NORWEGIAN SCHOOL
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The "Norwegian arm" of the Study on Hamstring Re-injury Prevention (SHARP)

A multi-center randomized controlled trial and descriptive cross-sectional study

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Abstract

Introduction: Hamstring injury (HI) is the most common injury in football and has the highest re-injury incidence. The nordic hamstring exercise (NHE) has shown to reduce the incidence of HIs in football players. The research on prevention of hamstring re-injuries is very limited. This master thesis was a contribution to the SHARP study, investigating the effect of the NHE in preventing hamstring re-injury in football players. Football players are known for having low adherence to the NHE. For injury prevention programs to work, it is important to understand the attitudes and beliefs of Norwegian pysiotherapists (PTs) on the NHE an protocol.

Method: This master thesis was part of an international multi-centre randomized controlled trial, the SHARP study. Players were allocated to either an intervention group (IG, NHE protocol) or a control group (CG, continued routine training). The primary outcome was the number of early hamstring re-injuries. Secondary outcomes were NHE adherence and training/match exposure. A descriptive cross-sectional pilot study was also conducted within the "Norwegian arm" study where a questionnaire was sent to Norwegian PTs to gain insight in their attitudes and beliefs on the NHE.

Results: Zero players were recruited from the "Norwegian arm" to the main SHARP study. Tweenty-seven players were recruited to the main SHARP from collaborationg institutes, eight were included to the "Norwegian arm". Zero hamstring re-injuries were found in IG and CG. The adherence to the NHE protocol (IG) was low (45%). Twenty-six PTs responded to the questionnaire. Results indicate that Norwegian PTs recognize the importance of hamstring prevention, with the NHE being well adopted and valued. One third of the PTs reported "sessions per week" and "reps per set/training" being "too high" in the prescribed NHE protocol used in the main SHARP study.

Conclusion: An insufficient sample size, including players of both genders at different ages and competitive levels was recruited, therefore no conculsion could be made on the short- and long-term effect of the NHE in preventing hamstring re-injuries. Future research should focus on optimizing the player recruitment process and to further investigate the attitude and beliefs of players and coaches to better understand potential barriers to the low study participation and adherence to the NHE.

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Foreword

After two exciting, challenging and rewarding years as a master's degree student at the Norwegian School of Sports Sciences, this is my thesis. During my study period I have had the pleasure of getting to know knowledgeable, inspiring and humble people – both lecturers and fellow students. They have all contributed to making these two great years.

Firstly, I would like to thank my supervisor Thor Einar Andersen. I am sincerely grateful for your contribution throughout the whole masters project. I highly value our conversations, discussions and your feedback which all has been a great learning experience. I admire and am inspired by your expertise and enthusiasm for sports medicine and appreciate the trust and opportunity you have given me by including me in the SHARP study.

Secondly, I would like to thank PhD candidate Muhammad Ikhwan Zein and supervisor Johannes Tol who are the main researchers accountable for the SHARP study. I appreciate our collaboration and the opportunity of being part of such an exiting and important study.

Thirdly, I would like to thank the contributors to this master project who are too many to mention by name. This includes colleagues at the FA Medical Centre (Idrettens helsesenter), the physiotherapists helping with player recruitment and all the physiotherapists who invested their time to responded to the questionnaire. You have all played an important part in this project.

Anders Knapstad

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1. Introduction

This master thesis is a part of an ongoing PhD project, hereby referred to as the SHARP (Study on Hamstring Re-injury Prevention) study (Zein et al., 2022). The SHARP study is a multi-centre, prospective, parallel group randomized controlled trial (RCT), conducted by PhD candidate Muhammad Ikhwan Zein, and supervised by Professor Johannes Tol at Amsterdam UMC, Department of Orthopaedic Surgery and Sports Medicine, Amsterdam and the Universitas Negeri Yogyakarta, Faculty of Sports Science, Yogyakarta. The purpose of this study is to investigate the effectiveness of the Nordic Hamstring Exercise (NHE) for preventing hamstring re-injury after return to play (RTP) following recent hamstring injury (HI). The invited participants of this study are football players of both genders, age group 18-40yrs, including recreational and professional level of football. Participants with a HI are randomly allocated to either intervention group (IG) or control group (CG) within one week after having fully recovered from their recent HI and cleared for RTP by the treating physician or physiotherapist (PT). The IG receive a NHE training protocol lasting for 52 weeks. Both the IG and the CG are expected to report weekly to the questionnaires for the first 10 weeks and then once during the 6th, 9th and 12th month. The questionnaires register baseline characteristics, injury history, self-reported perceived readiness, new HI report, non-HI report and training/match exposure for both groups. In addition, the IG reports adherence to the NHE program. The NHE protocol is chosen as intervention because of its well documented effectiveness preventing index hamstring injuries (Al Attar et al., 2017; van der Horst et al., 2015; van Dyk et al., 2019)

Injuries are a substantial problem in professional football clubs, compromising both the players' health and team performance (Hagglund et al., 2013; Lopez-Valenciano et al., 2020). Epidemiological studies show high incidences of injuries in football for both male and female players, with a general higher injury risk for male players and almost 10 times higher during match-play compared to training (Lopez-Valenciano et al., 2021; Lopez-Valenciano et al., 2020). The most common injuries reported in professional football are muscle/tendon injuries with the hamstring muscles being the most frequent muscles injured in both male and female football (Ekstrand et al., 2011a, 2011b; Horan et al., 2022; Lopez-Valenciano et al., 2020).

HI is defined as an acute physical complaint at the posterior thigh (Fuller et al., 2006). An acute HI can occur in two different ways, either during a high-speed sprint action or second, during stretching in the outer range of motion (Askling et al., 2013; Danielsson et al., 2020). Most commonly a HI occurs during the late swing phase of sprinting, jumping or kicking (Gabbe et al., 2005). HIs represents 37% of all muscle injuries to the lower limb in professional football with the most common risk factors of sustaining HI being previous HI and older age (Ekstrand et al., 2011a; Engebretsen et al., 2010; Green et al., 2020). HIs have the highest proportion of re-injury rate (12-63%) among all injuries in football, commonly occurring within 2 months after RTP (69%) (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022; Lopez-Valenciano et al., 2020; Wangensteen et al., 2016). This makes the RTP phase an important time period for both the player and treating clinician when there should be a great emphasis on avoiding hamstring re-injuries as these takes longer to recover from (Ekstrand et al., 2020).

In football, injury prevention programs and strategies including the NHE have proven effective in decreasing the incidence of acute HIs by 51% (Al Attar et al., 2017; van Dyk et al., 2019) despite a general low adherence efound towards the NHE among football players (Bahr et al., 2015; van der Horst et al., 2021). However, to our knowledge there are no studies that has tested if the NHE can reduce the short- and long-term incidence of hamstring re-injuries in football. Therefore, the primary aim of the SHARP study, including the "Norwegian arm" is to find out whether the NHE program can prevent early hamstrings re-injuries in football players. Secondary, we wish to investigate the attitudes and beliefs of Norwegian physiotherapists towards the NHE and protocol.

1.1 Research question

1. Is performing a NHE protocol following return to play from recent HI effective in reducing the incidence of short-term hamstring re-injuries in football players of both genders, 18-40 yrs and at any level of sport?

2. *What are the attitudes and beliefs of Norwegian PTs towards the NHE and the NHE protocol used in the main SHARP study and "Norwegian arm"?*

2. Theory

Football is the most popular sport in the world. Numbers from FIFA´s "Big Count" (2007), reports 265 million football players across the world (FIFA, 2007). The Football Association of Norway (NFF) reported 351 384 registered football players in Norway in 2021 (15.4% of the total Norwegian population) where 108 962 of these were women (NFF, 2022). FIFA (2006) and NFF (2022) report an increase in the number of registered football players over the past years, with an exception during 2020 & 2021 seasons due to the covid pandemic resulting in a reduction of 15 000 players in Norway (NFF, 2022).

Physical activity (PA) and exercise have multiple benefits on health-related outcomes, in addition of reducing mortality rates and preventing chronic diseases (WHO, 2002). In children, PA show beneficial results on the cardiorespiratory system, muscular fitness, bone health and cardiometabolic health (Chaput et al., 2020). PA also reduces the risk of depression and improves cognitive and academic outcomes (Chaput et al., 2020). The same results are also found in adults (van der Ploeg & Bull, 2020). The World Health Organization (WHO) recommend adults to complete 150-300 minutes of weekly moderate intensity or 75-150 min vigorous intensity of PA (WHO, 2002), while adolescents are advised to complete 60 minutes of moderate to vigorous activity on daily basis (Chaput et al., 2020). A Lancet publication suggests that sport participation may reduce as much as 20-40% in all-cause mortality rates compared with no sport participation in addition to the other health benefits (Khan et al., 2012). It is therefore thought that "exercise is medicine" where football seem to have several health benefits (Krustrup & Krustrup, 2018; Sallis, 2009). Football is a social, popular, fun, and versatile sport activity which is cheap and including for participants of any age, skill level and socioeconomical status. Football as medicine has physical (cardiovascular, metabolic, and musculoskeletal), psychological, social and cognitive benefits and can be recommended as an activity to reach WHO´s recommendation of PA (Chaput et al., 2020; Krustrup et al., 2010; Krustrup & Krustrup, 2018; Sallis, 2009)

2.1 Injuries in football

Despite health benefits, injuries are a common problem in multiple sports, with football not being an exception (Lopez-Valenciano et al., 2020). The overall injury incidence in male football independent of age and level of sport is 8.1 injuries (1000/hour) with an injury risk almost 10 times higher during match participation (36.0) compared to training (3.7) (Lopez-Valenciano et al., 2021). An epidemiology study of youth players (<19years) found an overall injury rate of 5.7 (1000/h), being higher for match participation (14.43) compared to training (2.77) (Robles-Palazon et al., 2021).

A systematic reviews (SR) showed an overall injury incidence of 5.7, 3.5 for training and 19.5 (1000/hour) for match participation in female football players (Mayhew et al., 2021). Female recreational players had a significantly higher overall injury incidence (47.84) compared to elite (Horan et al., 2023). A recent study on Norwegian female Premier League football players (Toppserien), found that 32% of all players reported having a health problem at any time, where 22% had a health problem which negatively affected their performance (Thorarinsdottir et al., 2023). They also found acute injuries to cause the biggest burden (68%), followed by overuse injuries (25%) and illness (8%) (Thorarinsdottir et al., 2023).

Acute injuries are the most common in adult male football (5.9) compared to overuse injuries (2.4) (Lopez-Valenciano et al., 2020). Acute injuries were the most common type of injury in youth football players (Robles-Palazon et al., 2021). The most common site of injury was in the lower limb for both male (6.8) and female players (4.8) (Horan et al., 2023; Lopez-Valenciano et al., 2021; Lopez-Valenciano et al., 2020). For males, muscle/tendon injuries were the most common type of injury (4.6) followed by contusions (1.4)(Lopez-Valenciano et al., 2020). The most common lower limb injuries in male football were thigh injury (1.8), knee (1.2), hip/groin (0.9), ankle (1.1), lower leg/achilles (0.8) and foot/toe (0.4) (Lopez-Valenciano et al., 2020). Muscle/tendon injuries were also the most common type of injury in female football (2.62), followed by joint and tendon injuries (0.76)(Horan et al., 2023).

In professional football, muscle injuries make up 31% of all injuries and 27% of all time loss from football (Ekstrand et al., 2011a). With as many as 94% of all injuries occur in the lower limb muscle groups, hamstrings (37%), adductors (23%), quadriceps (19%)

and the calf (13%) (Ekstrand et al., 2011a). A football player will in general sustain 2.0 injuries and 0.6 muscle tears per season (Bahr et al., 2018; Ekstrand et al., 2011a, 2011b). A team of 25 players could expect a total of 50 injuries per season and on average every player would be absent or unavailable for training/match 37 days due to injury per season (Ekstrand et al., 2011b).

Minimal injuries (1-3 days loss) have an incidence of 3.1 (1000/h), minor injuries (4-7 days) 1.7/ (1000/h), moderate injuries (8-28 days) 2.0 (1000/h), and severe injuries (>28 days) 0.8 (1000/h) of exposure (Ekstrand et al., 2011b; Lopez-Valenciano et al., 2020). There is an overall 12% incidence of re-injuries (7.0) where most of these occur during early phase (<2 months) following RTP, causing significantly longer absent from play than index injuries (Ekstrand et al., 2011b; Lopez-Valenciano et al., 2020).

The international insurance broker Howden (2002) published a report on the European injury index and the total injury cost in the top 5 European leagues (Howden, 2022). The report was published due to the concerns of the increasing demands of the modern footballer. The report showed a 29% increase in injury cost in the 21/22 season compared to previous season (Howden, 2022). Considering the economic cost of injuries and impact on team performance, it should be of the highest interest of any football team, to prevent as many sports injuries as possible (Ekstrand, 2013).

There are not only financial consequences related to football injuries, a study reported that 63% of former professional male football players retired due to impacts from former football injuries (Koch et al., 2021). Ardern et al. (2014) investigated the RTS (Return to Sport) rates following anterior cruciate ligament reconstruction (ACL-R) (Ardern, Taylor, et al., 2014). They found that only 55% of athletes with an ACL-R surgery returned to competitive sport while two out of three returned to pre-injury sport level (Ardern, Taylor, et al., 2014). Another long term follow-up study show that more than 50% of younger athletes who had meniscus surgery would develop osteoarthritis (OA) with associating pain and physical impairments (Maffulli et al., 2010). In retired professional female football players, 51% presented with MRI (Magnetic resonance imaging) confirmed osteoarthritis, 69% had substantial meniscus loss and 60% reported clinical symptoms. These findings indicate a risk of developing long term health impairments following a football career.

2.2 Hamstring injuries in football

HIs are the most common injury in football, causing 20% of all time loss from training/match for male players (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). Among all reported HI´s in the UEFA Elite Club study, 18% were re-injuries and 69% of these occurred within 2 months from RTP from previous HI. The HI incidence was ten times higher during football match compared to training and one study found that male players were 64% more likely of sustaining HI compared to female (Cross et al., 2013).

2.3 The hamstring muscles

The hamstrings are defined as the muscle group of the posterior thigh, with the medial muscles semitendinosus (ST) and semimembranosus (SM), while biceps femoris long head (BFlh) and short head (BFsh) make up the lateral part (Garcia et al., 2022). The Hamstring muscles originate from the ischial tuberositas and attaches at the lateral femur and head of fibula (BFlh), the medial proximal part of the tibia, pes anserinus (ST) and on the posterior medial part of the tibia (SM) (van der Made et al., 2015). The proximal hamstring attachment consists of two main tendons, where the SM tendon originate from the lateral part (facet) of the ischial tuberosity, while BFlh and ST together attach through the conjoint tendon which insert on the medial facet of ischial tuberosity (van der Made et al., 2015). The hamstrings have a complex function as they reach over the hip and knee joint as a multiarticular/biarticular muscles (Afonso et al., 2021). The main function of the hamstrings is producing hip extension during walking/running and knee flexion during the late swing phase (Afonso et al., 2021). During the "swing phase", the hamstrings work eccentrical on the hip to decelerate the force of hip flexion as well as eccentric on the knee to decelerate the knee extension before the heel strike and initial ground contact (Afonso et al., 2021). During the "stance phase", the hamstrings work concentric through the hip, producing a push back force which is important in running and sprinting. In the "pre-swing" and "toe off" phase, they act concentric on the knee producing flexion and lateral rotation of the tibia (Afonso et al., 2021).

A study on hamstring electromyography (EMG) activation showed that no exercise was close at reaching same level of hamstring activation as sprinting (100%), with an average in muscle activation of 40-65% (ST), 18-40% (BF) and 40-75% (SM) compared to sprinting (100 (van den Tillaar et al., 2017). For activation of the individual muscles of the hamstring, hip dominant exercises give higher activation of the lateral hamstrings (BFlh) while knee dominant exercises have higher activation of the medial hamstrings (ST and SM) and the BFsh (Bourne, Duhig, et al., 2017).

2.4 Hamstring injury mechanism and injury site in football players

Hamstring injuries are characterized by sudden onset of pain in the posterior thigh often during sprinting and kicking (Opar et al., 2012). There are two different types of acute hamstring injuries. We define these as type 1; acute injury occurring during running/sprinting with a maximal eccentric elongation of the hamstring in the late swing phase and type 2; acute injury due to excessive lengthening of the hamstring with a flexed hip and extended knee, typically during a high kick or a stretch of the leg (Garcia et al., 2022).

A study found that 19% of reported HI occurred during a stretching mechanism while 80% occurred from sprinting (Gabbe et al., 2005). A reason for this may be the 1.3-fold increase in hamstring muscle force produced during 80-100% of maximal sprint velocity (Hickey et al., 2022). The late swing phase of sprinting have been described as a "hazard zone" due to the hamstrings muscle-tendon unit being stretched eccentrically to its longest at this point (Opar et al., 2012). A study in German top division football shows a more equal distribution of the two different HI mechanisms, reporting an incidence of 48% type 1 and 52% type 2 injuries (Gronwald et al., 2022). Type 1 injuries commonly affect the biceps femoris (BFlh) with a proximal injury site (Crema et al., 2016) while type 2 injuries commonly affects the proximal SM tendon or muscle (Garcia et al., 2022). The BFlh was the most frequently injured muscle of the hamstrings, affected in 79% of all the reported cases of acute HI (Gronwald et al., 2022).

One type of HI receiving increasingly attention is the injury to the distal musculotendinous junction (DMTJ) of the Biceps femoris (Entwisle et al., 2017). The musculotendinous junction (MTJ) is the part of the muscle which transmits force produced by the muscle fibres to the tendon unit (van der Made et al., 2015). The anatomy of the DMTJ is complex and consists of the distal BFsh, BFlh and the distal tendon of the biceps femoris which attaches to the lateral tibia condyle and head of fibula. In an MRI case review of 104 DMTJ injuries, 51% were isolated to the BFlh, 7% isolated to the BFsh and 43% of the injuries involved both components of the BFlh and BFsh.

An MRI report described the association between anatomical location and extent of injury of acute HI in football players. Two hundred and seventy-five MRI scans with structural findings after acute HI in male players, aged 18-39 years was assessed (Crema et al., 2016). Their results support previous findings as the BFlh was the most affected muscle (56%) with the proximal MTJ the most common site of injury (Crema et al., 2016; Gronwald et al., 2022; Hickey et al., 2022). Only 21 injuries (5.3%) involved the proximal hamstring tendon with twelve of these being partial ruptures or avulsions (Crema et al., 2016).

2.5 Hamstring injury risk

When identifying risks of injury, we divide these in two sub-groups, either intrinsic (internal) or extrinsic (external) (Engebretsen et al., 2010). Intrinsic factors are defined being internal and non-modifiable such as age, sex, history of injury and ethnicity. Extrinsic factors are external and modifiable to the player and such as environment, equipment, match exposure, strength, flexibility, etc (Green et al., 2020; Meeuwisse, 1994).

There are identified numerous possible risks for sustaining HI, however many lack good evidence and are only a risk in theory. A SR from 2020 reviewed modifiable and non-modifiable risks of sustaining HI and found age, previous injury (HI, anterior cruciate ligament (ACL) and calf strain) to be the non-modifiable risk factors associated with HI (Green et al., 2020). Players >24 years had higher risk of injury and it was thought that age might correlate with exposure to activity over years as well as older age relate to physiological changes that might predispose players to injuries (Green et al., 2020). A previous HI may potentially lead to structural changes and neurological maladaptation, causing strength and flexibility deficits. Such deficits, if not addressed, are thought to reduce the hamstrings' ability to tolerate high amount of stress (Green et al., 2020). Football players with with a recent HI had twice as high risk of sustaining new hamstring injury (Engebretsen et al., 2010).

A medical expert review on potential risks of sustaining HI in elite male football identified 21 risk factors, twelve were defined as being extrinsic while nine were internal (Ekstrand et al., 2023). Most of the external factors seem to be influenced and controlled directly by the coach and coaching staff, such as miscommunication and training/match volume/frequency/intensity which may lead to fatigue, undertraining and muscular dysfunction (Ekstrand et al., 2023). Players exposed to high-speed running (HSR) with a sudden increase in load are found to be at risk of injury and therefore graded exposure to HSR and match play should be carefully monitored (Green et al., 2020).

Hamstring muscle strength and flexibility were the most investigated modifiable risk factors. In a case control study of 450 male amateur football players, there was no relation between hamstring flexibility and HI, were flexibility was tested with the Sit-and-reach test (SRT) (van Doormaal et al., 2017). A study found that those with baseline strength deficits were associated with an increased risk of injury. However, as pointed out in the study, hamstring strength fluctuates during a season in response to exposure and might not be of any value at the point of injury (Green et al., 2020). One study investigated eccentric hamstring strength and between-limb differences as potential risk factors for HI. They found that those who had an eccentric hamstring strength less than 256 newton (N) at the start of pre-season and less than 279N at the end of pre-season had a 2.7- and 4.3-fold increased risk of HI (Opar et al., 2015). An in-between limb strength difference of more than 10% did not seem to increase risk of HI (Opar et al., 2015). Another study in elite football players found that those with short BFlh fascicle length and a low level of knee flexor strength were at increased risk of sustaining HI (Timmins et al., 2016).

One study described the relation between running kinematics and HI (Schuermans et al., 2017). They found that index HI was associated with higher levels of anterior pelvic tilt and thoracic side bending through the swing phase of a sprinting (Schuermans et al., 2017).

The first match following RTP from injury was found to expose the player to higher injury risk (any injury) (87%) compared to average seasonal matches. More training sessions and a longer delay from injury until returning to RTP was associated with less risk of sustaining any new type of injury (Bengtsson et al., 2020).

2.6 Hamstring re-injury

In professional football, the general incidence of re-injury is lower than for index injuries (1.3 vs 7.0) with a re-injury incidence of 7% to 22% in professionals and 14% to 33% in amateurs (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022; Hägglund et al., 2016). Men have a higher proportion of re-injuries (22%) compared to women (12%) (Cross et al., 2013).

HIs have the highest re-injury incidence of all injuries in football, varying from 12% to 63% and are nine times more likely to occur during match than training (de Visser et al., 2012; Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022; Ekstrand et al., 2020; Hägglund et al., 2016; Wangensteen et al., 2016; Woods et al., 2003). Hamstring re-injuries commonly occur early following RTP (< 2 months) (69%) and often at the same site of index injury (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022; Lopez-Valenciano et al., 2020; Wangensteen et al., 2016). The mean difference in absence of days from participation in football between hamstring index and re-injury was -3.6 days (structural) and -3.4 days (functional) being a significant difference (Ekstrand et al., 2020). An MRI report found that the re-injury inidence was as high as 54% in those with injury to the DMTJ, being the injury site with the highest re-injury incidednce. As many as 76% of these re-injuries occurred within first 3 months and 89% following 12 months from RTP (Entwisle et al., 2017). A study by Ekstrand found a higher re-injury incidence in the BF for both early and late re-injury compared to ST and SM (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). A study on elite track and field athletes found that there was no difference in hamstring re-injury incidences between grade 1-3, age or gender. However, "grade c" injuries affecting the intratendon (British muscle injury classification, BAMIC) had higher re-injury incidence and delayed time before RTP (Pollock et al., 2016).

The research on hamstring re-injury prevention in football players is highly limited to one RCT on male recreational and professional Danish football players (Petersen et al., 2011). Their main outcomes were number of overall HIs, new HIs and hamstring re-injuries. They showed that by implementing a 10-week progressive eccentric NHE program followed by a weekly seasonal program, this could reduce the risk of sustaining a new HI (re-injury) by 85% in the players which had a history of hamstring injury during previous season. The NNT (number needed to treat) to prevent one hamstring re-injury was 3. However, this study only included male Danish players from the top 5 divisions and did not monitor long term adherence to the NHE after first 10 weeks.

2.7 Hamstring injury burden in football

Burden is a collective measure of an overall impact of a health issue in a specific population (Bahr et al., 2020). In public health, burden is often measured as mortality rate, morbidity, or financial cost, and we use these measures of burden to compare different health issues against each other. In sports, time loss from participation in football training/match is the most common measure of burden. However, time loss as a measure of burden in sports fail to consider the most severe health issues such as fatalities and non-fatal catastrophic injuries where the player fails to return to sport after injury, potentially leading to early retirement. Time loss measures are also underrepresenting overuse injuries and illness in sport (Bahr et al., 2020).

Data form the UEFA Elite Club Injury Study 2021 found a median time loss from football training/match of 13 days with an inter quartile range (IQR) of 7-22 for HIs (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). Biceps femoris injuries had significantly more days of time loss compared to SM and ST injuries (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). For index HI the mean absent of days from injury to RTP was 5.9 (functional) and 18.0 (structural) (Ekstrand et al., 2020). In general, 20% of football players will miss training or match due to a HI, where a team of 25 players can expect eight HIs per season (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022).

Over the last 21 seasons, the proportion of all injuries diagnosed as HI have increased from 12% to 24% (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). The UEFA study show a 2.3% year on year increase of HI and an increase in injury severity of 4.1% per season (Ekstrand et al., 2011a). There is no clear evidence on why HI is increasing in professional football, however it is thought to be related to the increasing physical demands in professional football over the past years. A study reviewing data from seven consecutive seasons of the English Premier League (EPL) (2006-07 to 2012-13) found that high intensity running increased by 30%, total sprint distance increased by 35% and the total number of sprints increased by 85% (Barnes et al., 2014). Another study in men´s EPL found that between the 2014/2015 and 2018/2019 season, there was a small to moderate increase in total distance (TD), high intensity running (HIR; $5.5 ms^{-1}$), and sprint distance (SprD; $7\ ms^{-1}$) (Allen et al.). Male football players cover a significantly higher distance at higher speeds compared to females, due to the biological differences between genders. However, in terms of physical demands of female football players, the mean values of total distance covered was 4-13km and 0.2-1.7km of HSR per match (FIFA, 2007; Martínez-Lagunas et al., 2014).

2.8 Injury classifications

There are multiple different classifications of muscle injuries. The first were described by O´Donoghue in 1962, later followed by Ryan (1969), Takebayashi (1995), Peetrons (2002) and Stoller (2007) (Mueller-Wohlfahrt et al., 2013). In recent years, muscle injury classification have been described by the British athletics team (Pollock et al., 2014), the Munich consensus statement (Mueller-Wohlfahrt et al., 2013) and latest by the medical team of FC Barcelona (Valle et al., 2017). The British Athletics Muscle Injury Classification (BAMIC) and the Munich consensus statement agree that the terminology "strain" is not recommended and that "tear" should be used instead to describe grade 1-4 injuries (Pollock et al., 2014).

The BAMIC is perhaps the most common classification used per date to describe muscle injuries. The BAMIC is based on a 0-4 grading which describes the structural extent of the injury and is combined with an "a", "b" or "c" category to describe the injury site and tissue involvement (Pollock et al., 2014). The letters refer to myofascial (a), muscular/musculotendinous (b) or intratendinous (c) tissue involvement (Pollock et al., 2014). Grade 0a is described as a neuromuscular injury while 0b injury is characterised as delayed onset of muscle soreness (DOMS), both with normal (negative) findings on MRI. A grade 1 injury will present as small tears to the muscle. Grade 2 injuries are moderate, and the athlete will normally need to stop activity. Grade 3 injuries are extensive tears where the athlete typically will present with acute pain, fall to the ground, and have reduced function. A grade 4 injury is a complete tear to the muscle or tendon unit. These injuries commonly present with limited function, pain and often a palpable gap (Pollock et al., 2014).

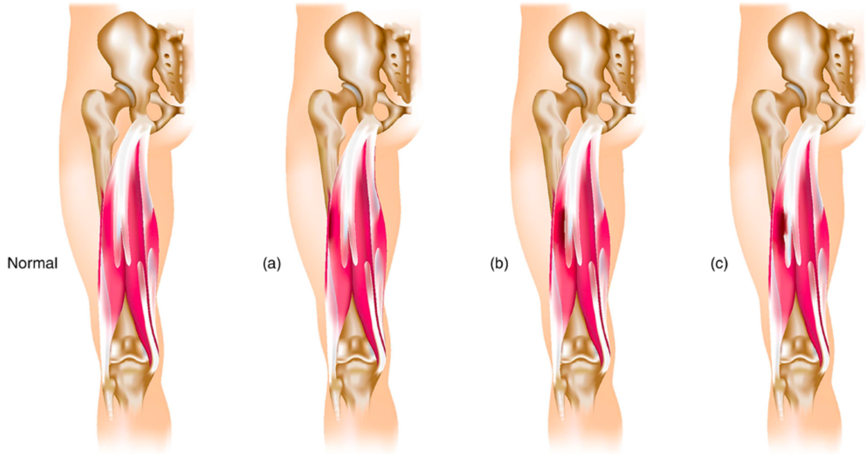

***Figure 1**: Illustration of the The British Athletics Muscle Injury Classification. (a) myofascial injury, (b) musculotendinous junction injury and (c) intratendinous injury (Pollock et al., 2014)*

The Munich consensus statement has another classification system, using a grading of 1-4. Type 1 and 2 are described as "Functional muscle disorder" caused by overexertion-related (type 1) or neuromuscular (type 2) disorders. Type 3 and 4 are structural muscle injuries with partial tear (type 3) and (sub)total tear (type 4) (Mueller-Wohlfahrt et al., 2013). They classify injuries as either indirect muscle disorder/injury (type A) (grade 1-4) or direct muscle injuries, typically contusions or lacerations (type B) (Mueller-Wohlfahrt et al., 2013).

The latest to describe a new classification system for muscle injuries is the medical group at FC Barcelona (Valle et al., 2017). Theire consensus-based classification system is based on a four-letter initial system, MLG-R. Theses initials represents mechanism of injury (M), location of injury (L), grade or severity of injury (G) and number of muscle re-injuries (R). The intention of the new classification system was to enhance the communication between health care professions and facilitate good rehabilitation and RTP decision making (Malliaropoulos et al., 2012). They describe injury mechanism (M) as either direct (D), indirect (I) or negative MRI findings (N). Location is described as either proximal (P), middle (M) or distal to muscle belly (D).

They use a 0-3 scale to classify injury severity and the number of re-injuries were described with a 0-2 scale (Valle et al., 2017).

2.9 Clinical diagnosis of acute hamstring injury

The diagnosis of an acute HI is usually made by the presentation of acute onset of pain to the posterior thigh, occurring during HSR or from an excessive lengthening of the hamstring muscle with a flexed hip and extended knee, commonly through a stretch (Garcia et al., 2022; Hickey et al., 2022; Opar et al., 2012). When a player presents with posterior thigh pain it is important to carry out a thorough subject history and physical assessment. Even though the clinical diagnosis of an acute hamstring injury is quite straight forward, the assessment should start by asking the subject about the injury mechanism, pain, previous hamstring injury or other previous injuries to the same limb as all these may predict rehabilitation time or be used to monitor progression (Hickey et al., 2022). It is important to rule out potential differential diagnosis such as proximal hamstring tendon avulsion, proximal hamstring tendinopathy, lumbar spine radiculopathy or adductor muscle injury as these will require a different assessment and treatment (Hickey et al., 2022).

For the clinical diagnosis of the HI, there are several tests and measures. The most common tests used and described in the literature are presented below (table 1) and are either range of motion testes (ROM) or strength tests (Hickey et al., 2022; Reiman et al., 2013).

Table 1: *Criteria for diagnosing acute hamstring injury (Reiman et al., 2013)*

Acute onset of posterior thigh pain in relation to specific motion, either sprint or excessive stretch
Pain during stretching of the hamstring muscles (ROM) - Passive straight leg raise (SLR) - Passive knee extension test - Active knee extension test
Pain during isometric contraction of the hamstring muscles (strength) - Inner range (prone, 90^0 of knee and hip flexion) - Mid-range (prone, 15^0 of knee flexion and natural position of hip) - Outer range (supine, maximum knee extension and 90^0 hip flexion) - Taking-off-shoe-test
Pain localization on palpation of the hamstring muscles

2.9.1 Range of motion testing

When testing ROM after an acute HI, pain may restrict the actual extensibility of the muscle-tendon unit. Therefore, ROM should be a measure to evaluate the difference between injured and uninjured limb as it may give an indication of injury severity as well as providing a prognosis of RTP throughout the rehabilitation (Hickey et al., 2022). It seems that acute HI in sprinters (Type 1) often present with larger ROM deficits by initial assessment. Acute HIs in dancers typically caused by an excessive stretch (Type 2), often involving the proximal hamstring tendon, present with smaller ROM deficits but have a longer recovery time (Askling et al., 2006). Whiteley et al. (2018) looked at the clinical value of ROM testing in hamstring injuries, comparing the straight leg raise (SLR) against the maximum hip flexion active knee extension test (MHFAKE) (Whiteley et al., 2018). They found ROM was normalized early during first days after injury when using the SLR as very few subjects presented with <90% of ROM of uninjured limb within few days. The MHFAKE test, however, appears more valuable as a clinical measure of injury recovery as it varies from 70% of uninjured limb to 100% by the end of rehabilitation (Whiteley et al., 2018).

2.9.2 Strength testing

Strength testing of the hamstrings are usually assessed by isometric muscle contractions in the initial assessment and can be tested in different positions (Hickey et al., 2022; Reiman et al., 2013). Hamstring strength can be measured objectively by using a handheld dynamometer, force plates or, subjectively tested through manual muscle resistance (Hickey et al., 2022). Handheld dynamometers have excellent inter-rater reliability for testing of knee flexion strength and are reliable in cases of HI (Reurink et al., 2016; Whiteley et al., 2012). One study investigated the diagnostic and prognostic value of the different strength test positions, where outer range testing with the hamstrings in a lengthened position appears most valuable when assessing the limb symmetry index (LSI) (Whiteley et al., 2018). By adding external and internal rotation of the tibia may help differentiate injury to the lateral or medial hamstring muscles (Hickey et al., 2022). In healthy athletes, peak hamstring strength is seen at 30^0 knee flexion with tibia in neutral position, peak lateral hamstring strength in 30^0 knee flexion and maximal tibial external rotation, peak medial hamstring force seen at 60^0 knee flexion with neutral tibia position (Beyer et al., 2019).

2.9.3 Palpation

With the player laying in a prone position, the clinician can palpate the posterior thigh and the hamstring muscles. By finding the point of maximal pain provocation with palpation, it is possible to estimate the site of injury. As a clinical measure, it is advised to measure the distance from the ischial tuberosity to the site of maximum pain as well as the total area of pain/tenderness by palpation. This is recommended to assess throughout the rehabilitation (Hickey et al., 2022; Whiteley et al., 2018).

2.9.4 Pain

Pain is often used as criteria for a safe RTP (van der Horst et al., 2017). When assessing, pain is measured by using a 0-10 scale, often referred to as the visual analogue scale (VAS), where no pain = 0, and worst possible pain = 10 (Hjermstad et al., 2011). A study found daily pain measures to normalize after approximately 30% of the RTP time, meaning that pain as a clinical measure only has a value during the first half of the rehabilitation (Whiteley et al., 2018). For participation on field-based training, pain free repeated maximum effort sprinting is recommended (Whiteley et al., 2018).

2.9.5 MRI – diagnostic and prognostic value

Magnetic resonance imaging is what we would define as current "golden standard" for imaging of muscle and tendon injuries. MRI scans are used by sports physicians and PT all over the world as a diagnostic tool for injury diagnosing, evaluation of injury extent and to help predict time before RTS (Hickey et al., 2022; Reurink et al., 2015).

A study found that there were no significant day-to-day changes in the extent of edema within the first seven days after sustaining HI. An MRI scan can therefore be performed at any time within the first week following acute HI (Wangensteen et al., 2017). MRI scans on acute HI are found to have excellent intra-and interobserver reliability between two experienced radiologists for grading of injury severity (Hamilton et al., 2014; Wangensteen et al., 2018). However, there is yet no MRI classification system of HI for providing a RTP prognosis (Hickey et al., 2022). A prospective MRI study intended to compare different muscle classification systems and their association with RTP after HI, where they found great variation between the different grading systems. Therefor none of these systems (Petrons, Chan acute muscle injury classification and BAMIC) can or should be used to predict RTP following HI (Wangensteen et al., 2018).

Wangensteen et al. (2015) investigated 180 acute HIs in male athletes and found that MRI did not add any additional value above patient history and clinical examination in predicting RTP (Wangensteen et al., 2015). However, it is seen that there is a prolonged RTP period after HI when MRI scans show signs of tissue damage compared to no damage or if there is damaged to the proximal hamstring tendon compared with being intact (Hickey et al., 2022). Regardless, it may give the clinician a more accurate diagnosis and the possibility to rule out tissue damage of the proximal tendon or the intramuscular tendon which may give an indication of prolonged rehabilitation period (Hickey et al., 2022).

2.10 Return to play criteria following injury

A consensus statement was published by the International Olympic Committee (IOC) with the intentions of; (1) Defining RTS (Return to sport), (2) present models to help guide the RTS process, (3) highlight the evidence on RTS decision making and (4) find future priorities for research on RTS (Ardern et al., 2016). In this paper, the term RTS was preferred as RTP was found most relevant for team athletes. RTS was defined as a continuum parallel with recovery and rehabilitation, consisting of three steps, (1) return to participation, (2) return to sport and (3) return to performance. With the purpose of guiding clinicians to good decision making and provide a safe RTS, *The Strategic Assessment of Risk and Risk Tolerance* (StARRT) framework was made, figure 2. The consensus statement concluded that biological, psychological, and social factors all affect RTS, and should all be considered by the PT or physician in a shared decision-making process for a safe RTS (Ardern et al., 2016).

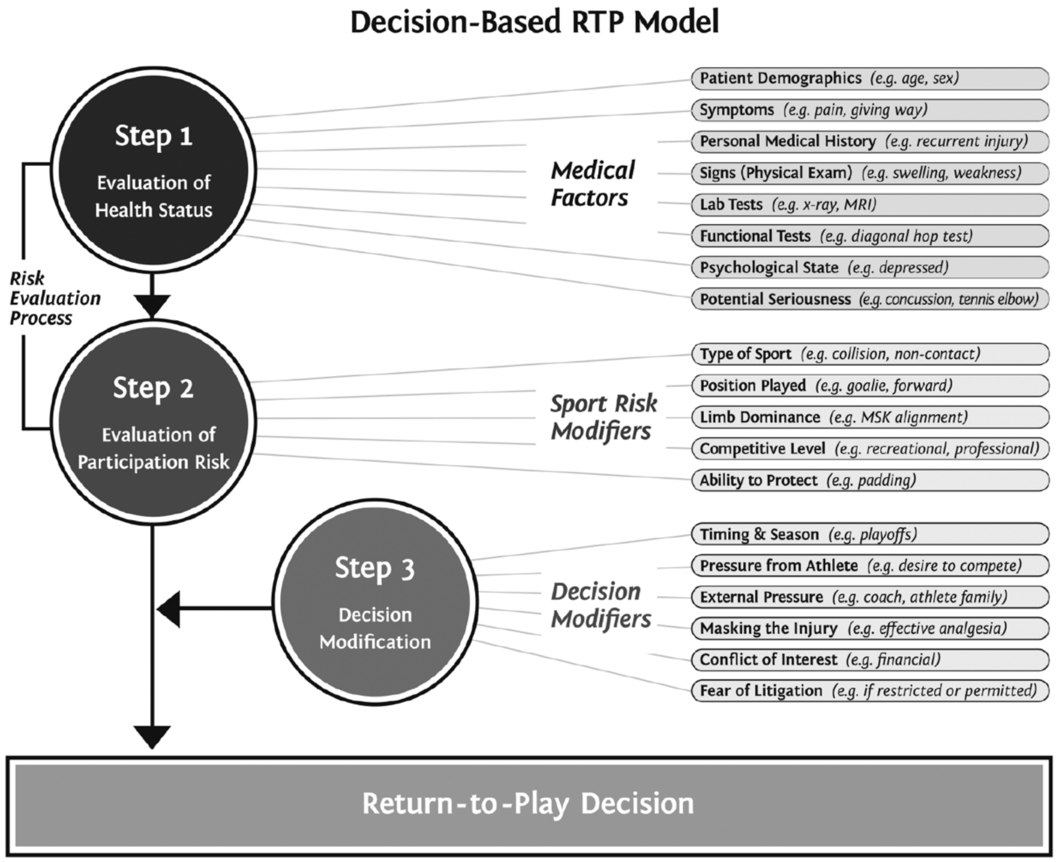

Figure 2: *Illustration of the StARRT framework – Return to play decision making. (Ardern et al., 2016)*

2.11 Return to play criteria following hamstring injury

Multiple papers have tried to describe the highest level of evidence for RTP criteria following HI, however, it seems to be challenging with lacking consensus. A worldwide survey including 131 premier league football teams was conducted with the purpose of (1) investigate to which extent professional teams follow an RTP continuum, (2) identify RTP criteria used and (3) understand the RTP decision making applied in daily practice (Dunlop et al., 2020). From this paper it seems most teams match the general recommendations of RTP, assessing clinical, functional and psychological criteria for RTP following HI throughout the RTP continuum (Dunlop et al., 2020).

Van der Horst (2017) conducted a worldwide Delphi study with the intention of defining clear medical criteria for RTP following HI (van der Horst et al., 2017). They reached agreement on the RTP criteria presented in table 2. RTP decision should be based on shared decision-making, including stakeholders such as the player, sports physician, PT, fitness trainer and team coach (van der Horst et al., 2017).

Table 2: *Criteria for RTP following hamstring injury – consensus agreement. (van der Horst et al., 2017)*

RTP criteria to include	Potential RTP criteria	RTP criteria to exclude
Absence of pain on: - palpation - strength and flexibility tests - during and after functional performance Similar hamstring flexibility (active and passive) Psychological readiness Performance testing on field: - Repeated sprint ability test - Deceleration drills - Single leg bridge GPS specific rehabilitation, position specific Medical staff clearance	Similar eccentric hamstring strength	Similar concentric/isometric hamstring strength Neuromuscular function MRI Completion of a number of full friendly matches Completion of a number of full training sessions

It should be noted that there is presently no strong evidence that any findings from the baseline assessment provide any prognosis for the time to RTS after sustaining HI (Schut et al., 2017). There is, however, moderate evidence that pain at the time of injury and the predicted RTS time by the player and clinician are associated by with the time of RTS (Schut et al., 2017).

2.12 Injury prevention

There are different terms and definitions of prevention, commonly referred to as primary, secondary, and tertiary prevention. Primary prevention aims to prevent injury or illness occurring in the first place by reducing the incidence of new cases, such as index HI. Secondary prevention aims to reduce the impact of an injury or illness which has already occurred or to prevent recurrence or re-injury. Tertiary prevention aims to reduce the impact of an ongoing illness or injury with lasting effect. This commonly involves chronic diseases and injuries with lasting impairments (Jacobsson & Timpka, 2015; Pless & Hagel, 2005).

Several studies show well documented results on injury prevention in football. Two SR´s found that the NHE could reduce all HIs by 51% (Al Attar et al., 2017; van Dyk et al., 2019). For other muscle/tendon injuries, implementing a strengthening program for the adductor muscles found to reduced groin injuries by 41% in football players (Haroy et al., 2019). Soligard and colleagues reduced one third of all injuries and reduce half of all severe injuries by implementing a structured warm up program in young female football players. (Soligard et al., 2008). The FIFA 11 and 11+ programs are recognised as effective as implementing the 11+ program may reduce as much as 39% of all football injuries and 60% of HIs (Thorborg et al., 2017). Despite studies with large preventative effects of multiple football injuries, Bahr (2015) found that European elite clubs and Norwegian premier league teams either do not implement or use the NHE to a very small degree (Bahr et al., 2015). One study confirms the findings of Bahr (2015) as the NHE is still poorly adopted in professional football, even though those teams who use the NHE as an intervention on the whole team or many of the players had an overall lower burden of HI (Ekstrand, Bengtsson, Walden, Davison, & Hagglund, 2022). There is unfortunately very limited research conducted on general injury prevention and HI prevention in female football as most of the previous mentioned studies include male players only (Crossley et al., 2020). Those studies on injury prevention in female football players are of low evidence and with a higher risk of bias (Crossley et al., 2020).

2.12.1 Injury prevention models

To be successful in preventing sports injuries, it is crucial to know how injuries occur (mechanism), the extent of the injuries (incident and severity) and potential risk factors of sustaining specific injuries. Several models have been developed and tested to help clinicians in the process of injury prevention. Perhaps the most common model is "the sequence of prevention" model which was first presented by Van Mechelen in 1987, figure 3 (van Mechelen et al., 1992). The model consists of four steps.

- Step 1, establishing the extent of the injury. This includes injury incidence, prevalence and severity (van Mechelen et al., 1992). Epidemiological studies are used to investigate the extent of a problem or injury.
- Step 2, the aetiology and mechanisms of injury. This step identifies potential risk factors to why and how injuries occur in the first place. When the aetiology and extent of an injury is known, one can move on to the next step.

- Step 3, introducing preventative measures, depending on the problem being a modifiable factor. The preventative measures such as an injury prevention program, are tested through experimental studies such as an RCT.
- Step 4, assessing the effectiveness of the given preventative measure from step 3. This is done by repeating step 1 (van Mechelen et al., 1992) For e.g. assessing the extent of an injury in a population after testing a preventative measure such as an injury prevention program.

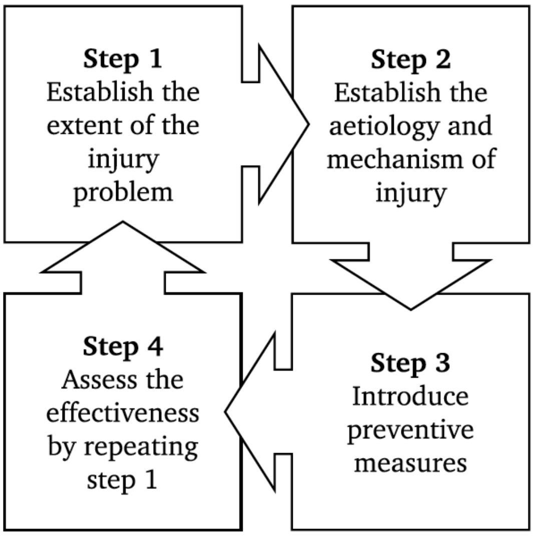

Figure 3: *Illustration of Van Mechelen´s 4 step approach to injury prevention (van Mechelen et al., 1992)*

The "4 step approach" has proven valuable in the process of conducting research on sports injuries, from a research perspective (Finch, 2006). Carolyn Finch suggests that prevention of sports injuries is more complex than first thought and that a more dynamic approach is needed. Football players and other stakeholders beliefs of a prevention program is crucial as only the interventions that can and will be used by the player and coaches will manage to prevent injuries (Finch, 2006). Verhagen (2014) highlights that there is a huge gap between research and practice. They believe that despite the current evidence on cost effective injury prevention programs it still seems challenging to implement these prevention programs in a real-world situation and suggest that evidence of an effective injury prevention program from research does not equal a successful real-world implementation (Verhagen et al., 2014). Therefore, based on the challenges of applying research to a real-world setting, Caroline Finch published a new model in 2006, “The Translating Research into Injury Prevention Practice” (TRIPP) (Finch, 2006).

The TRIPP model (Figure 4) is based on 6 steps, whereas the first three are equal to step 1-3 in van Mechelens “4 step approach”. The fourth step in the TRIPP model is based on the critic Finch points at step 4 in van Mechelens model were Finch argues that the research on injury prevention is mostly applied under “ideal conditions” and in a “artificial environment” created by the researcher (Finch, 2006). As a consequence of this, studies on injury prevention seem to miss potential barriers which the player meet in the daily life when applying the injury prevention program outside the study situation (Finch, 2006).

Model stage	TRIPP	van Mechelen et al 4 stage approach [1]
1	Injury surveillance	Establish extent of the problem
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Develop preventive measures	Introduce preventive measures
4	“Ideal conditions”/scientific evaluation	Assess their effectiveness by repeating stage 1
5	Describe intervention context to inform implementation strategies	
6	Evaluate effectiveness of preventive measures in implementation context	

Figure 4: *Illustration of the “Translating Research into Injury Prevention Practice (TRIPP) model (left) and van Mechelen´s 4 stage approach (right) (Finch, 2006).*

Finch added an additional two stages in her TRIPP model. In step 5, Finch points out the importance of understanding how the efficacy of research could best be implemented in a real-life setting on-field. She highlights the importance of understanding the attitudes, beliefs, and knowledge of players, coaches and other stakeholders. The clinician should consider if there are there any signs of safety behaviour from the player or coach, and if not, what are potential barriers (e.g., resources, knowledge, beliefs) for no safety behaviour. Safety behaviour may be described as any actions made with the intention of promoting the health and safety of players. These actions will only be applied when safety is a major motivation to the any of the stakeholders within the club or team. Safety behaviours in sport are typically implemented with the intention to reduce injuries and illness which can improve the performance and participation of the player.

Step 6 includes both the implementation of a preventative measure in a real-world context and evaluating the effectiveness (Finch, 2006). Finch wanted a larger focus on understanding the effect of scientific proven injury prevention when applied in a real-world setting of individual athlete behaviour and in different sport cultures. Step 6 evaluates the intervention proven effective in stage 4 and implementing it in the real-world setting considering the sports safety cues from stage 5. The intention of this model was to close the gap between the research and what is actually done of injury prevention on field (Finch, 2006). The work by Carolyn Finch has been supported by Verhag and co-workers which suggests that the results of an intervention study such as in RCT´s, are heavily biased by the participants adherence to the intervention program (Verhagen et al., 2011).

2.13 Hamstring injury prevention in football

Several studies have investigated hamstring injury prevention strategies in football. The NHE is perhaps the most known exercise to be tested and has through research shown to have good preventative effect (Al Attar et al., 2017; van Dyk et al., 2019). Table 3 presents studies conducted on HI prevention with NHE alone or combined with other exercises. The study by Petersen (2011) is the only to evaluate the re-injury prevention (Petersen et al., 2011).

Table 3: *Overview hamstring injury prevention programs*

Injury prevention program	Author	Population	Effect of intervention
Systematic reviews and meta-analysis			
Injury prevention programs including the NHE	Al Attar et al 2017	Football players	51%
Injury prevention programs including the NHE	Van Dyk et al 2019	Any athletes in sport activity	51%
FIFA 11 and 11+. Field based warm up programs (football) – including the NHE	Thorborg et al 2017	Male and female recreational and sub-elite football players	39% (all injuries) 60% (HI)
Intervention studies			
Nordic hamstring exercise (10-week period + weekly seasonal program)	Petersen et al 2011	Male amateur and professional football players	60% (all HIs) 85% (re-injuries)
Nordic hamstring exercise (13-week period)	Van der Horst 2015	Male amateur football players	OR: 0.282 (p=.005)
Prevention of hamstring strains– NHE and flexibility	Arnason et al 2007	Elite male football players	RR: 0.43 (p=0.01)
Nordic hamstring exercise (27-week period)	Hasebe et al 2019	Male high-school football players	RR: 1.14 (p=0.83)
Eccentric training for preventing - including NHE (21-week period)	Espinosa et al 2015	Female elite football players	81% risk reduction *Not significant

2.14 The Nordic Hamstring Exercise

The NHE has become well known for its highly documented effect on preventing HI, especially in football players. The NHE may be described as an eccentric strengthening exercise for the hamstring muscles. The exercise can be performed alone or with a partner as illustrated in figure 5. The players are instructed to start from a kneeling position and then resist the forward-falling motion as long as possible by eccentrically activating their hamstrings.

Studies investigating the preventative effect of the NHE have found that injury prevention programs including the NHE alone or in combination with other exercises can prevent the incidence of HI by 51-60% (Al Attar et al., 2017; Petersen et al., 2011; van der Horst et al., 2015; van Dyk et al., 2019). The cluster RCT by Petersen showed that the NNT for preventing 1 overall HI was 13 players (index injury or re-injury) and NNT to prevent one new HI was 25 players (Petersen et al., 2011). There was more than 60% risk reduction of index HI (Petersen et al., 2011). Evidence is limited on the effect of the NHE on preventing short term and long-term hamstring re-injuries in football players despite these findings. No studies have investigated the effect of the NHE on preventing hamstring re-injuries in female football players or at the outcome of performing the NHE regularly over a long period of time with sufficient sample size.

Figure 5*: Illustration of the Nordic hamstring exercise. A, start position. B, mid phase where subject leans forward with an eccentric hold. C, End phase. Red lines indicate that subjects' knees and torso must be in a line (Zein et al., 2022)*

In addition to the preventative effect of the NHE, there is an increase in focus on potential performance effects of implementing the NHE as part of injury prevention programs. A SR from 2021 showed that there is a small effect on sprint performance in team players and a moderate effect on eccentric knee flexor strength in relatively untrained individuals. These results were reported to come with some risk of bias as there was a small number of included articles in the meta regressions (Bautista et al., 2021). A study by Mjolsnes et al. (2004) showed that implementing a 10 week program of NHE was effective in improving maximal eccentric hamstring strength in well trained football players (Mjolsnes et al., 2004). Most of the studies on HI prevention that include NHE are only lasting for a short period of time and with limited studies on female football players. A different study found a small to moderate effect in sprint performance and a large improvement in peak eccentric hamstring strength after a 10-week NHE protocol (Ishoi et al., 2018).

One study investigated the difference of high and low training volume of the NHE on strength, jump height and sprint performance in female football players (Amundsen et al., 2022). They found that both female players performing a low volume NHE program during pre-season did not improve hamstring strength to greater extent compared to high volume NHE program. Both groups improved maximal eccentric strength. No improvement was seen in neither groups for jump height or sprint performance (Amundsen et al., 2022).

Despite the NHE having good effect on preventative HIs, as many as 68% of professional football players “never” used the NHE, 16% use it “sometimes”, 5% “often” and 4% “always” (van der Horst et al., 2021). The adherence to the NHE injury prevention program was to low among male elite football players to expect a preventative effect in a real world setting (van der Horst et al., 2021).

2.15 Physiological adaptations to loading through exercise

When the body is exposed to mechanical load, this initiates a process called mechanotransduction. The body converts load into a cellular response which promotes structural response and adaptation of tendons, muscles, cartilage and bone (Khan & Scott, 2009). This process consists of three steps, (1) Mechanocoupling, which is the mechanical load, either shearing or compressing forces, (2) Cell-cell communication, where the stimulated cell communicates with surrounding cells and (3) Effector cell response, were the cell responds to a stimulus. For e.g. when loading a tendon or a muscle, this causes an upregulation of insulin-like growth factor (IGF-1) and mechanogrowth factor (MGF) leading to muscle hypertrophy by the activation of satellite cells and cellular proliferation causing remodelling of the tendon (Khan & Scott, 2009). Mechanical overload through high intensity resistance training is therefore associated with physiological adaptations in the skeletal muscles and tendons due to the mechanotransduction stimulating cellular response and increased protein synthesis. This adaptation occurs in the contractile (muscle) and non-contractile (tendon) structures (Hedayatpour & Falla, 2015)

When loading a muscle through exercise, there are three different types of muscle contractions to consider. (1) Concentric (shortening of the muscle during exercise), (2) isometric (muscle length maintains the same during exercise) and (3) eccentric (lengthening of the muscle) where the external load is greater than the force produced by the muscle (Hedayatpour & Falla, 2015). Resistance training is shown to increase the number of sarcomeres in parallel and series, leading to an increase in fascicle length, pennation angle and muscle hypertrophy (Hedayatpour & Falla, 2015). The combination of external overload to the muscle combined with a stretch (eccentric contraction), is associated to be the most efficient way of promoting muscle growth and increase the neural drive to the muscle (Hedayatpour & Falla, 2015).

Several studies have investigated the structural adaptations of eccentric strength training on muscle fascicle and sarcomere level. One study found that a 3-week NHE program with 3 sessions per week (9 session in total) increased the length of the distal BFlh fascicle (21%) and sarcomere (17%). They did however not find any change in estimated number of sarcomeres in series (Pincheira et al., 2022). Others have found an increase in BFlh fascicle length by 16% (seated isokinetic knee flexion) and 34% (leg curle) after 6 and 8 weeks of eccentric hamstring training (Bourne et al., 2018). The NHE alone can increase the BFlh fascicle length by 21-24% (Alonso-Fernandez et al., 2018; Pincheira et al., 2022; Presland et al., 2018; Ribeiro-Alvares et al., 2018). A retrospective study found that fascicle length, eccentric strength and pennation angle is significantly different in a previously injured BFlh compared to contralateral uninjured BFlh (Timmins et al., 2015).

2.16 Compliance and adherence

Compliance and adherence are two terms which have been used interchangeably in the context of sports injury prevention without recognising the important differences between the two (McKay & Verhagen, 2016). The purpose of this section is to clarify the definition of compliance and adherence, explain the importance of why these terms should not be mixed and show in which context they should be used.

Compliance refers to "the act of an individual conforming to professional recommendations with regards to prescribed dosage, timing, and frequency of an intervention"(McKay & Verhagen, 2016). Compliance addresses whether intervention components were performed as instructed. This is relatable to what Finch (2006) argues in step 4 of the TRIPP model where an intervention is followed as instructed under ideal conditions in an artificial environment (Finch, 2006). A practical example could be how many sessions (per protocol) a football player performed from a given strength program whereas adherence would be how many sessions performed per season (total number). In the context of research, McKay suggests that compliance should be used in efficacy studies, which measures the effect of an intervention in an ideal context as described in stage 4 of the TRIPP model (Finch, 2006; McKay & Verhagen, 2016).

Until the year of 2002, compliance was the most used term. However, there has been a paradigm shift where medical staff have started to view the patient-physician relationship as a cooperation instead of being one of patient obedience (McKay & Verhagen, 2016). From this time on, adherence has been the most common term and has been described as "*a process influenced by the environment, recognizing that behaviour is shaped by social context as well as personal knowledge, skills, and resources*" (McKay & Verhagen, 2016). Adherence in the context of injury prevention applies to a real-world intervention use which accounts for individual characteristics, environmental factors, within-subject or between-subject variability to behaviour an does not allow for cause-effect relationship between an intervention and outcome (McKay & Verhagen, 2016). This is relatable to what Finch described in stage 5 of the TRIPP model about context of intervention implementation, understanding beliefs/disbeliefs and potential barriers (Finch, 2006). Adherence should therefore be preferred in effectiveness studies where an intervention is tested in a real-world setting (Verhagen et al., 2011).

2.17 The RE-AIM model

Health promoting interventions often meet obstacles when being transferred from research and applied to real world settings (Kessler et al., 2013). The RE-AIM model was therefore made as a framework to increase the attention to the barriers that health promoting interventions meet in everyday life, figure 6 (Glasgow et al., 1999).

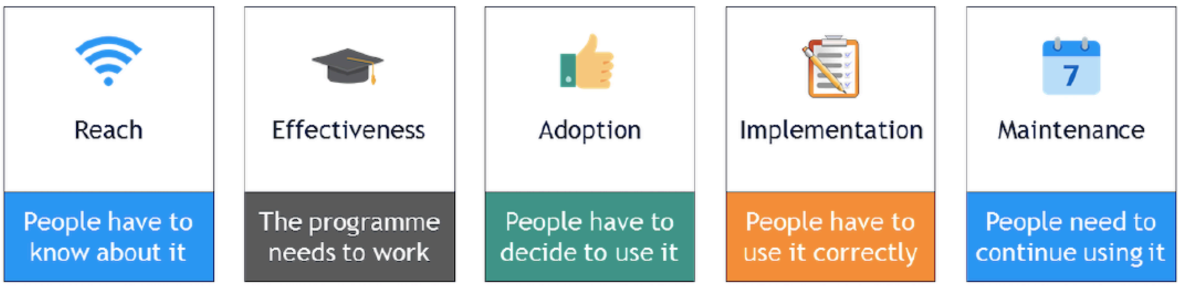

Figure 6: *Illustration of the RE-AIM framework, unpublished (Harøy, J.)*

RE-AIM represents five steps which are crucial for optimizing an intervention:

- Reach - refers to the proportion of the target population that participates in the given intervention. It is crucial for an intervention to work, the given population need to know about the it and one must understand why some chose not to adhere to it.
- Effectiveness - the intervention must be effective for people to stick to it. It is important to understand the impact of the given intervention on possible negative consequence's such as quality of life and economics.
- Adoption – People have to decide to use the intervention/treatment and implement it in the right context and setting.
- Implementation - the given program or intervention must be carried out as instructed, for e.g., by following a given protocol.
- Maintenance - the intervention must be carried out over time to reach a significant effect. This step highlights the importance of understanding potential barriers that the intervention met in a real-world setting,

2.18 Summary

Preventing sports injuries is considered highly complex in today's world of sports medicine despite research showing multiple effective intervention strategies and programs (Al Attar et al., 2017; Andersson et al., 2017; Bolling et al., 2018; Haroy et al., 2017; van Dyk et al., 2019). Even with well documented injury prevention programs and high injury/re-injury risk among football players, there is very low adherence to these programs among football teams and clubs (Bahr et al., 2015; Ekstrand et al., 2020; van der Horst et al., 2021). There is good evidence on the effect of the NHE in preventing hamstring index injury. However, there are currently no studies evaluating the short- and long-term effect of the NHE in preventing hamstring re-injury with a sufficient amount of male and female football players.

3. Method

With minor adjustments the "Norwegian arm" of the SHARP study has applied the method used in the published SHARP protocol (Zein et al., 2022). The primary outcome of the "Norwegian arm" was the rate of early hamstring re-injury, whereas in the SHARP study both early and late re-injuries rates were studied (Zein et al., 2022). Moreover, sprint and jump tests, measured by a 30-meter sprint test, a squat jump (SJ) and a counter movement jump (CMJ), were performed as part of the main SHARP study to look for possible performance enhancing effects of the NHE. These additional tests were not performed as part of the" Norwegian arm" study. The data used in the "Norwegian arm" study are collected from collaborating institutions in the Netherlands and Indonesia, respectively (Zein et al., 2022).

3.1 Research

The "Norwegian arm" study was carried out by the main researcher Anders Knapstad (AK) as part of his Master's degree (Sports Physiotherapy) at the Department of Sports Medicine, the Norwegian School of Sport Sciences and supervised by the principle investigator (PI), professor dr. med. Thor Einar Andersen (TEA). TEA is professor at the Oslo Sports Trauma Research Centre, Department of Sports Medicine, the Norwegian School of Sport Sciences. TEA is also Medical director and Senior consultant in Physical Medicine & Rehabilitation at the Norwegian FA's Medical Centre.

3.2 Study design and population

The "Norwegian arm" study is part of an international multi-centre randomized controlled trial. An IG was instructed to follow the NHE protocol while the CG followed their routine warm-up, injury prevention and training program. Whether the participant was cleared for RTP or not, was decided by the treating PT in collaboration with the participating player.

Inclusion criteria:

- Male and female football players
- Age 18-40 years

- Within 1 week after fully recovered from a hamstring injury and/or has returned to play

Exclusion criteria:

- Declining the invitation to participate in the study

3.3 Recruitment procedure

The recruitment of participants for the "Norwegian arm" study of SHARP started 15th of March 2022. Two main strategies were used to recruit players with HI to the study. These strategies are described below.

3.3.1 Strategy 1 - Including and collaborating with Norwegian physiotherapists

The main objective of this strategy was to reach out to experienced PTs across Norway who either currently are working with, or have previously treated and rehabilitated HI football players, either in a club setting or in a sports physiotherapy clinic. In the beginning of March 2022, a list of Norwegian PTs who are part of the Norwegian FA Medical Centre's network or working with Norwegian premier league teams (male and female) and national teams was collated. PTs in the bigger cities Oslo, Bergen, Trondheim, Stavanger, Drammen, Kristiansand were invited to participate as well as PTs from specialized sports medicine clinics in smaller towns in Norway.

The invited PTs received an informative e-mail from the researcher (AK) containing the following:

- General information and description of the SHARP study
- Intention/purpose
- Instructions on the recruitment procedure
- Inclusion/exclusion criteria
- Expectations/demands from researcher to the participating PTs

Fifty-six Norwegian PTs were invited to take part and contribute to recruitment of football players with a HI injury to the "Norwegian arm" of the SHARP study (strategy 1). Thirty-four responded positively and wished to take part in the player recruitment. All the PTs were invited to schedule a meeting by phone or Zoom/MS Teams to clarify any questions. Otherwise, they were recommended to contact AK by e-mail or phone if they had any additional questions at a later stage. Those PTs who did not respond to the initial e-mail received a follow-up e-mail. The PTs were asked to forward the information to colleagues who they knew also rehabilitate football players with HI. If colleagues wanted to contribute to the recruitment of participants, they were told to contact AK directly.

The PTs were instructed to notify potential participants who fulfilled the inclusion criteria about the ongoing HI prevention project. The PTs would then forward the contact details (name, email, phone number) to the researcher (AK) for further follow-up. No additional follow-up or contribution was required from the PTs as soon as AK received contact details of player.

To make sure the PTs felt included, updated, and did not forget their key role in the recruitment process, they regularly received reminding e-mails from AK. These included updates on the study progress, publication of the SHARP protocol and novel relevant literature about hamstring injury. The PTs who contributed to the recruitment process received no honorarium or other benefits. However, they were all informed that they would be acknowledged in the Master thesis and later on in the event of a scientific publication.

3.3.2 Strategy 2 – The Norwegian FA’s Medical Call Centre (Idrettens skadetelefon)

The Call Centre for sports injury assistance at the Norwegian FA’s Sports Medicine Centre offers a medical health service for 800 000 athletes in Norway. The main task of The Call Centre is to facilitate state of the art and evidenced based medical assessment, investigations, and treatment through a qualified assured network of sports medicine physicians, orthopaedic surgeons, sports physiotherapists and in special cases also other consultant physicians and clinicians. This service was provided by the Norwegian FA Medical Centre, owned by the Football Association of Norway (NFF). Football players and athletes from most other sports in Norway are covered by an insurance which provides them with access to fast medical assessment and treatment of their sports related injuries. All the injuries reported to the insurance companies are handled in terms of medical follow-up by the Call Centre. This provides a great opportunity to get in touch with football players at any level who report a HI across Norway, and also to get familiar with the clinicians treating them too. With permission from the board and the head of medical at The Norwegian FA's Medical Centre, the researcher (AK) has used the Call Centre to get in direct contact with football players that has reported a HI.

When initially starting this recruitment process September 1st, 2022, AK contacted colleagues at the Norwegian FA Sports Injury Call Centre to inform about the ongoing research project. They were instructed to look for football players fulfilling inclusion criteria and reporting an acute hamstring injury.

3.3.3 Description of contact process, from AK to participants

The researcher (AK) made direct contact by phone and e-mail to all football players sustaining a HI, recruited by either strategy 1 or 2. Those who did not respond to the initial or second phone call, received an informative e-mail with an open invitation to contact the researcher (AK) if interested in participation. Then, all participants were advised to contact a sports PT in the Norwegian FA Medical centre's network for rehabilitation and then, when the rehab was completed and within a week after the player had fully returned to play, to contact AK for randomisation.

3.4 Randomization, blinding and treatment allocation

The Castor Electronic Data Capture (EDC) software was used to randomize subjects to either the IG or CG. The participants were allocated with equal distribution to each group (50/50). An un-blinded external researcher, Muhammed Ikhwan Zein (MIZ) from Amsterdam University Medical Centers (UMC), The Netherlands, was responsible for the group allocation. The un-blinded researcher was not involved in any matters concerning the recruitment of Norwegian participants. The main researcher (AK) and the PI (TEA) of the "Norwegian arm" the study were blinded to the group allocation. The participants were told not to communicate their group allocation or type of intervention to any other participating players or to any member of the project group.

3.5 Intervention group – NHE protocol

The IG performed 27 sessions of the hamstring exercise protocol in a 10-week program, table 4. Following the first 10 weeks, the exercise protocol was performed once weekly (3 sets of 12, 10, and 8 repetitions) until the end of the 12 months (52 weeks) follow-up. A full NHE intervention consisted of a total of 69 sessions.

The un-blinded researcher (MIZ) provided participants in the IG with NHE protocol and instructions on how to perform the NHE. Players were instructed on how to perform the exercise program on their own at home or in a gym, including involvement of a partner. NHE instructions, information documents and link to video instruction are found in appendix (6).

Table 4: *Nordic Hamstring Exercise Protocol (Zein et al., 2022)*

Week	Frequency, per week	Number for sets per training	Repetitions per set
1	1	2	5
2	2	2	6
3	3	3	6-8
4	3	3	8-10
5-10	3	3	12-10-8 reps
11-52	1	3	12-10-8 reps

3.6 Control group

The CG was instructed to follow their routine RTP training schedule. To capture a real-world setting, the CG was allowed to continue taking part in the project if they had used a self-initiated injury prevention program (e.g., FIFA 11+, Nordic hamstring exercise, Copenhagen adductor) in their routine training. The use of leg and/or core strength programs and other injury prevention programs/exercises (self-initiated) in the CG were monitored throughout the study period filling out an adherence section in the questionnaire (appendix 5). There was no specific monitoring of performing the NHE in the CG. Participants in the CG were considered drop-outs if they performed the Nordic Hamstring Exercise with the same or higher prescription (27 sessions or more) than the standard protocol conducted in the IG. Participants in the CG were not considered drop-outs if they performed the NHE with lower prescription than the standard NHE protocol used in the IG (26 sessions or less).

3.7 Data collection procedure

Data used in the "Norwegian arm" of the SHARP study was collected between October 2021 and 1st of January 2023. Data was collected through an electronic online-based questionnaire which was filled out once a week during the first 10 weeks, then once during the 6th, 9th and 12th month. Both groups received the same questionnaire, however, the IG had an extra section to fill out related to the NHE. Data was collected and stored in Castor EDC. To make sure that the participants continued reporting in the weekly questionnaires, the researchers had access to Castor and could follow the progression of each participant. Those, who for any reason did not respond to the latest questionnaires would get a reminder and request by SMS or e-mail to explain why they had not completed the questionnaire, i.e., if they did not want to complete or had forgotten to complete the questionnaire.

Due to the long follow up period of 52 weeks and the recruitment for the "Norwegian arm" starting in April 2022, it was not possible to collect enough data on the late hamstring re-injury rates within the deadline of data extraction, 1st January 2023. Therefore, the "Norwegian arm" study only investigated the early re-injury rates occurring within 2 months (10 weeks) following RTP. However, the recruitment period in Norway will continue until (31.05.2023) and all collected data will contribute to the results of the main SHARP study, investigating early and late hamstring re-injury rate.

3.8 Outcome measures

3.8.1 Baseline data

All participants were to complete the baseline questionnaire at the beginning of the study as a part of the SHARP questionnaire. Overview of outcome measures are presented below (Table 5).

Table 5: *Overview outcome measures from baseline questionnaire, IG and CG*

Subject characteristics	
Gender	Male/female
Age	*Yrs
Wight	*Kg
Height	*Cm
Level of sport	Recreational, semi-professional or professional
Leg dominance	Right/left/both
History of injury	
Date of hamstring injury	*(dd/mm/yyyy)
Injured limb	Right/left/both
Injury mechanism	Sprinting/non-sprinting
History of performed hamstring exercise or other injury prevention programs	No/if yes, name of program, frequency-set-repetition
History of NHE during rehabilitation	No/if yes, total number of sessions
History of hamstring injury	No/if yes, number of injuries both legs and same leg, date of hamstring injury same leg
Psychological readiness before RTP and subject re-injury risk estimation	
Perceived recovery	0 = Not recovered at all, 100 fully recovered
Chance of sustaining hamstring re-injury	0 = Definitely get re-injury, 100 = definitely NOT get re-injury
Chances of sustaining another injury non-hamstring related	0 = Definitely sustaining another injury, 100 = definitely NOT sustain another injury

*Yrs, years; kg, kilogram; cm, centimetres; dd, day; mm, month; yyyy, year

3.8.2 Primary outcome

The primary outcome was the number of early hamstring re-injuries occurring within 2 months (10 weeks) after players had fully returned to play following recent HI, table 6. A re-injury was defined as "An injury of the same type and at the same site as the index injury and which occurs after returning to play from index injury" (Fuller et al., 2006). Re-injury occurring within 2 months after RTP was defined as an "early re-injury" while re-injury occurring 2-12 months after RTP was considered a "late re-injury" (Fuller et al., 2006). Participants reported any incidence of sustaining a hamstring injury during the follow-up period of 12 months through the online follow-up questionnaires.

Table 6: *Primary and secondary outcomes after 2 months (10 weeks)*

Primary outcome	
Hamstring re-injury rates	*No. of re-injuries
Secondary outcomes	
Adherence	Frequency, sets, repetition
Frequency (match)	*No. of sessions
Duration (match/training)	Minutes/hours
Non-hamstring injuries	*No. of injuries/site/acute or chronic
Injury burden	*Days (per 1000/h football exposure)

*No, number; h, hours

3.8.3 Secondary outcomes

Questionnaires were also used to report adherence to the NHE program in the IG. This included the frequency, sets, repetitions and side effects of performing the NHE as well as potential reasons for missing exercise/sessions (lack of time, illness, motivation, injury or other). Both the IG and the CG were asked to report any potential side effects of the NHE or other injury prevention exercises or programs.

The participants reported weekly frequency of matches, duration of matches (min) and duration of training sessions (h) in the questionnaire. Training exposure was defined as “team based or individual physical activities under the control or guidance of the teams coaching or fitness staff that are aimed at improving or maintaining players football skills or physical conditioning” (Fuller et al., 2006). Match exposure was defined as “play between teams from different clubs” (Fuller et al., 2006).

The incidence of other non-hamstring injuries was recorded over the 2 months (10 weeks) follow-up period based on the injured body part (head, neck, upper limb, trunk, and lower limb), injury site (left/right) and injury classification (acute/chronic). Injury was defined as “any physical complaint” sustained by a player during a football match or football training, irrespective of the need of medical attention or time loss from activity” (Fuller et al., 2006).

Injury severity was defined as “The number of days that elapsed from the date of injury to the date the player returned to full participation in team training and was availability for match selection” (Fuller et al., 2006). If a hamstring re-injury restricted the participant from taking fully part in football training or match, this was defined as "time loss" or duration of injury (Fuller et al., 2006). The duration of days from hamstring re-injury occurrence to RTP was reported in the questionnaire. By knowing the duration of re-injury, this data would be used to calculate the burden of hamstring re-injury. Re-injury burden was defined as number of re-injury days lost per 1000 hours of football exposure (Bahr et al., 2018).

3.9 Sample size

The estimated sample size in the SHARP study was based on a significance level of 0.05, a power of 0.9, a dropout rate of 10% and re-injury rate of 15%. In evaluating the early re-injury rate (2 months), a total of 368 subjects are needed (184 subjects in each group). The "Norwegian arm" of the SHARP study intended to recruit as many participants as possible, with a pre-set total target of 50 players.

3.10 Statistical methods

Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences) and MS Excel which was the preferred software's. Descriptive statistics were conducted to describe baseline characteristics and exposure data. The data was presented as total numbers (n) and/or mean values.

3.10.1 Analysis of primary outcome

The hamstring re-injury rate was recorded as total number of re-injuries.

3.10.2 Adherence and exposure calculation

Adherence with the protocol was calculated based on the monitoring questionnaire results.

Adherence calculation: Amount of NHE sessions /total NHE session x 100% = % of adherence

- 2 months follow-up for early re-injury = amount of NHE sessions/ 27 x 100% = % adherence

Exposure calculation

- Training exposure: Duration (hours) of training per week.

- Match exposure: Frequency (times per week) and duration (minutes per session) of football match.

Injury burden was presented as number of days with time loss per 1000h of football exposure.

3.11 Ethics

3.11.1 Information & consent process

Any football player wanting to participate received and was asked to read both the information letter and the consent form. Those willing to participate signed the consent form (appendix 1). Those who did not sign the consent form were excluded from study participation. Every potential player was informed that participation was completely voluntary and that he/she at any time had the option to withdraw from participation, also after signing the consent form, without any consequences. The signed consent form was sent to the researcher (AK) by e-mail.

3.11.2 Benefits, risk assessment and insurance

No adverse events were expected in any of the interventions, as these exercises are widely used and intend to have a preventive effect. Some mild muscle soreness has been reported for eccentric exercises. As participants in the non-intervention groups were instructed to follow their daily practice activities, the risk of participating was comparable to the risk of not participating in the study.

This study's benefit was that the players (IG) were all involved in the hamstring muscles' re-injury prevention protocol. A previous study showed that the intervention (NHE) proved as primary injury prevention to prevent acute hamstring injury.

The participants were not covered by a special insurance; however, they are already covered by the compulsory basic football licence coverage provided by The Football Association of Norway. The risks of participation in this study were negligible.

3.11.3 Handing and storing data

After giving their permission to participate in this study, participants received an internet link to access and complete questionnaires in Castor EDC. All data gained outside Castor EDC was stored on the Amsterdam University Medical Centers (location AMC) and the Oslo Sports Trauma Research Centre (Oslo) on a secured hard drive which was password protected. All data was coded and stored in the Castor EDC online data base, which met the Amsterdam University Medical Centers (location AMC) safety criteria and good clinical practice guidelines. The primary investigator (AK) and project leader (TEA) were accountable for safeguarding the coded data through password secured access. All participants data will be archived for at least 15 years and handled with in accordance with the General Data Protection Regulation (GDPR). Data protections was provided through the safety protocol of Castor EDC with automated backups and SSL security.

3.11.4 Ethical approval

This study has been approved by the regional ethical committee at The Norwegian School of Sports Sciences (NIH), Department of Sports Medicine (18.01.2022) and by the Norwegian Centre for Research Data (NSD) (24.02.2022). Se appendix (2 and 3) for signed and approved agreements.

3.12 The "Norwegian arm attitude and belief" questionnaire on the NHE and protocol

3.12.1 Background/rationale

Due to the low number of recruited players into the "Norwegian arm" of the SHARP study, I decided in collaboration with the main supervisor, to conduct a descriptive cross-sectional study, within the master thesis, to gain insights into PT's attitudes, beliefs & experience with the NHE and its implementation.

A questionnaire ("Norwegian arm attitude and belief" questionnaires) (Appendix 7). was developed by AK & TEA based on the Reach Adoption Effectiveness Implementation Maintenance (RE-AIM) framework in February 2023 after ending the recruitment for the "Norwegian arm" of the SHARP study".

3.12.2 Recruitment and data collection

All the PTs who responded to the initial participant recruitment invitation (SHARP) received the questionnaire. The data was collected between 05.03 and 25.03 2023. In addition, the questionnaire was sent to:

- All team PTs in the Norwegian female premier league (Toppserien)
- Some PTs working with Norwegian football national teams at different levels
- Some additional PTs working either at sports physiotherapy clinic or in a football club at any level.

The "Norwegian arm attitude and belief" questionnaire on the NHE and protocol was sent to a total of 49 PTs. Thirty-one of these had initially been invited to the player recruitment of the SHARP study, while additional 18 PTs not involved in recruitment, also were invited to respond do the questionnaire.

3.12.3 Outcomes

The primary outcome of the questionnaire was to

- Map the physiotherapists attitudes to HI prevention, beliefs of the NHE and to what extent and how they use the NHE or other exercises for HI prevention.

The secondary outcomes were to

- Study the PT's feedback on the number of sets, repetitions, and sessions prescribed in the NHE protocol used in "the Norwegian arm" of the SHARP.
- Give a demographic description of the PTs invited to recruit participants and additional other PTs who were not invited to participate in the SHARP but received the questionnaire.

The questionnaire collected descriptive information about where the PTs work (clinic or with a football team), at what level football players they work with, how often they examine football players with HI and if they were familiar with the NHE.

3.12.4 Handling of data

All PTs were informed that completion of the questionnaire was voluntary. They were instructed to return the questionnaire by email to the researcher (AK). The questionnaires that were filled out and sent in return by the PTs were stored on a password protected computer by the researcher (AK).

4. Results

In the this section, the results from the “Norwegian arm” of the SHARP study will be presented. This includes the results from the different recruitment strategies, the data collected on hamstring re-injuries from the main SHARP study and the results collected from the “Norwegian arm attitude and belief” questionnaire.

4.1 Results from the SHARP study

4.1.1 Recruitment from “the Norwegian arm”

From the two recruitment strategies used in the “Norwegian arm” of the SHARP study, a total of 18 football players sustaining HI were registered through strategy 1 and 2. Among the 18 registered players, zero Norwegian football players were included for participation in the study, figure 7. No female football players suffering HI were registered through either strategy.

From outreach strategy 1, four HIs were reported to AK whereas zero was included in the study as they did not respond to follow-up email or sign the consent form. For strategy 2, The FA Medical Call Centre reported 14 HIs to AK. Four players expressed the desire to participate, however they did not respond to follow up emails or sign the consent form and therefore excluded from participation.

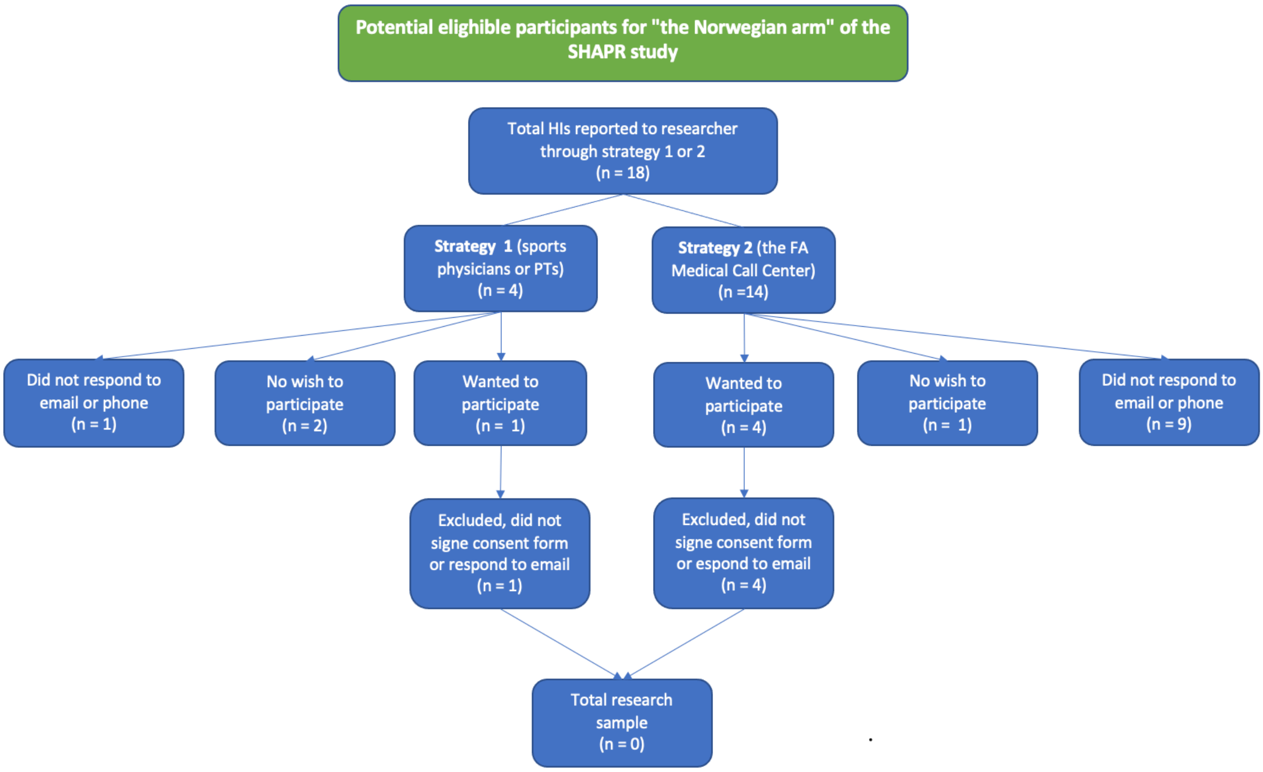

Figure 7: *Flowchart illustration of recruitment process and player registration in the "Norwegian arm" of the SHARP study*

4.1.2 Participants from the main SHARP study

Twenty-seven eligible players were registered in the main SHARP study and evaluated for participation in the "Norwegian arm", where of eight players were included. Of the 19 players excluded, they either did not meet the inclusion criteria, were not included within the first week after RTP or did not respond to emails after registration, figure 8.

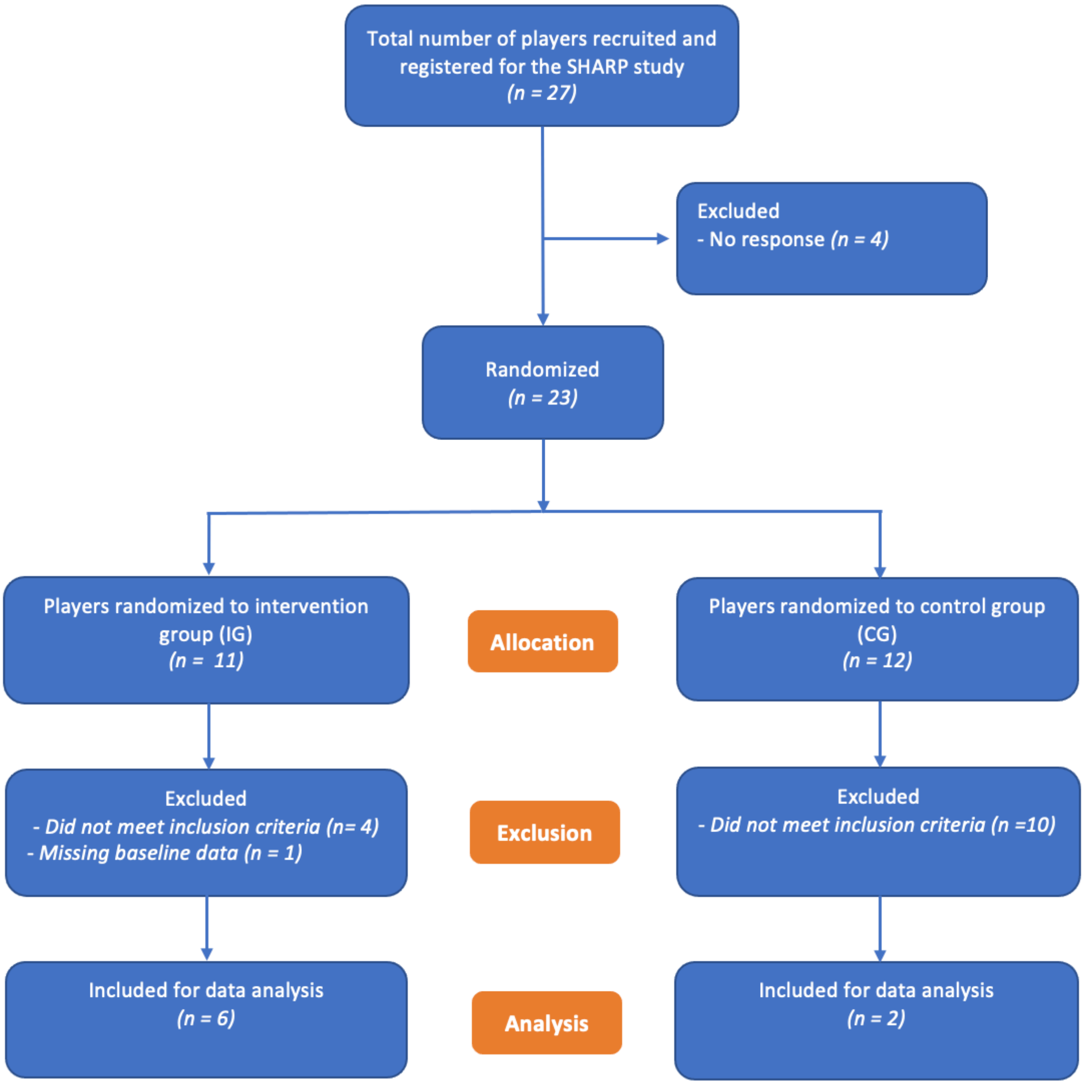

Figure 8: *Flowchart illustration of the process from registration to randomization, exclusion and data analysis. Data from the main SHARP study at the date of data extraction, January 2023.*

4.1.3 Player characteristics, the main SHARP study

Six players were allocated to IG and two players to the CG, table 7. Players were between 21-40 years old. Only recreational players were included (100%). For leg dominance, four players were right leg dominant, one left leg dominant and one was two legged. In the IG, only three out of six participants reported data on age, weight, height, and BMI. In the CG only one player reported data on age, weight, height, and BMI. Numeric data was presented as mean only.

Table 7: *Baseline characteristics of the intervention and the control groups, presented as n* or mean***

	Intervention group N=6	Control group N=2	Total/mean** N=8
Gender (n)*			
Male	6	2	8
Female	0	0	0
Age (yr)**	29.0	26.0	28.2
Weight (kg) **	63.5	55.0	61.4
Height (cm)**	168.3	169	168.5
BMI **	22.4	19.3	20.8
Level of sport (n)*			
Recreational	6	2	8
Semi-professional	0	0	0
Professional	0	0	0
Leg dominance (n)*			
Right leg	4	2	6
Left leg	1	0	1
Two-legged	1	0	1

*n, number of players reported data; **yr, years, kg, kilogram; cm, centimetres.

4.1.4 History of previous hamstring injury

In the IG, two out of six had experienced a previous hamstring injury, while in the CG group no previous HIs were registered, table 8. However, there was missing data as one player in CG did not report neither yes nor no on previous HI. A total of five previous HIs were reported in the IG, with all previous injuries occurring in the same thigh. One player registered a history of four previous HIs in same thigh, while one player had had one previous injury in same thigh. The right leg was the most affected limb, with 67% in the IG and 100% in CG. Sixty-three percent of the HIs were related to sprinting and 37% were caused by a non-sprinting mechanism. Two players, one from each group, did not report data on “history of performed NHE or other prevention programs during rehabilitation” or “history of NHE during rehabilitation”.

Table 8: *History of previous hamstring injury, n**

	Intervention group N=6	Control group N=2	Total N=8
History of hamstring injury			
Yes	2	0	2
No (index injury)	4	1	5
Total previous hamstring injuries	5	0	5
Injured limb / side of injury			
Right	4	2	6
Left	2	0	2
Injury mechanism			
Sprinting	4	1	5
Non-sprinting	2	1	3
History of performed NHE or other injury prevention programs			
Yes	2	0	2
No	3	1	4
History of NHE during rehabilitation			
Yes	3	1	4
No	2	0	2

*n, number

4.1.5 Perceived recovery/readiness to play following RTP from recent hamstring injury

Players were asked to report their psychological readiness to play before RTP, table 9. Only four out of eight players completed the form and responded to all questions. Blanc spaces indicate missing data.

Table 9: *Psychological readiness to play before RTP and subject re-injury risk estimation, presented as reported value per player and mean per group (IG & CG)*

Participants (ID)	Perceived recovery *(100-0)	Chance of sustaining hamstring re-injury **(100-0)	Chances of sustaining another injury non-hamstring related ***(100-0)
IG			
1	0	50	80
2	100	100	100
3	0	100	-
4	0	50	50
5	0	-	-
6	-	-	-
Mean	20	75	77
CG			
7	80	50	50
8	-	-	-
Mean	80	50	50

- = missing data; ID of participants
*100 = Completely recovered, 0 = not recovered at all
**100 = I will definitely NOT get re-injury, 0 = I will definitely NOT get re-injury
***100 = I will definitely NOT sustain another injury, 0 =I will definitely sustain another injury.

4.1.6 Reported sessions with PT or fitness coach during rehabilitation

Table 10 show the reported sessions each player reported having with either PT or other fitness coaches during their HI rehabilitation. There was missing data from player ID6 and ID8.

Table 10: *Total sessions with PT or fitness coach during hamstring injury rehabilitation, n**

Participants (ID)	Total sessions with PT	Total sessions with fitness coach
IG		
1	0	0
2	0	0
3	9	9
4	5	0
5	5	5
6	-	-
CG		
7	0	0
8	-	-

** ID of participants; n, number; PT, physiotherapist; -, missing data

4.1.7 Hamstring re-injury rates

Zero hamstring re-injuries were registered in neither the IG or CG during the first 10 weeks following RTP, table 11. Only non-hamstring injuries were registered where three players reported sustaining some kind of non-hamstring injury.

Player ID2 (IG) reported non-hamstring injuries during week 5,6,7 and 9 without specifying injured body part or injury type (acute or chronic). Player ID4 (IG) also reported an un-specified injury during week 3, 4, 6 and 9. It was not specified if HI or non-hamstring injury but since injured body part was not specified and the player did return to football between injuries it was assumed that the player did not sustain a HI. Player ID5 (IG) reported a non-hamstring injury for every week during the 10-week follow-up. This player reported an overuse injury to the lower back and pelvis over seven weeks, hip/groin injury for one week, knee injury for one week and one week of injury to the upper back and ribs.

Table 11: *Comparison of outcome measures between the Intervention and control groups, n**

Primary outcome	**Intervention group**	**Control group**
Hamstring re-injuries (n)	0	0
Secondary outcomes		
Non-hamstring injuries (n)	4	0
Injury burden (days lost per 1000/h)	n.a	n.a

*n, number; n.a, not assessed

4.1.8 Adherence to the NHE protocol

The results of the players adherence to the NHE are presented per group in table 12 and for individuals in table 13. The IG performed 45% of all sessions, 20% of all sets and 30% of all repetitions as expected per protocol.

Table 12: *Group adherence to the NHE protocol (IG) – presented as total number of sessions, set and repetitions performed by the IG as expected to the NHE protocol, n**

	Actual performed / Expected per protocol	**% Adherence**
Sessions	73 / 162	45.0
Set	95 / 468	20.2
Repetition	216 / 718	30.0

*n, number

There was a large variety in the adherence to the NHE protocol on an individual level. The player with the highest adherence reported having performed 22 of 27 sessions of NHE (81.5%) while the player with the lowest adherence performed 6 of 27 sessions (22.2%). On a group level, the mean number of performed sessions of NHE was 12 out of 27 (44%).

Table 13: Individual adherence to the NHE protocol in the (IG) with total number (n) of performed sessions of the NHE per protocol.*

Participants (ID)	Total sessions of **NHE (n)	Adherence (%)
1	13	48.1
2	10	37.0
3	11	40.7
4	6	22.2
5	22	81.5
6	11	40.7
Mean	12	45

*ID of participants; **NHE, Nordic hamstring exercise; n, number

The players were asked to report reasons for not performing the NHE as instructed and outlined in the protocol. The most common reason not performing NHE was "forgot the schedule" (n=7), "felt tired" (n=6) and "other" (n=6). None of the players registered muscle soreness as a reason for not performing NHE, figure 9.

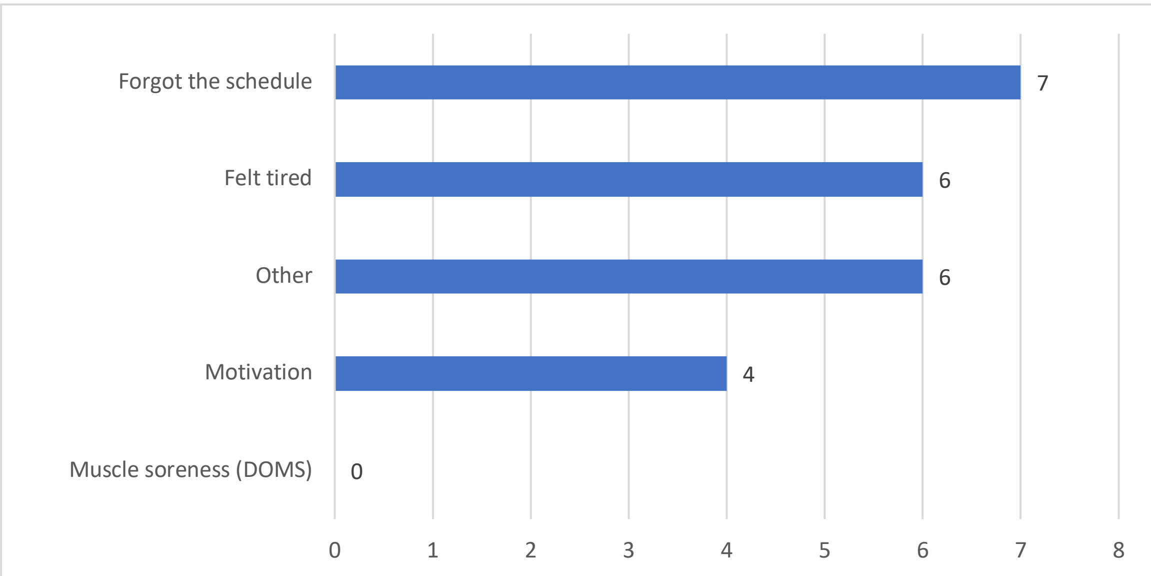

***Figure 9:** Player's registered reasons for not performing the NHE as outlined in the protocol, IG only, (n).*

4.1.9 Match and training exposure

The training and match exposure was presented on group level (figure 14) and individually per player (table 15).

Table 14: *Group exposure to training and match. Presented as mean values per week (1-10 weeks)*

Exposure per week	Intervention group (n=6)	Control group (n=2)
Total Training (h)	81	41
Mean training per week (h)	1.35	2.1
Total matches (n)	69	24
Mean matches per week (n)	1.15	1.2
Total match time (min)	3630	940
Mean match min per week (min)	52.6	47

*h, hours; n, number participants; min, minutes

Table 15: *Match and training exposure per participant over 10-week follow-up, IG and CG*

Participants (ID)	Matches played	Match time	Match exposure	Total training time	Training per week
IG	Total (n)*	Total min*	Mean min/week*	H*	H*
1	13	704	56.9	7	0.7
2	9	695	77.2	13	1.3
3	8	540	67.5	11	1.1
4	17	781	45.9	23	2.3
5	14	275	19.6	13	1.3
6	8	535	66.9	14	1.4
CG					
7	16	705	44.1	13	1.3
8	8	175	29.4	28	2.8

* ID of participants; n, number; h, hour; min, minutes; t, total; m, matches

There was some missing data in the data set for match and training exposure. Player ID3 (IG) reported 0 matches played and 1 minute of match exposure during week 6 and 8. This number was set to 0 minutes of match exposure as the player reported 0 matches played the same weeks. Same player reported 60 training hours during week 3. This was set to 60 minutes as it was considered likely that the participant meant minutes instead of hours. Player ID4 (IG) registered during week 3 playing 1 match and 1 min of match exposure, this value of match exposure was unexpectedly low, but was kept as 1 min exposure may happen.

4.2 Norwegian PTs attitudes and beliefs on the NHE and protocol

Twenty-six (53%) PTs responded by answering the questionnaire: 18 (69%) of these were PTs initially invited to participate in the "Norwegian arm" of the SHARP study while the remaining eight (31%) were additional PTs who did not take part in the player recruitment of the SHARP study, only responded to the "attitude and belief" questionnaire. There was missing data from the remaining 23 PTs (47%) who did not respond to the questionnaire. The results from the "Norwegian arm attitude and belief" questionnaire are presented below according to the RE-AIM framework.

4.2.1 Reach – People must know about it

Among the respondents, 14 (53%) of the PTs worked in a sports physiotherapy clinic, eight (31%) worked in a football club and four (15%) worked in both a football club and in a sports physiotherapy clinic, table 16. For those working in a football club, eleven (73%) reported to work with professional football players, three (20%) with semi-professionals and one (7%) with recreational football players. When asked if they were familiar with the NHE, 100% replied being familiar with the exercise and the NHE program.

Table 16: *Descriptive data of responding PTs, n**

"Do you work in a sports clinic or with a football team?" n (%)		
Sports clinic	**Football team**	**Both**
14 (53)	8 (30.7)	4 (15.3)
"If you work with a football team, at what level?" n (%)		
Professional	**Semi-professional**	**Recreational**
11 (73.3)	3 (20)	1 (6.6)
"Are you familiar with the NHE?" n (%)		
Yes	**No**	**Don't know**
26 (100)	0 (0)	0 (0)

*n, number

Table 17 presents how often the PTs reported that they examined football players presenting with HI. More than half of the PTs reported "monthly" examination of players with hamstring injury (61%) while three (12%) reported "weekly" and seven (27%) "rarely". No PTs reported examining HI either "daily" or "never".

***Table* 17:** Participants response to "*How often do you examine football players with an acute hamstring injury, either in your clinic or in the football team?" n* (%)*

Daily	Weekly	Monthly	Rarely	Never
0 (0)	3 (11.5)	16 (61.5)	7 (26.9)	0 (0)

*n, number

4.2.2 Effectiveness – the program needs to work

The PTs were asked about the importance of football players performing regular injury prevention training to prevent hamstring index injury or re-injury. Twenty-four (92%) reported this being "very important" with the remaining two respondents (8%) reporting "moderately important", table 18. As a follow up question, they were asked to rate to what degree the NHE could affect the extent of HI's in football. All respondents reported that the NHE could reduce HI to either a "certain extent" (31%) or "to a large extent" (69%). No respondents reported that the NHE "cannot reduce" or "can increase" the extent of HI, table 19.

Table 18: Participants responses to "*How important is it for football players to perform regular injury prevention training to prevent hamstring injury and hamstring re-injury?" n* (%)*

Very important	Moderately important	Somewhat important	Not important at all	Don't know
24 (92.3)	2 (7.6)	0 (0)	0 (0)	0 (0)

*n, number

Table 19: Participants responses to "*Do you believe the Nordic Hamstring Exercise can affect the extent of hamstring injuries in football?" n* (%)*

Yes, NHE can **reduce** Hamstring injuries to a *large* extent	Yes, NHE can **reduce** Hamstring injuries to a *certain* extent	No, NHE **cannot reduce** Hamstring injuries to *any* extent	Yes, NHE can **increase** Hamstring injuries to a *certain* extent	Yes, NHE can **increase** Hamstring injuries to a *large* extent
18 (69.2)	8 (30.7)	0 (0)	0 (0)	0 (0)

*n, number

4.2.3 Adoption – People must decide to use it

When asked if they used the NHE as part of the injury prevention or rehabilitation process, 14 (54%) respondents reported "yes, often", twelve (46%) "yes, rarely" and none reported "no, never". As many as 24 (92%) replied that they used other preventative training exercises in addition to the NHE, while none reported to use other exercises instead of the NHE for HI prevention, table 20. Those who reported using other injury preventative training were asked to specify the type of preventative training used. These results have been categorised and presented in figure 10. The most frequent exercise reported to be used in addition to the NHE was the Single Leg Romanian Dead Lift (SLRDL). Thirteen reported to use general hamstring strengthening exercises, with ten specifying hip dominant exercises and one using knee dominant exercise. The second most reported injury preventative training method were HSR, followed by "load management and monitoring".

Table 20: *Participants response to following questions, n* (%)*

"Do you use the Nordic Hamstring Exercise for injury/re-injury prevention and/or during the rehabilitation process of Hamstring Injuries?" n (%)			
Yes, often	**Yes, rarely**	**No, never**	**I prefer using other hamstring exercises**
14 (53.8)	12 (46.1)	0 (0)	0 (0)
"Do you use other preventative training in addition to the Nordic Hamstring Exercise with the intention to mitigate the burden of hamstring injuries in football?" n (%)			
Yes	**No**	**Don't know**	
24 (92.3)	1 (3.8)	1 (3.8)	

*n, number

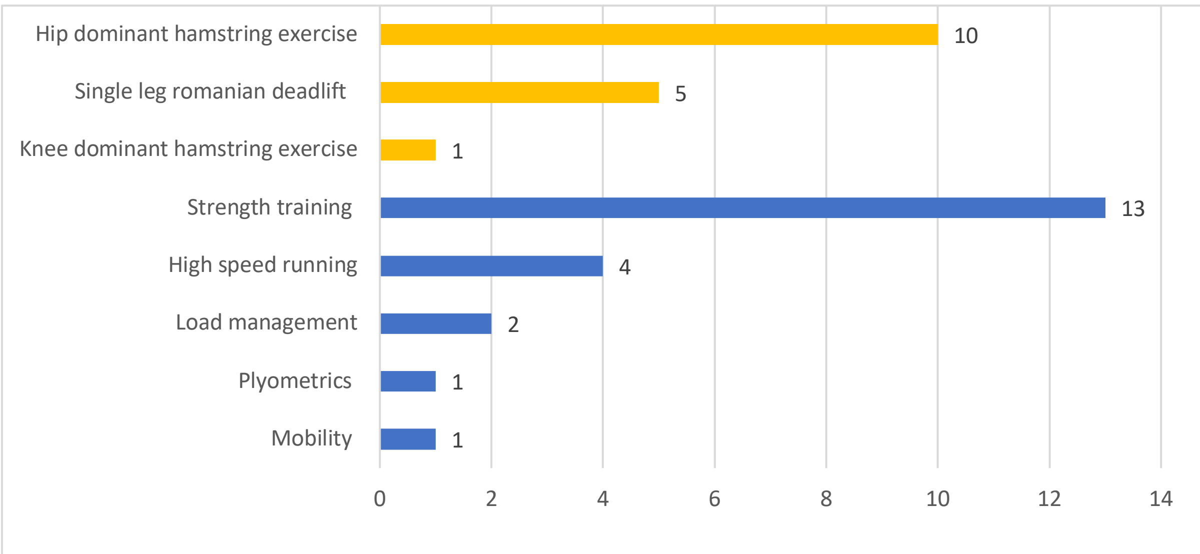

Figure 10: Participants responses to *"Other preventative training methods used in addition to the NHE with intention to mitigate the burden of HI". Yellow presents the three specific*

categories for hamstring strength exercises while blue indicate different hamstring specific training or interventions used for injury prevention.

4.2.4 Implementation – People must use it correctly

Multiple questions were used to investigate how PTs implement the NHE in their daily work. The PTs were asked to specify any reasons for why they chose to use the NHE as part of hamstring prevention or rehabilitation, figure 11. "The injury preventative effect" was the reason chosen by most of the respondents, followed by "does not require any equipment" and "the physical performance effect".

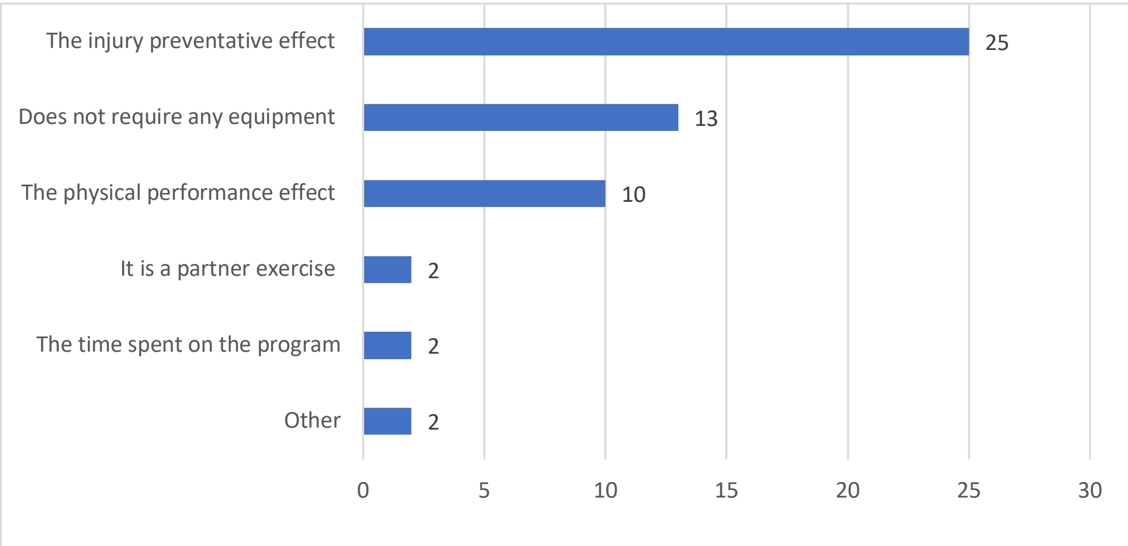

Figure 11: Participants responses to *"What are the reasons that underpin your decision to use the "Nordic Hamstring Exercise" as part of hamstring injury rehabilitation or prevention?". Participants were allowed to choose several options.*

Most respondents reported that they usually prescribed NHE as "modified to protocol", table 21. All the respondents used the NHE irrespectively of whether it was the competitive season or the pre-season, table 22. They were asked to respond in what context and setting they implemented the NHE as injury prevention, being informed they could choose more than one option (figure 12). The most frequently chosen option was "as individual strength training" and "as part of organized football training".

Table 21: Participants responses to "*How do you prescribe the NHE to football players during rehabilitation or as injury prevention?" n* (%)*

As described in NHE protocol	**Modified to NHE protocol**	**Don't know**
4 (15.3)	21 (80.7)	1 (3.8)

*n, number

Table 22: Participants responses to "*During the football season, when do you use the NHE?" n* (%)*

During pre-season only	**In competitive season only**	**Both**
0 (0)	0 (0)	23 (100)

*n, number

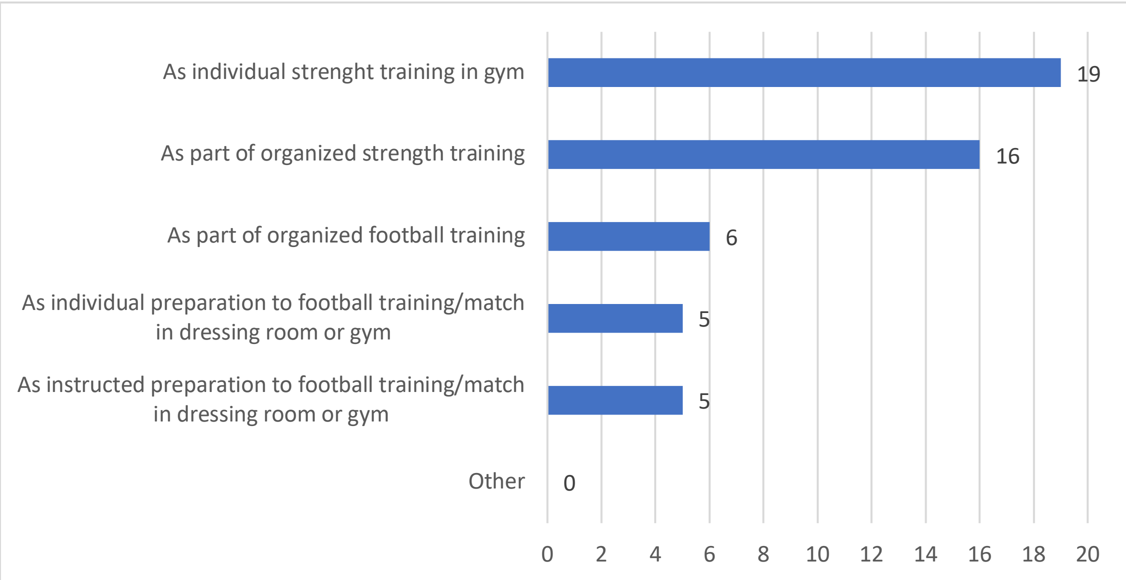

Figure 12: Participants responses to *"How do you use the NHE for hamstring injury prevention?". Participants were allowed to choose several options.*

4.2.5 Maintenance – People need to continue using it

The PTs were asked to reply, based on their experience, to what extend football players adhere to the NHE over time and if they experience the players being motivated to perform the NHE, figure 13. For the players adherence, the most common response was that the PTs experienced players adhering to the NHE "sometimes" (42%) and "yes, most of the time" (38%). None (0%) experienced that player adhered either "all the time" or "never". As many as 58% replied that football players most of the time express that they are motivated to perform the NHE. None (0%) of the PTs reported that the players “never” were motivated to perform the NHE as part of rehabilitation or injury prevention program.

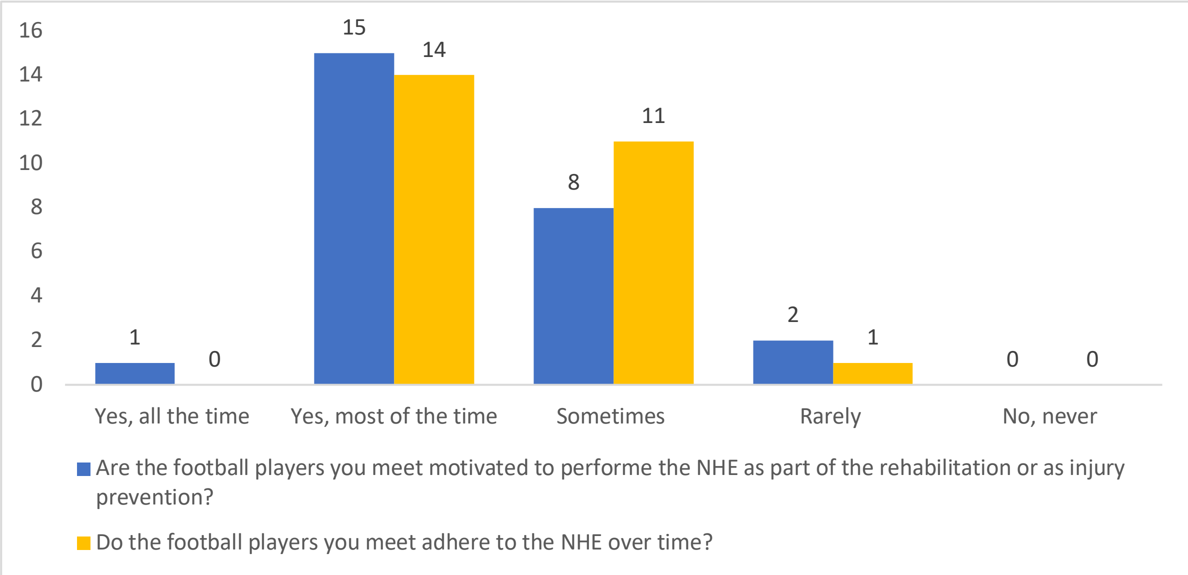

Figure 13: *Participants responses to player adherence and motivation to the NHE. *No respondents replied “no, never” to either questions or “yes, all the time” on player motivation.*

4.2.6 Responses to the prescribed NHE protocol

All participating PTs were asked to give feedback on the prescribed dosage and frequency used in the NHE protocol from the SHARP study, figure 14. They were instructed to choose one of the options given, “too high”, “appropriate”, “too low” or “don’t know”:

- For the prescribed number of sessions per week, 65% responded that the frequency was “appropriate”, while 27% respondents believe this was “too high” and 8% responded “don’t know”.
- The respondents had the highest agreement when asked about the number of sets per week. A total of 89% reported that the prescribed dose was appropriate. One respondent reported this being too high while two responded “don’t know”.
- For the given number of repetitions per set/training, 62% agreed this was “appropriate”. Twenty-seven percent believed the number of repetitions per week/training was “too high” while 11% replied “don’t know”.

For all the questions regarding the NHE protocol, none of the respondents (0%) reported that either the sessions per week, sets per week or repetitions per set/training were “too low”.

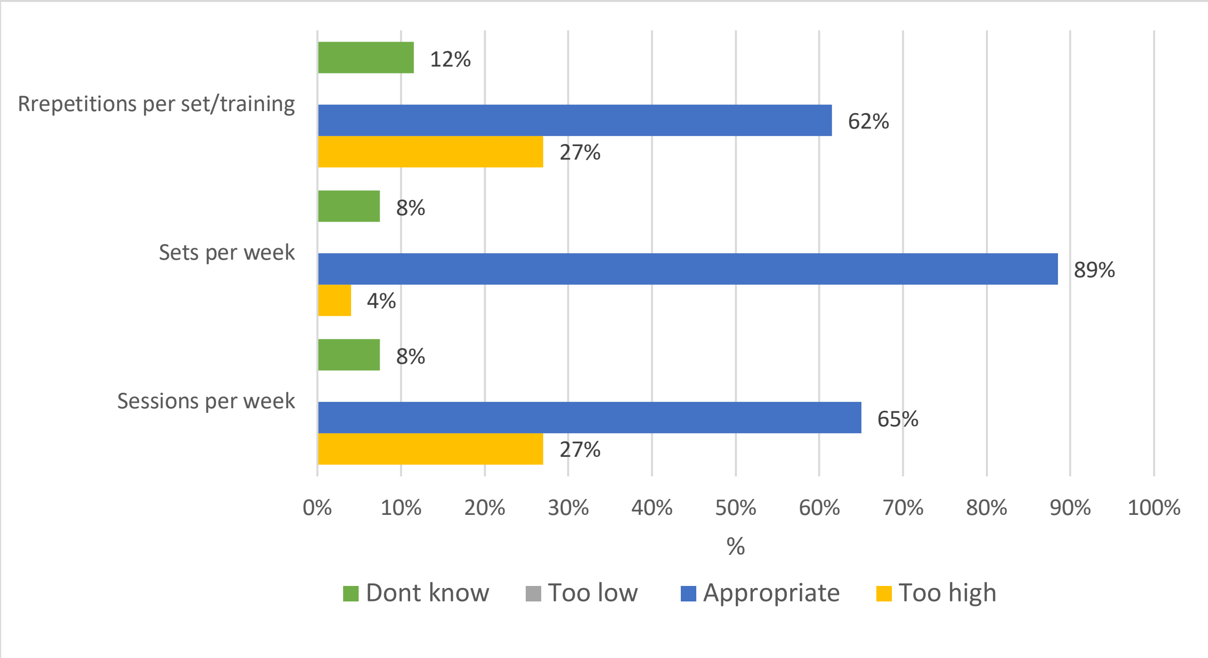

Figure 14: *Participants responses to thoughts on prescribed dosage of the NHE in the SHARP study. *No respondents replied “too low” on any of the points above.*

5. Discussion

The primary aim of this master thesis was to investigate the effect of the NHE in reducing the incidence of short-term hamstring re-injuries (secondary prevention) in football players following completed RTP from a recent HI. Secondly, we measured all players' match and training exposure, as well as individual adherence to the NHE protocol in the IG. In addition, in "the Norwegian arm" of the SHARP study, we investigated the attitudes and beliefs of Norwegian physiotherapists related to the NHE and protocol. The following sections of the discussion will include a short summary of the primary results, a discussion of the results and methodological considerations of the study.

5.1 Results SHARP

5.1.1 Hamstring re-injuries

Zero hamstring re-injuries were registered in both the IG and the CG during the 10-week follow-up period. When reviewing the literature, hamstring re-injuries often occurred early within 2 months from RTP (69%), re-injury incidence were higher among recreational football players compared to professionals (14% to 33%) and male football players suffered more re-injuries compared to females (Cross et al., 2013; Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022; Hägglund et al., 2016; Wangensteen et al., 2016). The most recent UEFA Elite Club Study showed a hamstring re-injury rate of 18%, two-thirds of these occurring within 2 months following RTP (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). Based on the literature it was expected a re-injury rate of 15% in the SHARP study. The result from this study is positive, as there were zero reported hamstring re-injuries within the first 10 weeks following completed RTP from a recent HI. However, it was not possible to predict if any of these players would have sustained a re-injury the following weeks and months beyond 10 weeks. Also, careful considerations have been made since the number of participants where too low to conclude on the effect of the NHE in reducing hamstring re-injuries. This will be discussed in more detail in section 5.3.3 "strengths and limitations".

5.1.2 Adherence

Players in the IG completed on average 45% of the recommended sessions in the NHE protocol, 1.2 sessions average weekly per player. They completed 20% of the sets and 30% of repetitions described in the protocol. The adherence to hamstring injury prevention exercises differs remarkably between studies. Similar studies investigating the injury preventative effect of the NHE, have reported adherence rates of 91%, 91% and 88% to the NHE, respectively (Hasebe et al., 2020; Petersen et al., 2011; van der Horst et al., 2015). However, other interventional studies on injury prevention in football have reported substantial non-adherence (Engebretsen et al., 2008; Gabbe et al., 2006). Harøy et al. (2019) reported an overall group adherence of approximately 70% (0.7 per sessions week) for groin injury prevention while Andersson (2017) reported 53% adherence (1.6 sessions per week) on their shoulder injury prevention program (Andersson et al., 2017; Haroy et al., 2019). The study by McKay (2016) suggests that individual motivational aspects should be considered to improve the adherence to the intervention program (McKay & Verhagen, 2016). Van der Horst (2021) found that personal motivation and knowledge about the NHE was key for stimulating players to adhere to the NHE program or protocol (van der Horst et al., 2021). In the SHARP study, we had expected that the injured players would have had additional motivation to prevent hamstring re-injury as they had just fully completed RTP following recent HI. Unfortunately, the adherence to the NHE protocol in the SHARP study has been low which has impacted the ability to identify a dose-response effect.

Despite that the NHE protocol has proven highly effective in preventing hamstring index injuries, the adherence to the NHE in elite and amateur football players was found to be low in a real world setting (Bahr et al., 2015; van der Horst et al., 2021). The adherence numbers found in the retrospective cohort study by Van der Horst (2021) does not match those found in the experimental studies (Hasebe et al., 2020; Petersen et al., 2011; van der Horst et al., 2015). This may reflect what Carolyn Finch (Finch, 2006) appraises in step 4 in Van Mechelen´s “4 step approach to injury prevention” (van Mechelen et al., 1992). She argues that experimental studies on injury prevention mostly test under “ideal conditions” and in an “artificial environment” created by the researcher. This is where studies can miss potential barriers, which the players could meet in a daily life setting, affecting the adherence (Finch, 2006). It is crucial to understand potential barriers and safety behavior from PTs since they are the primary health and injury prevention providers in Norwegian football. Attitudes and beliefs towards the NHE protocol will be discussed further in section 5.6 the "Norwegian arm attitude and belief questionnaire" on the NHE and protocol.

A common reason for non-adherence to the NHE is the fear of DOMS (Chesterton et al., 2022; Chesterton et al., 2021; Gabbe et al., 2006; Goode et al., 2015; van der Horst et al., 2015). In the SHARP study, players were asked to report reasons for not performing the NHE. Interestingly, none of the players reported DOMS as reason not performing the NHE, figure 9. This could be interpreted as a positive finding as players did not refrain from the NHE protocol due to DOMS. Yet, studies have found that eccentric training with higher volumes (sets and repetitions) give higher reported experience of DOMS (Behan et al., 2023). In our study, the low adherence to the NHE protocol in the IG could explain why no player reported experiencing DOMS. Another potential reason for no reporting of DOMS could have been due to the players performing the exercise with a very low intensity. In the context of strength training, intensity defines the player's perception on how exhausting the exercise was. Intensity is commonly described and measured as players' Rate of Perceived Exertion (RPE) on a 0-10 scale, often in combination with one repetition maximum (1RM) and repetitions in reserve (RIR) (Helms et al., 2016). Intensity, can easily be modified for the NHE by varying time under tension (TUT), adding additional external weights or de-loading. For the participating players, the eccentric hold of the NHE may not be "heavy enough" through the eccentric hold of the exercise. This may result in stimulation under the threshold, and therefore the players should be advised to add additional resistance when performing the NHE. Adequate intensity is key to optimize outcomes of resistance training (Borde et al., 2015; Schoenfeld et al., 2017).

5.1.3 Training and match exposure

Training and match exposure was intentionally reported to calculate the hamstring re-injury burden in the main SHARP study. Nonetheless, due to zero hamstring re-injuries reported and a very limited sample size, it was not feasible to calculate the hamstring re-injury burden. The measure of accumulated match and training exposure may be good indicators for injury risk assessment in individual football players (Ekstrand et al., 2023). However, the physical demands and intensity of training and match exposure may differ hugely between the individuals in both groups. It is unknown whether training or match participation were at high or low intensity, therefore context is decisive. For example, a tactical session would typically be of low intensity without any sprinting, a 7v7-10v10 football session would require a higher total of HSR distance with moderate intensity, while playing 1v1-6v6 on a restricted pitch demands higher intensity with less HSR and maximal sprints. There are many factors which should be recognized and considered which affect the load and demands of the hamstring muscles during football training and match-play.

5.1.4 Report of perceived recovery

The response on "perceived recovery" and "chances of sustaining hamstring re-injury" or "other non-hamstring injuries" was poor in terms of report rate and outcome. There were missing data from four of the eight participants. Despite the high level of missing data, it was interesting to observe that the IG reported a mean value of 20/100 (100 = completely recovered), table 9. These numbers indicate that players in the IG returned to football participation without having fully recovered from their recent HI. The main SHARP study reported the number of sessions the players had with PT or athletic trainer during the rehabilitation, table 10. With a larger sample size, this could have provided valuable feedback on the role of the PTs in HI rehabilitation and prevention of hamstring re-injuries. Importantly, and for consideration, the players who participated in the study all competed on a recreational level. Therefore, these players most likely did not have access to a club PT or fitness coach which could have guided rehabilitation and facilitated a safe RTP.

We observed an unexpected inverse correlation between PT sessions and recorded recovery, however this was most likely due to the small sample size: player ID3, ID4 and ID5 reported the most sessions with PTs while still reporting 0 (0= Not recovered at all) on "perceived recovery", while ID2 reported only 2 sessions with PT, but a perceived recovery of 100. Players also reported a perceived considerable risk of sustaining a new HI or a non-hamstring related injury. Fear of sustaining re-injuries is common in sports and can potentially lead to poor rehabilitation outcomes (Hsu et al., 2017). Moreover, psychological factors should be considered during rehabilitation to optimize a safe RTS, which can increase the chance of player returning to pre-injury performance (Ardern, Osterberg, et al., 2014; Ardern et al., 2013). In addition to the RTS continuum and StARRT framework for RTP, Ardern et al (2016) created the “biopsychosocial model of RTS after injury” which not only addresses the physical factors but also the psychological and social/contextual factors. For optimizing rehabilitation outcomes, King (2019) advocates PTs should empower the player through education, engage the player in the planning of the rehabilitation period, give feedback and be transparent by frequently involving other stakeholders in the process (King et al., 2019).

Definitive conclusions could not be made based on these reported measures. The amount of missing data on perceived recovery must be recognized as a limitation. Also, the reported outcomes of “perceived recovery” seems unusual with 4 players reporting a score of zero (no recovery). It should be considered that it is possible that the players may have misinterpreted the question and scoring system. These findings imply the importance of PTs guiding football players to a safe RTP. There is unfortunately no high-level evidence for “best practice” in involving PTs in HI rehabilitation and RTP criteria (Paton et al., 2023; van der Horst et al., 2017).

5.2 Study population

Zero players sustaining HI were recruited to the “Norwegian arm” of the SHARP study. This was unexpected, considering HIs are the most common injury in football, representing 20% of all time- loss from training/match (Ekstrand, Bengtsson, Walden, Davison, Khan, et al., 2022). Unfortunately, 27 players were recruited through the main SHARP study, whereof only eight were found to be eligible and included in the data analysis of this master thesis.

The distribution of players between the groups after randomization and exclusion was skewed, with six players in the IG and two in the CG. This could be explained by the high number of excluded players (n=19) which potentially would have balanced out the groups more. With a loss of 70% of all players after final exclusion, this reduced the power and validity of the study. One cannot deduce if the potential outcomes of the excluded participants would have had a positive or negative effect on the outcome of the study if there were not so many players unaccounted for in the results.

Of the included players, 100% of them were men, with zero female football players suffering HI reported from either the "Norwegian arm" nor the Indonesian, Dutch or Danish study groups. Previous studies do show that male players are 64% more likely of sustaining HI compared to female (Cross et al., 2013). However, the physical demands to female football is on the rise, and currently HIs are one of the most common injuries among female football players (Bradley, 2019; Horan et al., 2022; Lopez-Valenciano et al., 2020). The total absence of female players recruited to the main SHARP study and the "Norwegian arm" were unexpected. Whether the Indonesian, Dutch or Danish study groups collaborated with any female football clubs/team or only male, is unknown. Based on the incidence of HI among female football players, we would have expected more female players suffering HI to be reported especially through strategy 2.

Five previous HIs were reported in the IG while zero in the CG. Knowing that previous HI does increase the risk of sustaining hamstring re-injury, this could predispose the IG of hamstring re-injury (Green et al., 2020). Older age is also considered a risk factor of HI. Despite large age variation within both groups (IG 26-40, CG 21-31), we observed a higher mean age in the IG and more HIs reported in the IG. Due to the sample size it was not possible to conclude if the IG were at higher risk of hamstring re-injury compared to CG (Green et al., 2020).

5.3 Methodological considerations

5.3.1 Study design and randomization

Randomized controlled trials implies randomized allocation of participants to either an intervention group or control group. RCTs conducted with good quality are considered to be the "gold standard" of medical research and the most rigorous way to determine a cause-effect relationship between an intervention/treatment and a given outcome (Godin et al., 2011; Sibbald & Roland, 1998). A RCT was therefore the most suitable study design for investigating the causal-effect relationship between the NHE and number of hamstring re-injuries. However, RCTs have several vulnerable aspect's which can harm the validity of the study.

Randomization was blinded and performed by the principle external researcher (MIZ) of the SHARP study using Castor EDC, eliminating any allocation bias. The main researcher of the master thesis (AK) and PI (TEA) were blinded to any group allocation until data collected and analysed, January 2023. Unfortunately, it was not possible to blind the participants from group allocation as they were aware of allocation when they received either the NHE protocol or were informed to continue with normal training/activity.

5.3.2 Data analysis

The main SHARP study included a power analysis for the 2-month (10 week) follow-up (Zein et al., 2022). Based on re-injury reduction with a two-sided testing, significance level of 0.05, power of 0.9, estimated 10% drop-out rate and re-injury prevalence of 15%, a total of 368 subjects (184 per group) were needed to evaluate the desired re-injury reduction of the NHE (Zein et al., 2022). As this master thesis was based on recruitment of as many Norwegian players as possible to the main SHARP study, it was not possible to conduct the same data analysis and evaluate the preventative effect of the NHE on hamstring re-injuries due to the low sample size. The data was intentionally to be presented as mean and standard deviations or median and interquartile range if data was not normally distributed. Results were instead presented as total number (n) of hamstring re-injuries and/or mean values.

To calculate the effect of the NHE, an "intention to treat" (ITT) analysis should have been conducted. An ITT analysis includes all participants who were randomized in the statistical analysis and analysed according to the group allocation regardless of whether the treatment or intervention that was given (McCoy, 2017). Verhagen and colleagues argue that the interventions applied in experimental studies are heavily biased by the adherence to the intervention (Verhagen et al., 2011). They suggest that conducting a "per protocol" (PP) analysis alongside the ITT analysis would provide better insight to the efficacy and true potential of the interventions among those who adhere to the intervention. A PP analysis is a comparison of the treatment groups including only those who completed the treatment or intervention originally allocated (Shah, 2011). The reporting and assessment of adherence to the intervention is crucial in an intervention study to understand to what extent the intervention is carried out by the participants (Verhagen et al., 2011). However, the PP analysis must not be used alone as it leads to bias and the results are not generalizable, therefore ITT and PP should be used together (Shah, 2011).

5.3.3 Strengths and limitations

The SHARP study is the first international multicentre RCT to evaluate the effect of the NHE in secondary prevention (re-injury) of HI with a sufficient large sample size (Zein et al., 2022). The already published study protocol for the main SHARP study is considered a strength as it may eliminate flaws such as “cherry picking”. The main SHARP study and the “Norwegian arm” have set broad inclusion criteria, including both genders, age from 18-40 years and football players at any level. This provide the opportunity to generalize the result to a larger extent of the population than previous studies, as these mostly include either one gender or a specific level of sport (Hasebe et al., 2020; van der Horst et al., 2015). The eligibility criteria were also clearly defined.

Another strength was the close monitoring of adherence to the NHE protocol, which allows for interpretation of the dose-response relationship between the amount of performed NHE and hamstring re-injuries. The SHARP study is until now the first study to investigate both short and long-term effect of the NHE on hamstring re-injury prevention. Unfortunately, the long-term effects were not possible to investigate in this master thesis due to time constrains. The absence of reported “dropouts” during the first 10 week of follow-up should be considered a strength. The single exercise approach used in this study was an advantage, with the NHE alone being time efficient as well as easily applied to different settings either performed alone or together with a partner. This could potentially increase the adherence to the exercise compared to multi exercise programs (Henry et al., 1999). By only using one exercise, this could prevented potential bias from other exercises influencing the outcome measure of hamstring re-injury rates. However, the players could have performed other strength exercises in addition to the NHE, affected the re-injury rates. This were however though to be balanced out between the two groups with a sufficient sample size.

The selection and recruitment of PTs that were invited to take part in the recruitment of players sustaining HI was considered a strength. Most of these PTs were part of the Norwegian FA’s Medical Centre’s network, while the rest were PTs known for working with Norwegian men’s and women’s premier league football teams, first division teams, Norway’s national teams, or recognized PTs working at sports physiotherapy clinics. By including well educated and experienced PTs, one is likely to eliminate recruitment of players with wrongly diagnosed HIs and when recruited ensuring players had received adequate rehabilitation. This was of particular importance as the diagnosis of HI was solely based on a clinical examination and the study relied on the competency of the PTs, as an MRI investigation was not part of the diagnostic assessment.

There were several limitations in the “Norwegian arm” of the SHARP study which may have had an impact on the outcomes. One limitation was the size of the study population, with a low number of participants, as well as being homogenous in terms of gender and level of sport. The homogenous study population does not allow for generalization as initially intended. The fact that 70% of the recruited players to the main SHARP study was excluded from analysis as they did not respond to questionnaires (n=4), did not meet inclusion criteria (n=14) or had missing baseline data (n=1), should be considered a limitation of the study. The high exclusion rate caused a low number of participants and skewd distribution to the IG and CG, making the prognostic baseline indicators (e.g., age, history of injury, gender and competitive level) different between the groups, which is not ideal in a RCT. Also, the high number of players declining or not responding to invitation to participate was a limitation. This may indicate an inadequate recruitment and contact strategy by the researcher or this may point to an insufficient study design not feasible or appealing to the targeted population.

The main SHARP questionnaire used for baseline measures and follow-ups had to our knowledge not been thoroughly tested through a pilot study, affecting the validity of the questionnaires (Zein et al., 2022). Several players had missing data in the reported baseline questionnaire, or the 10-week follow-up questionnaires. The missing data directly affected the validity of the results from this study. The SHARP questionnaires were also only available in English for the players. Minor adjustments were made to the “Norwegian arm” questionnaire; to avoid misinterpretation some words were translated into Norwegian to allow for clarity. There might, however, still have been some language barriers, which could potentially affected the player’s responses. The consent form was for that reason developed in Norwegian to make sure every player was well informed and understood important information and instructions regarding study participation.

Another limitation of the study was the monitoring of self-initiated performance of NHE in the CG. The SHARP protocol stated that the CG could perform NHE after fully completed RTS after HI but would be excluded if performing the NHE more often than prescribed in the protocol. However, there was no section in the questionnaire for monitoring the NHE adherence (session, sets and reps) in the CG. This could directly impact the results and re-injury rates of the IG if not controlled. Also, no control of whether and how players in the IG performed the NHE was collected during the study period. Even though players allocated to the IG received both hand-outs and video link with description on how to perform the NHE (appendix 8) there were no direct control of their actual performance. With minimal control on how the intervention was carried out by each player in terms of technique and intensity of the NHE, this could potentially affect the results.

5.4 The NHE Protocol

The NHE protocol applied in the SHARP study followed a progressively increased number of total sessions, sets and repetitions during the first 5 weeks while week 5-10 remain the same, table 4. Various protocols have been described and used in previous experimental studies on hamstring injury prevention, table 3. Comparing the first 10 weeks of NHE protocol from Van der Horst (2015), Hasebe (2020) and Zein (2022), all three protocols followed same number of sets per training for every week(Hasebe et al., 2020; van der Horst et al., 2015; Zein et al., 2022). The SHARP study NHE protocol consisted of a total of 700 NHE repetitions (10 weeks), this was 264 repetitions more than Hasebe (2020) and van der Horst (2015) which had a total of 436 repetitions (10 weeks), respectively. The main difference of the SHARP protocol was the prescribed 3 sessions per week (week 3-10), not two sessions as prescribed in the other studies (Hasebe et al., 2020; van der Horst et al., 2015; Zein et al., 2022).The studies by Van der Horst et al. (2015) and Hasebe et al. (2020) showed good preventative effect with a lower volume protocol than the SHARP NHE protocol (Hasebe et al., 2020; van der Horst et al., 2015).

A systematic review by Cuthbert and co-workers (2020) found that reducing the prescribed volume in the NHE did not negatively affect adaptations of eccentric knee flexor strength and muscle architecture compared to higher doses (Cuthbert et al., 2020). In a RCT by Behan et al. (2022) they found that lower volumes of NHE were unable to increase fascicle length but strikingly only 48 repetitions over 6 weeks were enough to increase eccentric knee flexor strength (Behan et al., 2022). A recently published article showed that a low volume NHE protocol (10 sessions, 144 rep in 8 weeks) did not lead to any less adaptations in hamstring strength compared to a high-volume protocol (21 sessions, 538 reps in 8 weeks) (Amundsen et al., 2022) Neither groups had any improvement in jump height or sprint performance. These findings advocate the value of prescribing lower volumes of NHE for strength improvement in football players.

5.5 Recruitment strategies

The "Norwegian arm" of the SHARP study utilize two different recruitment strategies to reach out to as many football players as possible in Norway who recently had sustained HI. Despite two different strategies and 34 PT´s volunteering to take part in the recruitment, we were not able to recruit any players to the main SHARP study through the "Norwegian arm" study. This section will discuss the recruitment strategy and potential reasons for the poor recruitment outcomes.

5.5.1 Strategy 1, The outreach to Physiotherapists

Strategy 1 was the initial main recruitment strategy in this master thesis. However, it was the strategy which reported the least number of HI´s. There may be several reasons to why this strategy did not turn out as effective as intended. The contact between AK and the volunteering PTs were maintained by email. A hypothesis was that the PT's might not have felt included and motivated enough to invest time in the recruitment process. Secondly, the PTs could easily forget reporting HI´s to AK. All PTs were invited to a have a conversation/meeting over Teams/Zoom when invited to participate as this was thought to be a more personal way to include each one to the project. However, no video meetings were conducted as they either just wanted information by e-mail or did not respond to follow up mail when suggesting day and time for meeting. Therefore, joint emails were sent to all PTs with the intention of creating a community where the PTs felt included and involved in the main SHARP study as well as part of a collaborating group of PTs. This was thought to increase the awareness of the PTs for eligible players for participation and increase their motivation for reporting HIs.

Four emails were sent to the PTs, once every 2-3 months, including updates on the study progress, new literature on hamstring injuries, the published SHARP protocol and a poster. The poster was made by MIZ as a visual reminder to the PTs which they could hang up in their office or other places around the physiotherapy clinic. However, this did not increase the number of recruited football players to the study. Some PTs did respond that they often forgot about the recruitment. This could indicate that the PTs were not reminded frequently enough by email or other means.

Another hypothesis to why this strategy might have failed to recruit more players was the lack of assets to reward the PT´s for their contribution to the recruitment process. For the PTs to recruit players, this would be time-consuming and not prioritized in a hectical day in the clinic or club. When working as a PT in a sports physiotherapy clinic, there is limited time for a thorough anamnesis, examination and treatment. One PT reported time as an issue in the player recruitment process as the PT experienced limited time to inform players about the SHARP study. Reimbursement fees to the PTs could have compensated for the additional time spent to take part in this project. However, there was no financial support to reward the PTs for player recruitment activities.

Motivation is crucial for players to adhere to any treatment or intervention, both in research and in a real-world setting (McKay & Verhagen, 2016; van der Horst et al., 2021). For players to participate in a 52 week-long study when already had RTP following recent HI may have been difficult to motivate for as they were back to playing football as normal. Players therefore might not have felt there was much to gain from participation at the point of recruitment. For players to participate and adhere to the study program for the following 52 weeks presupposed that the players were motivated for participation and understood the potential impact of re-injury by study participation, which might have been a potential barrier for the player recruitment to the SHARP study.

5.5.2 Strategy 2 - The FA Medical Call Centre

This strategy turned out more efficient in terms of getting directly in touch with football players reporting sustaining HI. Fourteen players with HI were reported by the FA Medical Call Centre to the researcher, AK. There is a possibility that not all players who registered injuries through the FA Medical Call Centre were reported to AK as some of the Call Centre workers did say they at times forgot to look for players reporting HI. The Call Centre staff did not receive the same number of reminders to keep recruiting as the PT´s in strategy 1.

This recruiting method does however give an indication that there were more HI´s occurring then strategy 1 might indicate. Strategy 2 may have proven more effective as it lets the researcher get in direct contact with the player, instead of going through the local treating PT. For future research and recruitment to similar studies, this strategy should be of interest where it is beneficial to get in direct contact with individual players. These results also highlight the importance of understanding the impact on player recruitment in cooperation with external PTs which the "attitude and belief questionnaire" give an indication of.

All players reported either through strategy 1 or 2 were directly contacted by AK by phone. We used a standardized form when contacting each player, to make sure every player received the same and necessary information (appendix 9). None of the five players expressing interest in study participation through phone call responded by signing and returning the consent form, neither did they inform why they did not respond or change their minds. Therefore, it is to our knowledge unknown why they did not respond. Three out of the 14 players contacted through the "Norwegian arm", kindly declined the invitation explaining that they had no interest in participating, figure 7.

5.6 The "Norwegian arm attitude and belief" questionnaire on the NHE and protocol

This section will discuss the methodological considerations of the questionnaire, recruitment strategy and results from the "Norwegian arm attitude and belief" questionnaire on the NHE and protocol. The results will be discussed consistent with the RE-AIM model.

5.6.1 Methodological considerations

The second and additional part of this master thesis was conducted as a pilot descriptive cross- sectional study where data was collected from PT´s about their attitudes and beliefs to the NHE. Cross-sectional studies are preferable when the intention is to collect information on how the knowledge or perception of a phenomenon varies between people in a specific population, at a specific point of time. This is typically done to create a hypothesis for future research (Kesmodel, 2018; Thomas, 2015).

The "Attitude and belief" questionnaire was developed by the PI (TEA) and researcher AK. It was neither assessed by external experts nor tested in a previous pilot. With the self-developed questionnaire not fully explored in the target group before data collection, this may have affected the results and validity of this part of the study. Validity is decisive when drawing conclusions. The three central points of evaluating validity of a questionnaire are content validity, construct validity and criterion validity. Feedback from "experts" on the questionnaire could have improved the content validity. However, as we used the RE-AIM framework and inspiration from similar questionnaires and studies this may have compensated for the construct validity (Pripp, 2018). It must be considered that the "attitude and belief questionnaire" on the NHE was intended only as a pilot study within this master thesis.

5.6.2 Response rates and recruitment

The response rate to the "attitude and belief questionnaire on the NHE" was 53%, with missing data from remaining 47%. Similar studies using questionnaires to investigate health professionals' attitudes and beliefs on injury preventative measures have shown similar response rates. McCall (2014) achieved a response rate of 47% on questionnaires sent to a selection of professional football clubs while O´Brien & Finch (2014) achieved 57% response rate (McCall et al., 2014; O'Brien & Finch, 2014). However, other studies have achieved much higher response rates from questionnaires on attitudes and beliefs towards injury prevention programs, with response rates of 91% and 100% (Andersson et al., 2019; Stensø et al., 2022). Both these two studies used electronic online surveys. Some PTs did respond that it was difficult filling out the form in MS Word. This may, compared to the two other studies explain the "low" response rate of the "attitude and belief questionnaire" found in our study. Among the respondents to the questionnaire, the population was to some degree skewed with the majority (53%) working in a sports clinic, 31% worked with football team and among these, 73% worked with professional football players. We did not investigate whether the PTs working in a football club reported examining more football players sustaining HI compared to those working in a sports clinic. Unfortunately, the questionnaire did not report if the PTs in football clubs primarily worked with male or female football players. If this question had been included, it could have given an indication to why we were not able to recruit any female players.

We sent the questionnaire to the PTs who responded to the initial invitation to help with player recruitment to the main SHARP study, with an additional 18 PTs who were not included in the player recruitment. By not inviting the non-responding PTs that initially were invited to participate in the recruitment process of the SHARP study, it was possible that the responding population was biased towards only those who were positive to the NHE. The rationale was that PTs who were familiar with the injury preventative effects of the NHE and applied it in daily practice were more likely to respond and show interest in recruiting players to the SHARP study. The outcome of the responses might have been different if all PTs were invited to respond to the questionnaire. However, as it was assumed that the response rate from these PTs would be limited (as they did not respond to initial invitation and follow-up invitation) an additional group of PT´s working at sports clinics and with football clubs were invited. This was done with the intention of minimizing the population bias.

To avoid potential barriers, we could have conducted a “pilot study” to test the questionnaire and ensure that the questions were precise, well defined and understood by the users. This would have allowed for feedback on the chosen questions, structure, user friendliness and potential other missing questions that could have been highly relevant, for example to suggest using an online survey. However, due to a very limited time for data collection, this was not possible

Some PTs from the “Norwegian arm”, reported by email, that they either did not see any football players sustaining HI at all or very rarely. However, through the “Norwegian arm” “attitude and belief questionnaire”, 12% of the PTs reported examining football players with HI weekly, 62% reported “monthly” and 27% “rarely”, table 17. This is interesting, as these results would suggest more HIs than reported during the study. Even though the PTs invited to participate in the pilot study were chosen especially as they were thought to be recognized clinicians working with sports and/or football injuries, one third reported rarely examining a football player sustaining HI. On the other hand, with 62% reporting to examine football players with HI monthly and 12% "weekly", this indicates that there was a potential for recruitment of football players sustaining HI to the SHARP study. However, we do not know yet why this strategy failed.

5.6.3 Reach

Knowledge about the extent of a sustaining any type of sports injury and the risk of getting an injury is considered crucial in the process of injury prevention (Finch, 2006). Also, the delivery agent's knowledge and beliefs on injury preventative exercise programs are essential to facilitate these programs in a real-world setting (Ageberg et al., 2019; Richmond et al., 2020). Our study suggests that Norwegian PTs working at football clubs and in sports physiotherapy clinics are familiar with the NHE. Future research should consider investigating coaches' knowledge, attitudes and beliefs towards the NHE. Chesterton (2021) suggests that a cultural change is needed from the players in order to successfully implement the NHE in a real-world setting (Chesterton et al., 2021).

5.6.4 Effectiveness

In the a 5th step of the TRIPP model, Finch highlighted the importance of understanding the attitudes and beliefs of stakeholders such as coaches, players and PTs to be able to understand and find signs of safety behaviour (Finch, 2006). This study found that 92% of the PTs thought regular hamstring injury prevention for football players were "very important" for preventing hamstring index and re-injury. The belief that the injury prevention program will lead to a desired outcome is crucial for the implementation of the program to be successful (Lindblom et al., 2018). Looking at the responses from the questionnaire, the PTs have a "somewhat strong" belief that the NHE can prevent hamstring injuries and re-injuries to either a "large extent" (69%) or to a "certain extent" (31%). Similar studies have found the NHE being valued by medical professionals both in English and American professional football despite the clubs only partially agreeing that the NHE could substantially reduce the number of HIs in their respective clubs (Chesterton et al., 2022; Chesterton et al., 2021).

5.6.5 Adoption

Carolyn Finch also stated that only the injury prevention programs which are implemented either by players, coaches or PTs over time will manage to prevent injuries (Finch, 2006). Our study found that 54% reported using the NHE "often" while remaining 46% reported "rarely" while no one reported "not at all" using the NHE. These findings are interesting as previous studies may indicate otherwise (Bahr et al., 2015; van der Horst et al., 2021). Bahr (2015) found that among 18 Norwegian premier league teams and 32 European Champions League teams, only 11 teams were compliant, 6% partly compliant and 83% of the team non-compliant to the NHE (Bahr et al., 2015). Similar results were found in a recent study during the 20/21 season, reporting low adherence (Ekstrand, Bengtsson, Walden, Davison, & Hagglund, 2022). However, they also found that those teams using the NHE for the whole team or most of the players had a lower HI burden compare to teams only applying the NHE for individuals (Ekstrand, Bengtsson, Walden, Davison, & Hagglund, 2022). A possible explanation for the findings from our study may be the diversity of PTs working in different clinical settings, not only in football clubs.

Interestingly, 92% of the PTs reported using other preventative training in addition to the NHE. The most frequent reported strategies and interventions was either general strength straining (n=13) or HSR (n=4). For strength training, hip dominant hamstring exercises were preferred over knee dominant with the SLRDL the most frequent exercise reported. A possible explanation to these results might be the desire from the PTs to address both knee and hip dominant hamstring exercises. The NHE was considered a knee dominant exercise which to a to a larger extent target the medial hamstring groups (ST, SM) and the BFsh while SLRDL was a hip dominant exercise which has a higher activation of the lateral hamstrings (BFlh) (Bourne, Williams, et al., 2017). In relation to the ST, the BFlh was 4 times more active during hip extension (HE) than during the NHE. These findings indicate that HE exercises may be more useful than the NHE in selectively activating the BFlh. Looking back at HI mechanism, sprinting (type 1 injury) was the most common and most often affects the proximal part of the BFlh (Crema et al., 2016; Gronwald et al., 2022; Hickey et al., 2022). This may explain the frequent use of SLRDL as this exercise have high activation of the commonly injured muscle of the BFlh and load the hamstrings through a movement pattern which was similar to the position where HI normally occur, with a flexed hip combined with knee extension (Garcia et al., 2022). Another consideration in prevention of hamstring index and re-injury prevention is that acute injuries occur unilaterally whereas NHE is a bilateral exercise and the SLRDL is unilateral.

Furthermore, the study by Tillaar (2017) found that no exercise was close to sprinting in regards to hamstring activation (van den Tillaar et al., 2017). Another study found that sprint training was superior to the NHE in addition to regular football training in improving both hamstring muscle fascicle length and sprint performance. However, only the NHE was found to show an increase in pennation angle (Mendiguchia et al., 2020). Bourne (2018) showed that football players with short BFlh fascicle length (<10.54cm) were 4.1 times more likely of sustaining HI and that the injury probability was reduced by approximately 21% for every 1 cm increase in BFlh fascicle length (Bourne et al., 2018). These findings address the importance of regular and systematic sprint training for football players as part of hamstring injury prevention. Sprinting or HSR should be a major part of the rehabilitation, knowing that football players achieve 83% of max velocity sprinting and 100% total sprint distance compared to pre injury level already during first or second match following complete RTP from HI (Hoppen et al., 2022).

5.6.6 Implementation

Twenty-five PTs reported that they use the NHE due to the injury preventative effects. This is not a surprise as the NHE has shown great results, preventing 51% of all HI when used alone or as part of a multi exercise injury prevention program (Al Attar et al., 2017; van Dyk et al., 2019).

Thirteen reported to use the NHE as it does not require any equipment. This makes the NHE an effective strengthening exercise for the hamstrings in settings where there is limited access to other strength equipment and easy to facilitate on field.

Ten PTs reported using the NHE due to the physical performance effects. Performance enhancing is undoubtedly crucial in football where Shamlay et al. (2020) found that for injury prevention programs to be implemented, promoting the performance enhancing effects could improve acceptability and adherence to the program (Shamlaye et al., 2020). Even though the NHE has shown to give some positive effects on sprinting, jump height and knee flexion strength, the term “physical performance” was not well described in our questionnaire and therefore is seen as a limitation (Amundsen et al., 2022; Bautista et al., 2021; Mjolsnes et al., 2004). The terms “physical performance” and “football performance” should not be mixed. Nevertheless, one could argue that the NHE does have an indirect effect on football performance. By applying the NHE this could reduce the HI rates which again leads to further participation in football. There is a general belief that a large amount of training and practice is needed to develop and reach elite performance in sport (Ericsson et al., 1993). Kasper (2019) states through the principal of “specificity”, you become good at what you practice for but need to achieve a enough specific training in order to achieve sufficient results (Kasper, 2019). Staying free of injuries would therefore allow more time practicing football specific skill and developing performance.

All respondents reported to use the NHE during pre-season and during competitive football season. Green (2020) states that those with baseline strength deficits were associated with an increased risk of HI but also points out that strength fluctuates within the season in response to exposure to strength training (Green et al., 2020). This highlights the importance of applying the NHE not only during the pre-season, but regularly also in the competitive season. One study found that performing a 6-week NHE protocol gave structural adaptations in the BFlh (Presland et al., 2018). Strikingly, these adaptations were reversed to baseline after only two weeks and eccentric strength was back to baseline after 4 weeks when not performing the NHE (Presland et al., 2018). However, Kocak (2023) found contradictory results, as eccentric hamstring strength and asymmetry at the time of RTP did not differ between those who sustained hamstring re-injury within the first 3 months.

5.6.7 Maintenance

Maintenance concerns the importance of understanding potential barriers which the intervention could face in a real-world setting, just as Finch pointed out in step 4 of the “TRIPP” model (Finch, 2006). The NHE has been implemented in research and studies with reported high adherence (Hasebe et al., 2020; van der Horst et al., 2015). However, the adherence to the NHE in Norwegian and European elite football teams has shown to be low (Ekstrand, Bengtsson, Walden, Davison, & Hagglund, 2022). Since the adherence was monitored in the main SHARP study, it was desired to investigate the

PTs perception of players' motivation and adherence to the NHE. Interestingly, 15 PTs found players to be motivated for NHE "most of the time" and eight reported "sometimes". For NHE adherence, 14 reported "most of the time" while eleven "sometimes". None reported "no, never" to either adherence or motivation, figure 13. These numbers suggest football players are motivated and do adhere to the NHE despite some studies showing otherwise (Chesterton et al., 2022; Chesterton et al., 2021).

5.6.8 The NHE Protocol and feedback from the PTs

The findings from the attitude and belief questionnaire assessed the PTs perception of volume prescribed in the protocol. Interestingly, approximately one third (27%) of the respondents thought the prescribed "repetition per set" and "sessions per week" were "too high". Also, 81% reported prescribing NHE modified to protocol. These results show that Norwegian PTs do modify the NHE to protocol and often prescribe lower volume than used in the SHARP protocol. However why the PTs modify the prescription is unknown. These results underpin what was discussed in section 5.4 "The NHE protocol" on the several benefits of prescribing lower volume NHE programs.

5.7 Future directions

The primary outcome of this study was to investigate the effect of the NHE in preventing early hamstring re-injuries in male and female football players at any level of football at the age of 18-40 years. For secondary outcomes, we measured the players adherence to the NHE protocol and their training and match exposure. In addition, we conducted a pilot study to gain insight into the attitudes and beliefs of Norwegian PTs towards the NHE and protocol. Future research should be aimed at optimizing recruitment strategies, for easier to get in direct contact with eligible players for participation and improve the rate of players accepting the invitation to participate. Given that we have not been able to recruit any female players to the SHARP study and with limited research and knowledge on HI prevention in female football players, future research should be aimed on recruiting more female players. A closer collaboration with club and team PTs should be considered with not only correspondence by email, but also physical meetings to involve and include the PTs to a higher extent and on a more personal level. A follow up email to all involved PTs, responders and non-responders, cold be sent to ask for feedback on possible improvements on the process of recruitment. Also, reflecting on previous studies on hamstring injury prevention, it may be more effective for NHE adherence when the exercises is given to a whole team/club as part of organized training compared to individuals only, such as in the SHARP study.

The importance of understanding the attitudes and beliefs of healthcare providers, players and coaches is critical to achieve success with injury prevention. (Finch, 2006). A greater understanding of the attitudes and beliefs of both football players and coaches could provide further insights into how to implement the NHE more effectively with a higher adherence for primary and secondary prevention of HI in football. Also, to provide a greater understanding to why the adherence rates to the NHE and protocol was low. This could be investigated by conducting a descriptive cross-sectional study on Norwegian football players and coaches. An online questionnaire could potentially gather data from a large and diverse sample of players and coaches, giving a broader understanding of their attitudes and beliefs of the NHE. Also, qualitative semi-structured interviews with players and coaches could be conducted. This would however be more time consuming.

6. Conclusion

The “Norwegian arm” of the SHARP study found no hamstring re-injuries in either the IG or CG. The number of players included in the study was too low to indicate any actual effect of the NHE in preventing hamstring re-injuries during the first 10 weeks following complete RTP from previous HI. Therefore, we were not able to calculate the hamstring re-injury rate or the HI injury burden. The low adherence rate to the NHE protocol was concerning and low compared to other similar studies (Hasebe et al., 2020; Petersen et al., 2011; van der Horst et al., 2015). A larger sample size is needed to make a conclusion on the effect of the NHE in preventing short-and long-term hamstring re-injuries.

Our pilot study provided data on the attitudes and beliefs of Norwegian PTs toward the NHE and protocol. The NHE is well known, valued and adopted among Norwegian PTs working in football clubs and in sports physiotherapy clinics. Norwegian PTs acknowledge the importance of HI prevention in football players, with a belief that the NHE may help reduce the incidence of hamstring index and re-injury. Commonly the NHE is prescribed as modified to protocol and used independent of competitive season or pre-season. Based on the perception of Norwegian PTs, football players are motivated to perform and adhere to the NHE. Results of the pilot study also showed that one third of the PTs reported that their opinion was that the prescribed dosage of “repetitions per set” and “sessions per week” applied in the NHE protocol of the SHARP study was “too high”.

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Abreviations

ACL – Anterior Cruciate Ligament

ACL-R – Anterior Cruciate Ligament reconstruction

AK – Anders Knapstad

AMC – Amsterdam University Medical Centers

BAMIC – British Athletic Musclee Injury Classificcation

CG – Control group

CMJ – Counter Movement Jump

DK – Denmark

DMTJ – Distal Myotendinous Junction

DOMS – Delayed onset of muscle soreness

EDC – Electronic Data Capture

EMG – Electromyographi

FA – Football Association

FIFA – Fédération Internationale de Football Association

GDPR – General Data Protection Regulation

HI – Hamstring Injury

HIR – High Intensity Running

HSR – High Speedd Running

ID – Indonesia

ID – ID of participant

II – Index injury

IG – intervention Group

IOC – International Olympic Committee

ITT – Intention To Treat

IQR – Inter Quartile Range

KNVB – Koninkliijke Nederlandse Voetbal Bond

MHFAKE – Maksimum Hip Flexion Aktive Knee Extension

MIZ – Muhammed Ikhwan Zein

MRI – Magnetic Resonancee Imaging

MS – Microsoft

MTJ – Myotendinous Junction

N – Newton

NFF – Norges Fotball Forbund

NHE – Nordic Hamstring Exercise

NL – Netherland

NNT – Number Needed to Treat

OA – Osteoarthritis

PA – Physical activity

PI – Principle Investigator

PP – Per Protocol

PT – Physiotherapist

QA – Qatar

RCT- Randomized Controlled Trials

RE-AIM – Reach, Effectiveness, Adoption, Implementation, Maintenance

RIR – Repetitions in Reserve

RPE – Rate of Perceived Exertion

RTP – Return top Play

RTS – Return to Sport

ROM – Range of Motion

SHARP – Study on Hamstring Re-injury Prevention

SJ – Squat Jump

SLR – Straight Leg Raise

SLRDL – Single Leg Romanian Dead Lift

SMS – Short Message Service

SprD – Sprint Distance

SPSS – Statisticap Package for the Social Sciences

SR – Systematic Review

SRT – Sit Reach Test

SSL – Secure Sockets Layer

StARRT - The Strategic Assessment of Risk and Risk Tolerance

TD – Total Distancee

TEA – Thor Einar Andersen

TRIPP - Translating Research into Injury Prevention Practice

TUT – Time under Tension

UEFA – Union of European Football Associations

UMC – University Medical Centers

VAS – Visual Analogue Scale

WHO – World health Organization

1RM – 1 Repetition Maximum

List of Appendix

Appendix 1: Letter of informaition & consent form.

Informasjonsskriv og Samtykkeskjema

Med dette informasjonsskrivet får du informasjon om studiets formål og hva det vil innebære for deg å delta.

Formål med undersøkelsen:
Studiet er en masteroppgave i idrettsfysioterapi ved Norges Idrettshøyskole. Dette er en del av det internasjonal studie «SHARP - *Study on Hamstring Re-injury Prevention»*. Prosjektet har følgende formål – *Å undersøke om Nordic Hamstring- øvelsen (NHE) kan forebygge* en ny *hamstring* etter å ha hatt en tidligere skader (hamstring re-skade).

Hvem er ansvarlige for studiet:
Prosjekt leder for «SHARP» studiet er PhD kandidat:

- Ikhwan Zein (Academic Medical Centre, Amsterdam).

Ansvarlige for dette prosjektet som utføres i Norge er følgende:

- Thor Einar Andersen, Professor og idrettslege (Senter for idrettsskadeforskning, Institutt for idrettsmedisin, Norges Idrettshøyskole, Oslo) & overlege, spesialist i fysikalsk medisin og rehabilitering, Idrettens helsesenter, Oslo.
- Anders Knapstad, Fysioterapeut og master student (Institutt for idrettsmedisin, Norges Idrettshøyskole, Oslo).

Bakgrunn for undersøkelsen:
Hamstrings er en muskel gruppe som ligger på baksiden av låret og strekker seg over hofte og kne-leddet. Hamstring skader er den vanligste muskel skaden i fotball og sprint og har en høy forekomst av nye skader. Forskning viser at man er mest utsatt for en ny hamstring skade i første kamp etter retur til idrett (RTI) og de påfølgende 3 månedene. Nordic Hamstring øvelsesprogrammet er vist å kunne forebygge akutte hamstring skader, men vi mangler bevis for at den også kan forebygge ny hamstringsskade (re-skade) etter fulført rehabilitering.

Hva innebærer det for deg å delta i undersøkelsen?
Det vil ta deg totalt 12 måneder å gjennomføre dette prosjektet. Du er aktuell for prosjektet dersom du er fotballspiller, mellom 18-40 år gammel. I tillegg skal du være klarert for retur til spill etter hamstring skade for mindre enn 1 uke siden. Du vil ikke behøve å møte opp for fysisk testing eller vurdering i dette forskningsprosjektet. Deltagere randomiseres (deles tilfeldig) inn i 2 grupper:

- *Gruppe 1 (Intervensjonsgruppen). Deltagerne får et Nordic Hamstring treningsprogram de utfører i tillegg til vanlig trening*
- *Gruppe 2 (Kontrollgruppen). Vil kun gjennomføre vanlig trening, men uten å bruke Nordic Hamstring programmet*

Oversikt prosjektforløpet for deltagerne:

- Sette seg inn i studieprosedyre og samtykkeskjema. Om deltager gir samtykke vil følgende steg gjennomføres:
- Spørreskjemaer sendes per epost. Du vil måtte fylle ut et skjema med generell info ved oppstart. Deretter fyller du ut et skjema som omhandler overvåking av skader, hvor mye du trener og hvor ofte du har gjennomført Nordic hamstring programmet.

Du vil motta spørreskjema ukentlig de første 10 ukene, deretter en gang den 6., 9. og 12. måneden etter skaden. Det tar ca. 5 minutter å fylle ut skjemaet. Hva man skal gjøre vil avhenge av om deltager havner i kontroll eller intervensjons gruppen (Nordic Hamstring programmet).

Hva er fordelene og ulempene ved å delta?
Fordeler: Nordic Hamstring programmet vil potensielt kunne redusere risiko for ny skade (re-skade). Du vil bidra i forskning og videre kunnskap om forebygging av ny hamstring skade.
Ulemper: Det er en liten mulighet for muskelsårhet ved oppstart av Nordic Hamstring programmet. Videre vil prosjektet kreve at du setter av litt tid, og at du må følge avtalene som er del av prosjektet.

Forsvarlighetsvurdering
Deltager vil enten gjennomføre standard trening (kontroll gruppe) eller standard trening + Nordic Hamstring protokoll (intervensjons gruppe). Nordic Hamstring øvelsen har vist å ha en positiv effekt på skadeforebygging av hamstringsskader. Doseringen av øvelsen i intervensjonsgruppen vil være moderat, og det er ikke ansett å være en risiko for skade. Liten mulighet for muskelsårhet og at gjennomføringen tar litt tid, er eneste ulemper.

Hva forventer vi av deg?
Da vi ønsker at prosjektet skal gå så bra som mulig ønsker vi å gjøre følgende avtaler:

- At du ikke deltar i andre medisinske studier i denne perioden.
- At du fyller ut spørre skjemaene.
- At du vil gjennomføre Nordic Hamstring programmet om du blir plukket ut i den aktuelle gruppen.

Det er viktig at du kontakter forskeren (Anders Knapstad) om følgende oppstår:

- Du blir innlagt på sykehus.
- Andre akutte helseproblemer oppstår.
- Om du ikke lenger ønsker å delta i prosjektet.
- Om kontakt informasjonen din endres.

Deltagelse
Det er frivillig å delta i dette prosjektet. Dersom du ikke ønsker å delta, kan du til enhver tid trekke deg fra prosjektet uten å oppgi grunn for dette. Det vil ikke være noen negative konsekvenser for deg om du ikke ønsker å delta. Heller ikke om du ønsker å trekke deg fra deltagelse etter å ha signert samtykkeskjema. Alle dine personopplysninger slettes om du ønsker å trekke deg fra prosjektet.

Personvern – Oppbevaring og tilgjengelighet
Om du deltar i prosjektet gir du oss tillatelse til å samle, lagre og benytte følgende informasjon om deg; fult navn, kjønn, fødselsdato, høyde, vekt, skade historie, informasjon om nye potensielle skader og informasjon om trening og kamp belastning. Vi samler, lagrer og benytter denne informasjonen kun for å svare på formålet med prosjektet. Dine personopplysninger behandles konfidensielt og i henhold til personvernregelverket. Kun prosjekt gruppen bestående av professor Thor Einar Andersen, prosjekt koordinator M.I Zein og master student Anders Knapstad vil ha tilgang til dine opplysninger. Ingen av

resultatene i prosjektet vil være mulig å spore tilbake til deg som deltager. Informasjon som omfatter din deltagelse i prosjektet vil lagres forsvarlig og med kodenøkkel. Opplysningene dine vil avidentifiseres med ett deltager nummer når de er innhentet. Personopplysningene dine vil bli delt med prosjekt koordinator M.I Zein utenfor Norge, innenfor EU/EØS. Opplysninger som ikke er avidentifisert med deltagernummer vil ikke bli delt med andre utenom prosjekt gruppen. Dine resultater vil være tilgjengelige for publisering i master prosjektet og i internasjonale publikasjoner via SHARP studien (internasjonalt prosjekt).

Hva skjer med dine opplysninger ved endt studie?

Dine personopplysninger lagres med en kodenøkkel (av-identifisert) i perioden etter at prosjektet er fullført. Data vil lagres i 15 år ved Amsterdam UMC (frem til 2038). Hensikten er å kunne bruke data til videre utvikling av Nordic Hamstring programmet eller bidra til annen forskning på hamstring skader. Kodenøkkelen vil bli slettet av prosjekt koordinator 15 år etter at data er innhentet fra den aller siste deltageren. Fra kodenøkkel slettes i 2038 vil ikke data kunne spores tilbake til deg som deltager.

Forsikring og refusjon

Som deltager vil du ikke trenge ekstra forsikring for deltagelse i prosjektet. Men du er selvsagt som tidligere dekket av lisensforsikringen til Norges fotballforbund. Du vil heller ikke få betalt for din deltagelse i prosjektet.

Dine rettigheter

Om du kan identifiseres i datamaterialet har du følgende rettigheter:

- Innsyn til registrerte personopplysninger om deg, samt krav om utlevering av kopi om disse opplysningene.
- Å kunne få korrigert opplysninger om deg.
- Sletting av opplysninger om deg.
- Sende klage til datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?

Dine opplysninger behandles basert på ditt samtykke.
Etter søknad har NSD (Norsk senter for forskningsdata) vurdert at behandlingen av dine personopplysninger er i samsvar med personvernreglene. Det samme vil den etiske komiteen ved Norges Idrettshøyskole.

Hvor kan jeg finne ut mer?

Ved spørsmål til forskningsprosjektet eller om du ønsker å benytte deg av dine rettigheter, ta kontakt med en av følgende:

- Masterstudent Anders Knapstad, e-post andersk n@nih.no tlf 41423883
- Professor Thor Einar Andersen, e-post t.e.andersen@nih.no tlf 90153928
- Personvernombud NIH, personvernombud@nih.no

Ved spørsmål rettet til NSD om vurdering av studiet:

- NSD – Norsk senter for forskningsdata AS. E-post personverntjenester@nsd.no
  Telefon: 555 82 117

Med vennlig hilsen

Thor Einar Andersen
(Professor/hovedveileder)

Anders Knapstad
(Masterstudent)

Samtykkeskjema

SHARP – Study on Hamstring Reinjury Prevention (Master prosjekt)
Effekten av Nordic Hamstring øvelsen på forebygging av hamstring re-skader

- Jeg har lest dette skrivet. Jeg har kunnet stille spørsmål. Mine spørsmål har blitt besvart godt nok. Jeg har hatt tid til å vurdere om jeg ønsker å delta eller ikke.
- Jeg vet at deltagelse er frivillig og at jeg til enhver tid kan velge å avstå fra deltagelse i dette studiet uten å måtte oppgi hvorfor.
- Jeg gir forskeren tillatelse til å innhente og bruke min informasjon. Forskeren skal kun gjøre dette med hensikt å besvare forsknings spørsmålet i denne undersøkelsen.
- Jeg er klar over at enkeltpersoner vil ha tilgang til mine personopplysninger og svar fra spørreskjemaer. Disse personene er oppgitt i dette skrivet. Jeg gir med dette disse personene tillatelse til å se og bruke min informasjon.

Jeg gir tillatelse for å kunne lagre min informasjon for bruk i dette master prosjektet og SHARP studiet.	Ja ☐	Nei ☐
Jeg gir tillatelse til å kunne spørre meg ved endt deltagelse i dette prosjektet, om jeg ønsker delta i en oppfølgings studier.	Ja ☐	Nei ☐
Jeg gir forskerne tillatelse til å kunne få vite ved endt studie hvilken behandling/tiltak jeg har fått / i hvilken gruppe jeg var i (NHE eller kontroll)	Ja ☐	Nei ☐

- Jeg ønsker å delta i dette studiet

Mitt navn (deltager): ....

Signatur ....   Dato: __ / __ / __

Jeg bekrefter at jeg har informert deltageren fullt ut om denne studien.

Om informasjon skulle bli kjent under studien som kan påvirke deltagerens samtykke, vil jeg informere deltager om dette snarest mulig.

Navn på forsker...

Signatur...   Dato: __ / __ / __

Deltager vil motta et komplett informasjonsskriv sammen med en signert utgave av samtykkeskjemaet.

Appendix 2: Application approval NSD.

Sikt

Meldeskjema / SHARP – Study on Hamstring Re-injury Prevention / Vurdering

Vurdering av behandling av personopplysninger

Referansenummer	Vurderingstype	Dato
331700	Standard	24.02.2022

Prosjekttittel
SHARP – Study on Hamstring Re-injury Prevention

Behandlingsansvarlig institusjon
Norges idrettshøgskole / Institutt for idrettsmedisinske fag

Felles behandlingsansvarlige institusjoner
Amsterdam UMC

Prosjektansvarlig
Thor Einar Andersen

Student
Anders Knapstad

Prosjektperiode
15.02.2022 - 01.08.2038

Kategorier personopplysninger
Alminnelige
Særlige

Lovlig grunnlag
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)
Uttrykkelig samtykke (Personvernforordningen art. 9 nr. 2 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 01.08.2038.

Meldeskjema

Kommentar
OM VURDERINGEN
Personverntjenester har en avtale med institusjonen du forsker eller studerer ved. Denne avtalen innebærer at vi skal gi deg råd slik at behandlingen av personopplysninger i prosjektet ditt er lovlig etter personvernregelverket.

Personverntjenester har nå vurdert den planlagte behandlingen av personopplysninger. Vår vurdering er at behandlingen er lovlig, hvis den gjennomføres slik den er beskrevet i meldeskjemaet med dialog og vedlegg.

Prosjektet er også vurdert og godkjent av Etisk komite ved Norges Idrettshøyskole 18.1.2022.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige personopplysninger og særlige kategorier av personopplysninger om helse frem til 1.8.2038. Alle data til SHARP-studiet lagres elektronisk gjennom Castor EDC eller på lokal harddisk hos Amsterdam University Medical Centers (AMC).

LOVLIG GRUNNLAG

Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

For alminnelige personopplysninger vil lovlig grunnlag for behandlingen være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 a.

For særlige kategorier av personopplysninger vil lovlig grunnlag for behandlingen være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
Personverntjenester vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen:

om lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet.

DE REGISTRERTES RETTIGHETER
Vi vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18) og dataportabilitet (art. 20).

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
Personverntjenester legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

Amsterdam UMC er felles behandlingsansvarlig institusjon. Vi legger til grunn at behandlingen oppfyller kravene til felles behandlingsansvar, jf. personvernforordningen art. 26.

For å forsikre dere om at kravene oppfylles, må prosjektansvarlig følge interne retningslinjer/rådføre dere med behandlingsansvarlig institusjon.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til oss ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilken type endringer det er nødvendig å melde:
https://www.nsd.no/personverntjenester/fylle-ut-meldeskjema-for-personopplysninger/melde-endringer-i-meldeskjema

Du må vente på svar fra oss før endringen gjennomføres.

OPPFØLGING AV PROSJEKTET
Vi vil følge opp underveis (hvert annet år) og ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet/pågår i tråd med den behandlingen som er dokumentert.

Kontaktperson hos oss: Lisa Lie Bjordal

Lykke til med prosjektet!

Appendix 3: Application approval, Ethical Committee Norwegian School of Sports Schiences.

Thor Einar Anderssen
Institutt for idrettsmedisinske fag

OSLO 18. januar 2022

Søknad 216– 270122 - Effekten av Nordic Hamstring øvelsen for forebygging av ny hamstring skade (hamstring reskade)

Vi viser til søknad, prosjektbeskrivelse, informasjonsskriv og innsendt melding til NSD.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, har leder av komiteen på fullmakt fra komiteen konkludert med følgende:

Vedtak

På bakgrunn av forelagte dokumentasjon finner leder av komiteen at prosjektet er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har leder av komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*
- *At nødvendige samarbeidsavtaler inngås*

Leder av komiteen forutsetter videre at prosjektet gjennomføres på en forsvarlig måte i tråd med de til enhver tid gjeldende ifbm Covid-19 pandemien.

Leder av komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Med vennlig hilsen

Anne Marte Pensgaard

Professor Anne Marte Pensgaard
Leder, Etisk komite, Norges idrettshøgskole

NIH NORGES IDRETTSHØGSKOLE

Besøksadresse: Sognsveien 220, Oslo
Postadresse: Pb 4014 Ullevål Stadion, 0806 Oslo
Telefon: +47 23 26 20 00, postmottak@nih.no
www.nih.no

Appendix 4: The SHARP study, baseline questionnaire.

Dear football player,

You participate in the SHARP (Study on Hamstring Re-Injury Prevention). Please answer the following questions as honestly as possible. You will not be judged or addressed on the chosen answer.

It is important that you fill in the questions as accurately as possible and that you answer all questions. Filling in the questionnaire takes about 5 minutes.
Do you have any questions? Please contact Anders Knapstad, master student at the Norwegian School of Sports Science.

Email: anderskna@student.nih.no.
Tlf: +47 414 23 883

Thank you for your participation!

Anders Knapstad
Master student, Norwegian School of Sports Science.

BASELINE QUESTIONNAIRE

STUDY NUMBER :
Age : **years**
Sex : ◯ male ◯ female

SPORT CHARACTERISTICS

Level : ◯ Professional
◯ Semi-professional
◯ Amateur or Recreational

Dominant Leg : ◯ Right
◯ Left
◯ Both

HISTORY OF INJURY AND REHABILITATION

Date of recent hamstring injury : dd/mm/yyyy
Side of recent hamstring injury : ◯ Right ◯ Left
Date of return to full, unrestricted match or training : dd/mm/yyyy

Mechanism of injury : ◯ Sprinting
◯ Non sprinting

Did you perform any hamstring exercise **and/or** other preventive exercise program before you injured?
◯ No
◯ Yes
- Name/type of program: ____________
- Frequency: _________x/week
- Set : _________x/session
- Repetition : _________x/set

Did you perform Nordic Hamstring Exercise during your rehabilitation?
◯ No
◯ Yes
- Frequency: _________x/week
- Set : _________x/session
- Repetition : _________x/set
- Total sessions in the program: _______

Is it your first-time hamstring injury
◯ Yes
◯ No
- Number of previous hamstring injuries in both legs_________
- Number of previous hamstring injuries in the same leg as your recent injury __________
- Date of last hamstring injury in the same leg: as your recent injury (mm/yyyy)

Total of rehabilitation sessions with physical therapist until return to play	:	________________sessions
Total of rehabilitation sessions with athletic trainer/sports therapist/ rehab coach/strength & conditioning coach until return to play	:	________________sessions

SELF REPORTED READINESS

1. How well do you feel recovered after the injury?

No recovered at all — A little recovered — Moderate recovered — Recovered a lot — Completely recovered

0	10	20	30	40	50	60	70	80	90	100

2. What are the chances that you will get a new hamstring injury?

I will definitely reinjury — I will probably reinjury — Maybe I will reinjury — I will probably not reinjury — I will definitely NOT reinjury

100	90	80	70	60	50	40	30	20	10	0

3. What are the chances that you will get a new **other (non-hamstring)** injury?

I will definitely sustain another injury — I will probably sustain another injury — Maybe I will reinjury — I will probably not sustain another injury — I will definitely NOT sustain another injury

100	90	80	70	60	50	40	30	20	10	0

Appendix 5: The SHARP study, weekly follow-up questionnaire (Week 1-10).

WEEKLY FOLLOW-UP QUESTIONNAIRE
WEEK 1-10

STUDY NUMBER :

A. HAMSTRING INJURY REPORT

A1. Did you have any missed training or match because of an injury last week?
- ☐ No. Continue to question **C1. Training and Match Exposure**
- ☐ Yes. I had an injury

A2. Did you suffer a new hamstring injury?
- ☐ Yes
- ☐ No. Continue to question **B1. Non-Hamstring Injury Report**

A3. Is your hamstring injury in the same leg as your previous injury (re-injury)?
- ☐ Yes
- ☐ No

A4. Side of hamstring injury:
- ☐ Right
- ☐ Left

A5. Mechanism of injury
- ☐ Sprinting
- ☐ Non-sprinting

A6. When did the hamstring injury occur?
- ☐ Match
- ☐ Training

A7. Have you started to full, unrestricted training/match after your hamstring (re)injury? (re-injury mean that you had a new hamstring injury in the same leg as at the beginning of the study)
- ☐ Yes, I have started to full, unrestricted training/match since (dd/mm/yyyy): ___________

☐ No, I am still absent from training/match

B. NON-HAMSTRING INJURY REPORT

Please fill this questionnaire only if you had non-hamstring injury

B1. Injured body part (**non-hamstring**)

☐ head/face
☐ neck
☐ ribs/chest/upper back
☐ abdomen (mage)
☐ low-back/pelvis (korsrygg/bekken)

☐ shoulder/clavicle
☐ upper arm
☐ elbow
☐ forearm
☐ wrist
☐ hand/finger/thumb

☐ groin/hip (lyske/hofte)
☐ front thigh (Fremside lår)
☐ knee
☐ lower leg
☐ ankle
☐ foot/toe

B2. Side of Injury
☐ Right
☐ Left
☐ Not applicable

B3. Classification of injury:
☐ Sudden onset (acute)
☐ Gradual onset (overuse/chronic)

C. TRAINING AND MATCH EXPOSURE

C1. Total number of training hours last week: _______________hours
*If you had 4 training session/week and duration of each session is 1.5 hours, so your total training session is 4x1.5 = 6 hours

C2. Total number of football match(es) last week: ______match(es)

C3. Total number of match minutes last week?_________minutes
*If you had 2 matches and you played 60 minutes in each match, so your total match playing is 2x60 = 120 minutes

D. ADHERENCE REPORT

D1. Did you perform a leg and/or core strengthening program last week?
☐ No.
☐ Yes

D2. Did you perform an injury prevention program last week?
☐ Yes
☐ No

D3. Have you had any complaints after performing your strengthening program or prevention program last week?
☐ No
☐ Yes, my complaints were (please describe): ____________________________

NORDICS GROUP ONLY

N1. How many times/set/repetitions you performed Nordic Hamstring Exercise last week?

- Frequency_________sessions/week (hvor ofte per uke)
- Set _________sets/session
- Repetition_________repetitions/set

For example:
Nordic Hamstring Exercise Week 5
Frequency 3 sessions/week, 3 sets/session, 12-10-8 repetitions/set.

N2. Have you had any complains after performing Nordic Hamstring Exercise last week?

- ☐ No
- ☐ Yes, my complaints were (please describe): ____________________________

N3. Did you perform the full Nordic Hamstring Exercise program last week?

- ☐ Yes, I performed the full Nordic Hamstring Exercise program last week.
- ☐ No, I did not perform the full program last week. Reason:
  - Forgot the schedule
  - No motivation
  - Felt tired
  - Muscle soreness
  - Other, _________________

Appendix 6: NHE handouts – exercise description and protocol.

STUDY ON HAMSTRING REINJURY PREVENTION (SHARP)

Nordic Hamstring Exercise Program

SCHEDULE

Week	Frequency per week	Number of sets per training	Repetitions per set
1	1	2	5
2	2	2	6
3	3	3	6-8
4	3	3	8-10
5-10	3	3	12-10-8 reps
11-52	1	3	12-10-8 reps

Attention

- Keeps your lower legs firmly on the ground (by your partner or by the fixed equipment)
- Your head, upper body, hips and thighs should be in a straight line
- Do not tilt your head backwards
- Do not bend at your hips
- The movement is only in the knee joints
- If you're just beginning to exercise, start cautiously (break the fall forward as slow as possible with your hamstring) and then progress the intensity slowly

Watch the Exercise

http://y2u.be/-Ypn8ezkKsg

SHARP Study on Hamstring Re-injury Prevention

NIH NORGES IDRETTSHØGSKOLE

IDRETTENS HELSESENTER

Contact Person : anderskn@nih.no

Appendix 7: The "Norwegian arm attitude and belief" questionnaire on the NHE and protocol.

Questionnaire regarding the Nordic Hamstring Exercise protocol – the SHARP study

IDRETTENS HELSESENTER

NIH
NORGES IDRETTSHØGSKOLE

Dear physiotherapist,

You are participating in the Norwegian arm of the SHARP study (Study on Hamstring Re-Injury Prevention). Please reply thoroughly to the questions below. Your answers will be kept anonymously, and you will not be held accountable for any of your responses.

Filling in the questionnaire should take about 2-5 minutes.
If you have any questions? Please contact Anders Knapstad, master student at the Norwegian School of Sports Science. Please check one of the options unless other is specified.

Email: anderskn@nih.no

Telephone: +47 41423883

1. Do you work in a sports clinic or with a football team?
   - ☐ Sports clinic
   - ☐ Football team
   - ☐ Both

2. If you work with a football team, at what level?
   - ☐ Professional (National team, Toppserien Kvinner, Eliteserien or OBOS League, men)
   - ☐ Semi-professional
   - ☐ Amateur

3. How often do you examine football players presenting with an acute hamstring injury, either in your clinic or in the football team?
   - ☐ Daily
   - ☐ Weekly
   - ☐ Monthly
   - ☐ Rarely
   - ☐ Never

4. Are you familiar with the "Nordic Hamstring Exercise" (NHE)?
   - ☐ Yes
   - ☐ No
   - ☐ Don't know

5. In your opinion, how important is it for football players to perform regular injury prevention training to prevent hamstring injury and hamstring re-injury?
   - ☐ Very important
   - ☐ Moderately important
   - ☐ Somewhat important
   - ☐ Not important at all
   - ☐ Don't know

6. Do you believe the "Nordic Hamstring Exercise" can affect the extent of hamstring injuries in football?
   - ☐ Yes, NHE can **reduce** hamstring injuries to a large extent
   - ☐ Yes, NHE can **reduce** hamstring injuries to a certain extent
   - ☐ No, NHE cannot **reduce** hamstring injuries to any extent
   - ☐ Yes, NHE can **increase** hamstring injuries to a certain extent
   - ☐ Yes, NHE can **increase** hamstring injuries to a large extent

7. Do you use the "Nordic Hamstring Exercise" for injury/re-injury prevention and/or during the rehabilitation process of Hamstring Injuries?
   - ☐ Yes, very often
   - ☐ Yes, often
   - ☐ Yes, rarely
   - ☐ No, never
   - ☐ I prefer using other hamstring exercises

8. How do you use the "Nordic Hamstring Exercise" in hamstring injury prevention?
   It is possible to check several options
   - ☐ As part of organized football training sessions
   - ☐ As part of organized strength training sessions
   - ☐ As individual preparation to football training/match in the dressing room or gym
   - ☐ As instructed preparation to football training/match in the dressing room or gym
   - ☐ As individual strength training in a gym
   - ☐ Other (specify)_________________

9. During the football season, when do you use the "Nordic hamstring Exercise"?
   - ☐ During pre-season only (December – March)
   - ☐ In the competitive season only (April – November)
   - ☐ Both, during pre-season and in the competitive season

10. How do you prescribe the "Nordic Hamstring Exercise" to football players during rehabilitation or as injury prevention
    - ☐ As described in the protocol
    - ☐ Modified to protocol
    - ☐ Don't know

11. Are the football players you meet motivated to perform the "Nordic Hamstring Exercise" as part of the rehabilitation or for injury prevention?
    - ☐ Yes, all the time

☐ Yes, most of the time
☐ Sometimes
☐ Rarely
☐ No, they are not motivated

12. Do the football players you meet adhere to do the “Nordic Hamstring Exercise” over time?
    ☐ Yes, every time
    ☐ Yes, most of the time
    ☐ Sometimes
    ☐ Rarely
    ☐ No, never

13. What are the reasons that underpin your decision to use the “Nordic Hamstring Exercise” as part of hamstring injury rehabilitation or prevention?
    It is possible to check several options
    ☐ The injury preventative effect
    ☐ The physical performance effects
    ☐ The time spent on the program
    ☐ It I s a partner exercise
    ☐ Does not require any equipment
    ☐ Other (specify)________________________________

14. Do you use other preventative training in addition to the “Nordic Hamstring Exercise” with the intention to mitigate the burden of hamstring injuries in football?
    ☐ Yes
    ☐ No
    ☐ Don’t know
    If Yes, please specify:______________________________

The following questions refer to the *Nordic Hamstring Exercise* protocol by Zein et al 2022, shown below:

15. What are your thoughts on the total number of **sessions** per week?
    ☐ Too high
    ☐ Appropriate
    ☐ Too low
    ☐ Don’t know

16. What are your thoughts on the total number of **sets** per training?
    ☐ Too high
    ☐ Appropriate
    ☐ Too low
    ☐ Don’t know

17. What are your thoughts on the total number of **repetitions** per set/training:

☐ Too high
☐ Appropriate
☐ Too low
☐ Don’t know

Table 1: *Nordic Hamstring Exercise Protocol (Zein et al., 2022)*

Week	Frequency, per week	Number for sets per training	Repetitions per set
1	1	2	5
2	2	2	6
3	3	3	6-8
4	3	3	8-10
5-10	3	3	12-10-8 reps
11-52	1	3	12-10-8 reps

Appendix 8: SHARP – poster handout for PTs involved in player recruitment.

Appendix 9: List of information for initial player recruitment conversation.

Prosedyre tlf samtale med utøvere:

1. Kort om meg, Anders Knapstad
   - Fysioterapeut
   - Master student Norges idrettshøyskole – idrettsfysioterapi

2. Introduksjon – SHARP (study on Hamstring Re-injury Prevention)
   - Internasjonal studie (Nederland, Danmark, Indonesia og Norge)
   - Forskning om forebygging av hamstring re-skader i fotball
   - Nordic Hamstring (NHE)

3. Hva vet vi om NHE nå:
   - Kan forebyggende 50% av alle hamstrings skader
   - Svært effektiv i eksplosive idretter som fotball

4. Hensikt – å finne ut om
   - Hamstring er den mest vanlige skaden i fotball med høyest forekomst av re-skade
   - Kan NHE forebygge nye hamstrings re-skader?
   - Forebyggende effekt ved kort og lang tids oppfølging (2 og 12 måneder)

5. Struktur på studiet
   - RCT – NHE protokoll vs kontroll gruppe
   - Tilfeldig fordeling av gruppe
   - Kontroll gruppe
     - Spørreskjema, uke 1-10 og hver 6, 9, 12 mnd
   - Intervensjons gruppe
     - 52 uker NHE protokoll + spørreskjema

6. Kriterier for deltagelse
   - Fotballspiller
   - Kvinner og menn
   - 18-40 år
   - Under 1 uke siden fullført rehabilitering etter nylig hamstring skade

7. Hva kreves av deg som deltager?
   - Nordic gruppe: Forholde seg til NHE protokoll + spørreskjema
   - Kontroll gruppe: Kun svare på spørreskjema
   - Behøver ikke møte fysisk til oppfølging
   - Alt rapportering skjer digitalt

8. Veien videre
   - Lese samtykke skjema, signere hvis ønskelig å delta – sendes i retur til AK på e-post
   - Frivillig deltagelses – kan til enhver tid frastå fra deltagelse uten konsekvenser
   - Rapportere til AK innen 1 uke fra retur til fotball for tildeling av gruppe
   - Anbefales å kontakte fysio for hjelp med rehabilitering – IHS eller privat