use of the program but volume of use vs. recommendation (every training session) was not quantified	Coaches recorded adherence in combination with larger data collection process
Parkkari et al. 2011	Neuromuscular strength, agility	Army, acute MSK injury	Army training, including individual component	100% adherence with platoon training, 83% met individual component of once per week	Platoon recording followed by retrospective self-report
Pasanen et al. 2008.	Generalized neuromuscular training	Floorball, lower limbs	Team training	74% of sessions were completed,	Coach completed diary

				69% of players attended sessions	
Sherry & Best 2004	Strength, flexibility, trunk stabilization, agility	Not sport specific, hamstring	Individual home exercise program	Greater than 70% adherence was required for inclusion in statistical analysis. 83% of participants reported >70% of prescribed session	Athlete self-report
Soligard et al. 2010	Neuromuscular training, FIFA 11+	Football, lower limb	Team training	On average 77% of sessions included the program. On average 60% of rostered players attended each session.	Coach reported participation of individual players
Steffen, Myklebust, Olsen,	Neuromuscular strength	Football, lower limb	Team training	During the first 4-months program used in 60% of training sessions. Only	Self-report

Holme & Bahr 2008				24% of teams met target of 20 sessions in first four months.	
Steffen, Bakka, Myklebust & Bahr 2008	Neuromuscular training	Football, lower limb/core	Team training	52% adherence > 20 sessions, 48% <20 sessions	Team reported
Steffen et al. 2013	Neuromuscular training	Football, lower limb/core	Team training	Team adherence 73-86%. Exercises per sessions 54-76%. Player attendance 65-76%.	Team reported with random verification visits.
van Beijsterveldt et al. 2012	Neuromuscular training, FIFA 11+	Football, lower limb	Team training	73% of team sessions included the program. 71% of players completed the training when	Coach reported

				they attended training.	
van Mechelen, Hlobil, Kemper, Voorn & de Jongh 1993	Warm up Cool down Stretching	Running, general injuries	Individual incorporation into running ritual	68% warm up 64.7% cool down 46.6% stretching	Athlete self-report as part of daily running log
Waldén, Atroshi, Magnusson, Wagner & Hägglund 2012	Neuromuscular training	Football, lower limb/core	Team training	52.5% adherence as defined as >1 session per week	Team reported