Høgskulen på Vestlandet

MASTEROPPGAVE

Effekt av en 12 ukes Nordic hamstring treningsintervensjon på sprint og spenst ytelse blant unge elite fotballspillere.

The effect of a 12-week Nordic hamstring training intervention on sprint and jump performance in youth elite football players.

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Preface

Writing my master's thesis and researching the effects of the Nordic hamstring exercise on performance parameters in football players has been an educational and exciting period during my studies at the Western Norway University of Applied Sciences.

The background for choosing my study focus was due to my interest in injury prevention exercises and the development of performance factors in football. The aim for football players is to always improve and become the best version of themselves. By focusing more on the physical aspects and effects of the NHE, the research project explored how an injury prevention exercise can impact performance. Throughout my work as a football trainer and physical trainer in Norwegian football I have integrated injury prevention exercises and rehabilitation exercises into my training sessions. However, the adaptability of these exercises and their effect on performance parameters in football is relatively less researched on. The interest of these aspects is becoming a larger topic area in all kinds of sports, with more research required focusing on the effect of these exercises on development factors in athletes.

I would like to thank my two supervisors, Atle Hole Sæterbakken and Vidar Andersen for their patient and constructive advice throughout the whole process of writing this master's thesis. They have helped motivate and guide me from start to finish through the research and writing. Without the collaboration and volunteering of Sogndal football, this study could never have taken place. A great appreciation to all the subjects for their patience and willingness to complete all the NHE trainings involved in the intervention and completion of testing. A further thanks is warranted to the University of Western Norway of Applied Sciences. The excellent facilities available to the students, where use of the strength lab, the gym and the 3g football pitches were crucial for my study. The resources available to all students made my research project easier and accessible, having all the utilities available on one campus.

With thanks,
Oskar Bårtvedt-Payne

Sammendrag

Nordic hamstring øvelsen (NHE) er en skadeforebyggende øvelse som brukes i mange idretter for å redusere risikoen for å forebygge skader og øke eksentrisk styrke. Tidligere forskning har vist de positive effektene av NHE på ytelsesparametere som styrke, spenst og sprint. Videre forskning må definere hvordan NHE kan påvirke prestasjonsparametere i fotball og, hvordan øvelsen kan tilpasses til de vanlige treningsrutinene til fotballspillere. Målet med studiet var å undersøke effekten av NHE på sprint og spenstytelse blant unge elite fotballspillere i aldersgruppen 16-18 år.

Metoden som ble anvendt var en intervensjonsstudie med deltakere randomiserte i to intervensjonsgrupper og en kontrollgruppe. Totalt 20 deltakere ble rekruttert til å delta i intervensjonsgruppe, hvorav en gruppe gjennomførte NHE trening med elastisk motstandstreningsbånd og en gruppe uten. Totalt 12 deltakere ble rekruttert til å delta i kontrollgruppen utvalgt uten randomisering. Studiet startet med pre-testing for å kartlegge baseline verdier for 40m sprint og Countermovement jump-testen (CMJ). Treningsprogrammet gikk over en 12-ukers NHE-intervensjon med økende sett og repetisjoner utover antall uker. Alle deltakere trente de vanlige fotballtreningene i tillegg til NH-intervensjonen. Etter frafall underveis ble de to intervensjonsgruppene slått sammen til en for analyse. Treningseffekten av det elastiske motstandsbåndet ble derfor fjernet fra studiet. Post-testing ble gjennomført umiddelbart etter den 12 ukers NHE-intervensjon. Testingen inkluderte 40m sprinttesten for å evaluere effekten på sprintytelsen og CMJ-testen for å evaluere spenstytelsen.

Resultatene fra studiet ble som følger; 3,1 % observert forbedring for intervensjonsgruppen i 40m sprint ($5{,}63 \pm 0{,}35$ vs. $5{,}46 \pm 0{,}32$, $p = 0{,}004$; ES = 0,5). Spenstytelse viste en reduksjon på 13,9 % for intervensjonsgruppen i CMJ-testen ($38{,}98 \pm 6{,}81$ vs. $33{,}56 \pm 5{,}57$, $p = 0{,}009$; ES = 0,87).

Effekten av NHE intervensjonen forbedret sprintprestasjonen betydelig, noe som viser de gunstige effektene NHE har på sprintytelse for unge elite fotballspillere. En nedgang i spenstytelse ble observert for intervensjonsgruppen, i motsetning til tidligere forskning som har vist de positive effektene av NHE på spenstytelse i andre idretter som håndball. Videre forskning er nødvendig for å forstå sammenhengen og koblingene mellom NHE og effekten på viktige prestasjonsparametere som sprint og spenst i fotball.

Abstract

The Nordic hamstring exercise (NHE) is an injury prevention exercise utilised in many sports and specifically for reducing the risk of hamstring strain injuries and increasing eccentric strength. Previous research has shown the positive effects of the NHE on performance parameters such as strength, jumping and sprinting. Defining how the NHE effects on performance parameters in football should be focused on in future research and, how they can be adapted into the regular training routines of football players. The aim of this study was to investigate the effect of the NHE on sprint and jump performance in youth elite football players in the age range of 16-18 years old.

The method used was an intervention study with randomised intervention groups and one control group. A total of twenty total subjects were recruited to participate and were randomized into two intervention groups, one group training with an elastic resistance training band and one without. 12 further subjects were recruited without randomisation to participate in the control group. The study started with pre-testing to set baseline scores for all subjects. The intervention period was a 12-week NHE intervention with increasing sets and repetitions. All groups trained the normal football sessions in addition to the NHE intervention. Due to withdrawals, the two intervention groups were merged for analysis to one. The training effect of the elastic resistance band was removed from the study. Post-testing took place immediately after the 12-week intervention. Testing included the 40m sprint test to evaluate the effect on sprint performance and the CMJ test to evaluate jump performance.

The results showed a 3.1% improvement for the intervention group was observed in the 40m sprint test (5.63 ± 0.35 vs. 5.46 ± 0.32, $p = 0.004$; ES = 0.5). Jump height decreased by 13.9% for the intervention group in the CMJ test (38.98 ± 6.81vs. 33.56 ± 5.57, $p = 0.009$; ES = 0.87).

The effect of the NHE improved sprint performance in the intervention group significantly, demonstrating the beneficial effects the NHE has on sprint performance for youth elite football players. However, there was a decrease in jump performance for the intervention group, unlike previous research which has shown the positive impacts of the NHE on jump performance in other sports such as handball. Further research is required to fully understand the correlation and links between the NHE and its effect on important performance parameters such as sprinting and jumping in football.

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1. Introduction

This study aims to investigate the effect of a 12-week training intervention on sprint and jump performance in youth elite football players in the age range 16-18 years old. The selected training intervention for this study was comprised of an injury prevention movement called the Nordic hamstring exercise (NHE). This movement is an eccentric strength exercise that targets all three of the hamstring muscles, the biceps femoris, semitendinosus and semimembranosus. The NHE targets eccentric muscle strength and muscle hypertrophy inducing an injury preventative effect, by activation of the knee flexor muscles. The purpose of this study was primarily to investigate the effect of the NHE on sprint and jump performance. This is due to the limited knowledge between the NHE and the effect it can have on various performance parameters.

Previous research has shown the positive injury preventative effect the NHE has for athletes in all sports. However, specifically in football, the hamstring muscles have a crucial impact on performance. Football players perform at high intensities with periods of low intensities, where quick direction and speed changes are a necessity. The most decisive in game moments are those executed with a high intensity and explosivity, such as sprinting, jumping and accelerating for the ball.

The NHE is an exercise regularly implemented in the daily routines of elite youth football players across Norway in its use for injury prevention. In the theory section of my master's thesis, I discuss the relevance of hamstring injuries, plyometric and sprint training in focus of the chosen tests, injury prevention exercises and, the effects of the NHE on performance parameters in football. The research investigates the potential benefits of why the NHE should be integrated into the training routines of youth elite football players in Norway.

2. Theory

2.1. Hamstring injuries

The background for choosing to research the effects of a Nordic hamstring (NHE) training intervention is based on the overall importance of the hamstring muscles in sports. The high injury prevalence of the hamstring muscles explains why research should focus on the effects of injury prevention exercises such as the NHE.

A recent study showed that muscle injuries are the most common types of injuries, representing 30% of all injuries (Ekstrand et al., 2012). Among muscle injuries, hamstring strains are the most prevalent types of injuries in non-contact sports such as football, rugby and sprinting (Opar et al., 2012). Injury to the hamstrings represents 12% of all injuries (Ekstrand et al., 2012). Hamstring strains have been the most prevalent sporting injuries over the last 8-10 years with focus on athletics and football, of which these sports incorporate high intensity movements (Brockett et al., 2001). Specifically in football, strain injuries to the hamstrings account for 10% to 23% of all acute injuries (Engebretsen et al., 2010).

The hamstrings are the group of muscles located on the posterior side of the thigh. The muscles which make up the hamstrings are called musculus semitendinosus, musculus semimembranosus and the largest, musculus biceps femoris (long head and short head) (Schache et al., 2012).

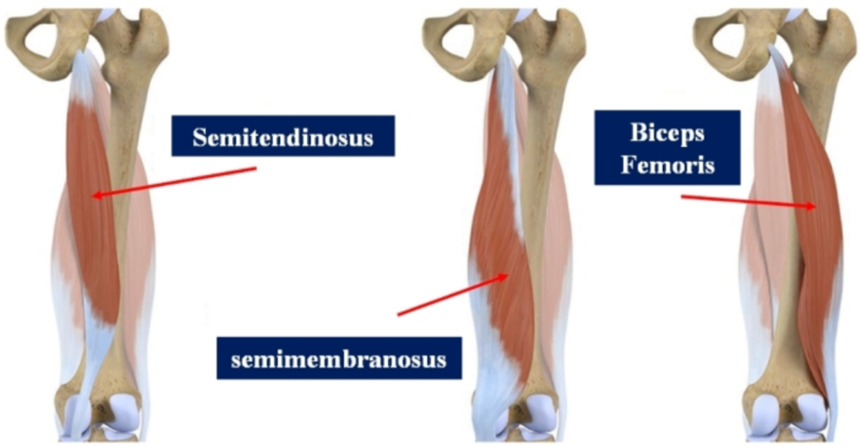


Figure 1: The three muscles which make up the group of muscles called the hamstring (Rodgers & Raja, 2022).

The muscle in the hamstrings which has the highest injury incidence is the Biceps Femoris (Opar et al., 2012). The most common sites of disruption are in the muscle tendon junction and the adjacent muscle fibres. The hamstrings are defined as a biarticular muscle group where they cross and influence movement across two joints (Landin et al., 2016). Biarticular muscle groups are subjected to large length changes especially during exercise. The anatomical arrangement of the hamstring muscles makes them susceptible to injury. In sports such as football when running or kicking, knee extension causes the hamstrings muscles to extend to long lengths, increasing the risk of hamstring tears significantly (Brockett et al., 2001). Ekstrand et al. (2012) completed a study on the prevalence of hamstring injuries in the Champions League from the 2007 - 2011 seasons. The main discovery from this study was the total number of injuries over the four seasons visible to MRI scans. This number was 180 total injuries from grade 1 to grade 3 hamstring strains. 151 of the 180 injuries affected the biceps femoris muscle which made up 84% of the injuries presented in this study. These results show the high incidence of hamstring strains within football. Further research on injury prevention exercises to investigate their effect, how they can impact athletes and their performance is required. The grading of hamstring injuries is a classifying system from level 1-3. The injury is classified due to the level of pain experienced, weakness and loss of motion. The grades considered are reflected upon level 1 having minimal damage, up to grade 3 with a complete rupture or tear of the muscle (Heiderscheit et al., 2010).

A high percentage of hamstring injuries are caused by recurrences, suggesting the difficulty of the rehabilitation process (Brooks et al., 2006). Recurring hamstring injuries are described as a vicious circle, resulting in significant morbidity of symptoms, reduced performance and absence from sport (Engebretsen et al., 2010).

Risk factors for hamstring injuries are associated with sports that involve stretch shortening cycle activities such as high intensity running, sprinting and quick changes of direction (Brooks et al., 2006). There are several modifiable and non-modifiable risk factors involved in the prevalence of hamstring injuries. Modifiable risk factors include the athlete's fatigue, imbalance in strength between the quadriceps and the hamstrings and, the level of warm up before exercise. Non modifiable risk factors include the athlete's age, ethnic origin and previous hamstring injury history (Brooks et al., 2006). High intensity running or sprinting is generally the main cause of hamstring injuries. During the terminal swing phase of the gait cycle, where the hamstrings are active and lengthened, is where an injury can occur primarily to the biceps femoris muscle (Heiderscheit et al., 2010). The hamstring absorbs energy from the decelerating limb which prepares for foot contact. This places a greater musculotendon stretch on the biceps femoris in comparison to the other two muscles in the hamstring, the semimembranosus and the semitendinosus (2010). Focusing on injury prevention exercises is a key method to reduce the amount of hamstring injuries in sports, which will be discussed in the paragraph below (2010).

2.2. Injury prevention and eccentric strength training

The term injury prevention refers to exercises that prevent and reduce the risk of injuries. Intrinsic injury prevention strategies refer to factors such as the physical attributes and conditioning of the athletes in withstanding the demands of sports, reducing the risk of injury (Schiff et al., 2010). Plenty of research has been done on risk factors associated with injury occurrence in the hamstrings (Heiderscheit et al., 2010; Opar et al., 2012). The effectiveness of various injury prevention techniques is questioned in research. There are many forms of injury prevention training such as different programs tailored for specific sports and the movements required to perform. Heiderscheit et al. (2010) discuss normal hamstring stretching up against a flexibility program incorporated into training. Duration and the frequency of stretching were described as crucial factors in the affectability of a flexibility program, due to different levels of flexibility in the muscles. Heiderscheit et al. (2010) conclude that more randomized control trials are required to determine if stretching and flexibility programs should remain a part of injury prevention strategies in the future. Current rehabilitation programs should be evaluated in their effectiveness. Identifying the risk of re-injury and return-to-sport criteria should be adapted to develop effective strategies for rehabilitation (Heiderscheit et al., 2010).

General warming up before exercise is a key injury prevention method, which prepares athletes for the physical demands of sports. Increased motor performance and a reduction in injury risk are two main benefits of warming up before exercise (Wilke et al., 2018). Tailored programs specific to certain sports such as the FIFA 11+ for football players have become more prominent over the last few years, with the focus to reduce the incidence of all types of football injuries (Barengo et al., 2014). The FIFA 11+ is a simple and easy to follow warm up routine with various exercises focused on injury prevention for football players. Key areas focused on in this program are core stabilization, eccentric training, and plyometric training. The benefits of this program are the minimal requirement of equipment and, the ease of familiarization to the program (2014). The effects of following this structured program 1.5 times per week showed an estimated risk reduction to all injuries by 35%. In addition, showing improvements in neuromuscular and motor performance (2014).

Eccentric strength training is a key training method for athletes in injury prevention training programs, due to the one of the key risk factors linked to hamstring injuries. The high eccentric forces placed on the hamstrings and eccentric contraction from running, reveal the importance of eccentric strength training (Opar et al., 2012). The presence of stiffer scar tissue after a hamstring strain has a negative effect on the musculotendon stretch capabilities of the hamstring muscle, altering the muscle-tendon contraction mechanics. Training eccentric strength exercises has a positive effect in the peak force development of musculotendons. In respect to hamstring injuries this can explain how following a hamstring strain, eccentric training may restore the optimum musculotendon length (Heiderscheit et al., 2010).

The positive effects of injury prevention with the use of eccentric strength training for the hamstrings has been proven in previous research (Askling et al., 2003), (Mjølsnes et al., 2004). The use of eccentric training for athletes is further emphasised due to results from a randomised control trial by van der Horst et al, (2015) on amateur football players. In this study the researchers investigated the preventative effect of the NHE on hamstring injuries. Hamstring injuries affected 36 of the 579 subjects involved in the study, with a total of 38 hamstring injuries recorded. The intervention group integrated the NHE over a 13-week period and the results showed a decrease in the injury incidence compared to the control group. Athletes with a high level of eccentric muscle strength have a reduced risk of injury incidence (van der Horst et al., 2015). The effects of the eccentric strength training using the NHE on the human body will be discussed in more detail in the next paragraphs.

2.3. Muscular and strength adaptations to eccentric strength training

Eccentric strength training leads to a range of structural changes in the muscles. Various studies have investigated the effects of eccentric training on muscle strength, cross sectional area and the nervous system. Higbie et al. (1996) compared the effects of concentric training and eccentric training on muscle strength, neural activation and cross sectional area of the quadricep muscles. The intervention exercise chosen was a unilateral isokinetic knee extension both in the concentric and eccentric phases of the movement. Cross sectional area measured by an MRI increased more in the eccentric training group (6.6%) than in the concentric training group (5.0%). The researchers concluded the study that eccentric strength training had a greater effect than concentric strength training. Increases in muscle hypertrophy were also slightly greater, proving the beneficial effect of eccentric strength training (Higbie et al., 1996).

Potier et al. (2009) completed a study focusing on the effect of eccentric strength training on muscle architecture in the biceps femoris and, the range of motion of the knee. This study was the first to reveal an increase in fascicle length of the musculus biceps femoris (33.5%). The experimental group showed an increase in the average 1RM by 34.2%. In the passive knee extension test an increase of 5% was measured for the joint range of motion. The increase in fascicle length indicates the addition of sarcomeres within the biceps femoris muscle from specific eccentric strength training. The results indicate the effect of eccentric strength training in generating a greater torque at more extended joint positions, incidentally where the most damage occurs to the hamstrings. This can reduce the injury incidence of hamstring strains, indicating the injury preventative effect eccentric strength training can have on the human body. The increase in range of motion displayed from the results of this study are also similar other studies with focus on passive stretching of the hamstrings (Potier et al., 2009).

Seymore et al. (2017), researched the effects of the NHE on muscle architecture, stiffness and strength. The results showed increased volume and cross-sectional area of the hamstrings in the experimental group. The researchers concluded that the NHE was an effective training method for muscle hypertrophy of the hamstring muscles (Seymore et al., 2017).

2.4. The Nordic hamstring exercise

The next paragraph describes in detail the Nordic hamstring exercise (NHE) used in my study during the 12-week intervention period. The NHE is a very common exercise utilised in injury prevention programs for athletes in a wide range of sports. However, adoption of the NHE is low in Norwegian football (11%), despite the success the exercise has in reducing hamstring injuries (Bourne et al., 2017; Ribeiro-Alvares et al., 2018). The exercise starts in a kneeling position, standing with an upright upper body. When executing this exercise the subject lowers their upper body down to the ground, as slowly as possible to maximise the eccentric load on the hamstring muscles. The hands are used to break the fall at the end of the movement once the chest touches the ground, which also minimalizes the load in the concentric phase (van der Horst et al., 2015).

There are different variations of how to execute this exercise, however the principles stay the same. Ensuring that the feet stay touching the ground is essential. One common variant of this exercise is to have a person holding the heels or lower legs of the person performing the NHE (Elerian et al., 2019). Nordic Hamstring equipment is utilised by many training centres. For this research project there were two Nordic hamstring apparatus used by the test subjects. This equipment locks the feet of the person performing the exercise, removing the need of another person to hold and stabilize the legs. Making the exercise independent and easier to perform. One can also adjust the height of the apparatus that locks in the heels/legs of the test subject.

Arnason et al. (2008) investigated the effect of eccentric strength training and flexibility training on the incidence of hamstring strains in football. The chosen eccentric strength exercise was the NHE. The study took place over two football seasons where the subjects were instructed to perform eccentric strength training and/or flexibility training. The results indicated that no injuries were recorded in the eccentric strength training group. The overall injury incidence of hamstring strains was 65% lower among the football teams that used the NHE program compared to the teams that only incorporated flexibility training (Arnason et al., 2008).

Similarly Van der Horst et al. (2015) investigated the effect of the NHE on the incidence of hamstring injuries among amateur football players. The intervention group were instructed to perform the NHE intervention over a 13-week period, with 25 sessions. The results indicated a higher injury incidence in the control group compared to the intervention group. Eleven hamstring injuries (31%) were recorded in the intervention group compared to 25 injuries (69%) recorded in the control group. After the intervention period was over, 18 hamstring injuries were recorded in the control group and 6 were recorded in the intervention group, showing a significant difference in the injury incidence between the groups (van der Horst et al., 2015).

Van dyk et al. (2019) performed a comprehensive systematic review and meta-analysis on the effectiveness of injury prevention programs, which included the effect of the NHE on injury incidence in the hamstrings. The results from this study showed the positive effect on injury incidence in programs that included the NHE. These programs reduced hamstring injuries by 51%, with the researchers concluding that the NHE essentially halves the rate of hamstring injuries when incorporated (van Dyk et al., 2019).

Application of the NHE in injury prevention programs is crucial for sports for increasing the eccentric strength of the hamstring muscles. The effects of increased eccentric strength for the hamstrings on performance will be discussed further in this theory section. The ease of implementation, the simplicity and, the minimal technique requirement are all benefits of the NHE.

2.5. Plyometrics

For my study the Countermovement jump (CMJ) test was utilized as a test for vertical jump performance. The reasoning for going in depth on plyometric training is to discuss the background on the effects of plyometrics and, why the CMJ test was chosen as a valid test for my study.

The term plyometrics refers to exercises which have a goal of enhancing strength and neuromuscular performance (Sáez-Sáez de Villarreal et al., 2010). For instance, for the lower body this includes jumping and bounding training. Typical examples of plyometric exercises are the CMJ test, the drop jump and the squat jump. Plyometric training is characterised by the stretch short cycle where each exercise encompasses a rapid stretch of the muscle in the eccentric phase. Closely followed by an immediate rapid shortening of the same muscle in the concentric phase of the movement (2010). Plyometric training has widely been given the status of the most effective training method for improving leg extensor power, strength, high power dynamic movement performance and, vertical jump ability (Markovic et al., 2007). For my study, the CMJ test was used as a test parameter to investigate the effect of the NHE on jump performance. Ultimately categorising the explosive effects of the NHE intervention.

Rimmer and Sleivert (2000) investigated the effects of a plyometric program on sprint performance. These researchers defined plyometric training as the ability of muscles to produce force at high speeds in dynamic movements. Before their study they hypothesized that plyometric training would improve acceleration over 20-40m to a greater extent than specific sprint training. The reasoning why they hypothesised that plyometric training would have a more beneficial effect on sprint performance is due to the ground reaction forces being higher in plyometric training than in sprint training (2000). Sprint time was significantly improved in the group subjected to plyometric training. The results showed increases in the intervals from 0m-40m in the plyometrics group. The greatest effect was shown in the initial acceleration phase. Athletes accustomed to performing sprints up to 40m in length could improve sprint performance with sprint specific plyometric exercises incorporated in their training programs (Rimmer & Sleivert, 2000). A meta-analysis completed by Sáez-Sáez de Villarreal et al. (2010) reviewed the role of various factors on the effect of plyometric training on strength performance. The inclusion criteria for this meta-analysis were plyometric training programs focused on the lower limb muscles such as the quadriceps and hamstrings. The results of this study indicated what previous research has already identified, that plyometric training has a positive effect on strength performance. The researchers also identified an ideal strategy for the plyometric programs with focus on the training volume. A total of 15 sessions or more over a 10-week period was deemed as the most beneficial for strength increases. A variation of plyometric exercises in the training program was also found to be more beneficial rather than the performance of individual exercises. Furthermore, the results show that regular plyometric training enhance an individual’s ability to develop force and power during the eccentric phase, hence increasing their total strength in other exercises (Sáez-Sáez de Villarreal et al., 2010).

Chimera et al. (2004) completed a study looking at the effects of plyometric training on muscle activation in the quadriceps, hamstrings, hip abductors and hip adductors. The subjects in this study were trained female athletes of which 20 subjects took part. With the use of electromyography, the researchers investigated the preparatory and reactive activity of different muscles involved in plyometric training. The results revealed beneficial neuromuscular adaptations in the hip adductor muscles in the pre-activation phase. The adaptation to an increase in muscle activation proves that plyometric training has a positive effect on the knee joint, producing an injury preventative effect for athletes (Chimera et al., 2004).

2.6. Sprinting

My study also investigates the effect of the NHE on sprint performance, by using the 40m sprint test. The reasoning for the choice of researching this element is due to sprinting being one of the most crucial elements involved in sports such as football. In competitive games, on average players perform short sprints from 2-4-second-long sprints every 90-180 seconds (Andrzejewski et al., 2013). Although maximal sprinting and acceleration represent 5% of the total distance covered in a professional football match, they are essential physical determinants of match performance (Ishøi et al., 2018). The results from a study by Barnes et al. (2014) show high intensity running and sprinting distance increased by 30-35% between the seasons from 2006/07 to 2012/13 (Barnes et al., 2014). This shows that high intensity actions are increasing in sports such as football. Often being the decisive moments where injuries can occur due to the extra load and power output created. The hamstrings are lengthened during sprinting, leading to overstretching of the muscle during the eccentric phase and increased moment of injury (Chumanov et al., 2007).

Understanding the process of how eccentric strength training can affect the muscles used in sprinting is crucial for my study. Furthermore, a basic understanding of the fundamental phases to a sprint and, what happens to the body needs to be established. The general phases attributed to sprinting are the acceleration and maximum speed phases. The actions of muscles such as the hip extensors (the hamstrings and gluteus maximus), the quadriceps, and the calf muscles (gastrocnemius and soleus) are required in the acceleration phase of a sprint. During the maximal speed phase, the forward and backward rotation of the hamstrings are crucial (Hasan et al., 2021). Most studies use electromyographic (EMG) activity to measure and evaluate the activity of the hamstring muscles involved in the process of sprinting. EMG measures have found the hamstrings to be active during the mid-swing to the terminal phase during a sprint (Schache et al., 2012). For my research I wanted to investigate if the intervention influenced total sprint time for the 40m sprint. However, measuring and evaluating hamstring performance using EMG should be investigated in future similar studies, to see the effect on the hamstring muscles in addition to sprint performance.

2.7. Effects of the NHE on sprint and jump performance

A range of different studies have both together and separately investigated the effects of the NHE on sprint and jump performance in different sports (Chaabene et al., 2020; Freeman et al., 2018; Ishøi et al., 2018; Krommes et al., 2017; Markovic et al., 2020; Váczi et al., 2022). Studies focused solely on the effect on sprint performance have shown a positive effect of NHE interventions. A 10-week NHE intervention using football players as subjects used a repeated sprint test to evaluate sprint performance. The results showed a moderate improvement of sprint time in the repeated sprint test by 1.8% for the intervention group (Ishøi et al., 2018). Another study by Markovic et al. (2020), using predominantly youth football players investigated Nordic hamstring strength and the relation to sprint performance. A large correlation (r= -0.52, p <0.01) between Nordic hamstring strength and sprint performance was observed. A 27% of variance of sprint performance was explained by the relative Nordic hamstring strength. High eccentric strength of the hamstring muscles was therefore concluded to positively effect sprint performance in the youth football players (Markovic et al., 2020). A study by Freeman et al. (2018), researched the effect of a NHE on sprint and strength performance. A total of 28 subjects were randomly allocated to two intervention groups (NH group and sprint group). The results revealed significant gains in hamstring eccentric strength for both intervention groups. Meanwhile 40m sprint results showed a trivial improvement in the NH group, whilst the sprint group experienced a moderate improvement in the 40m sprint (Freeman et al., 2018). Although the effect of the NHE in this study only showed trivial improvements, the increase in eccentric strength shows the potential effect on sprint performance with more extensive eccentric training over a prolonged intervention period.

The documentation of the NHE on performance abilities such as jump performance is relatively unknown for football players compared to other athletes. A study by Váczi et al. (2022), examined the effects of long-term eccentric NHE training on muscle strength and vertical jump ability in 10-11 year old female handball players. The subjects were randomly assigned into a NHE group and a control group. Interestingly eccentric hamstring impulse improved in both groups. Furthermore, the eccentric strength increases in the NHE group showed the transferability to an improvement in functional performance. The NHE increased height jumped in the CMJ test compared to the control group (Váczi et al., 2022). A similar study by Chaabene et al. (2020), examined the effects of an 8-week NHE intervention on components of physical performance on young female handball players. From this study the physical performance components measured that were useful to my research were the effects on sprint speed and jump height performance. Moderate improvements were shown in the NHE group from the sprint tests as shown by effect size (ES=0.68-0.82). Trivial improvements were seen in the CMJ test (ES=0.10), however, the NHE intervention showed the potential effectiveness in improving sprint and jump capabilities in young female handball players (Chaabene et al., 2020). Another study using untrained males as subjects, showed a significant increase in vertical jump height (3.4cm), when investigating the effect of eccentric hamstring strength training on dynamic jump performance (Clark et al., 2005). However, further research is required to categorise the effect of the NHE on jump performance focused specifically on football players.

A study using a similar intervention as my study on elite male football players by Krommes et al (2017), investigated sprint and jump performance following a 10-week NHE intervention. The results revealed improvements in CMJ performance (4.8%, 2.1cm at post-test) after 10 weeks of NHE training. The sprint tests over a 30m distance showed improvements over the split distances (5 and 10m), with 6 out of the 9 test subjects in the NHE group improving running time (Krommes et al., 2017). All of the studies described above investigate the use of the NHE as an intervention method to see the effect on different performance parameters. The results of these studies show the potential of the NHE in improving different performance factors in sports. The NHE can be adapted into the regular training routines for football players as a vital exercise for reducing injury risk, increasing eccentric strength, and improving performance parameters. The results from previous research backs up the credibility of the NHE, however the extent of how large an effect the NHE has on specific performance parameters needs to be researched more extensively. An intervention focused on eccentric strength training of the hamstrings shows promise for explosive characteristics such as sprint and jump abilities, which are crucial performance parameters for football players.

The aim of my study is to investigate the effects of using the NHE over a 12-week training period on sprint and vertical jump performance. I hypothesized that the NHE intervention would have a positive effect on sprint and jump performance from baseline to post-test. As mentioned earlier in the theory section, the NHE has shown a beneficial effect to important performance factors for football players. However, how significantly would the intervention effect the sprint and jump capabilities after the 12-week NHE intervention compared to the control group. The next chapter revolves around the methodology of my study. The reasoning for how the research was carried out and the explanations for why will be discussed in the paragraphs below.

3. Methodology

3.1. Type of study design

The purpose of this study was to examine the effect of a 12-week training program for the Nordic hamstring exercise (NHE). In particular, the goal was to see the effect on sprint and vertical jump performance on youth elite male football players.

For my research project, I used the quantitative research method in which numerical data is collected to answer my hypothesis (Christensen et al., 2015). The reasoning for my choice of quantitative research was to collect accurate and reliable measurements for statistical analysis. This study focuses on answering the effect of an intervention on two measurable variables, sprint and jump performance. The quantitative data collected in this research project highlights the trends across the data sets and study groups, but not the motivation or why (Goertzen, 2017). Goertzen et al. (2017) name some key characteristics of quantitative research. Researchers deal with numbers to assess information and, the data can be measured and quantified. In this study, my research aimed to be objective, the data collection involved an intervention group and a control group for comparison. The results collected can be utilised in several different ways such as in summarisations, comparisons, and generalisations (Goertzen, 2017).

3.2. Experimental approach to the problem

The research study design used is a within and between group comparison. The results from the different tests were analysed in respect to the difference between the experimental group and the control group for each test. Each group were also analysed in their results comparing pre and post test data. This study is based on data from an intervention study on youth elite male football players. This type of study is where subjects are randomly assigned to one of two or more intervention groups. The choice of using this study design was to prevent selection bias when assigning the subjects to the intervention. Random allocation distributes and balances the baseline systematic differences between the groups being tested.

Randomisation is referred to as the process of assigning study subjects randomly to experimental groups and control groups, enabling an equal chance of being assigned to any group (Akobeng, 2005). Randomisation is one of the key control methods in research, as it removes the systematic group differences which can bias the study results (Christensen et al., 2015). For my study, the randomising of the intervention groups was crucial in avoiding bias. As my study started with two intervention groups, without randomisation many subjects would have for example chosen a specific intervention group themselves. Another reason for randomisation here is due to the sprint and jump abilities of players in different positions. To play a certain football position one utilises different skill sets. If all the defensive players chose the intervention group that trained the intervention period with an elastic resistance band, there would be bias present in the study. Random assignment is the only technique for controlling and eliminating systematic bias (2015).

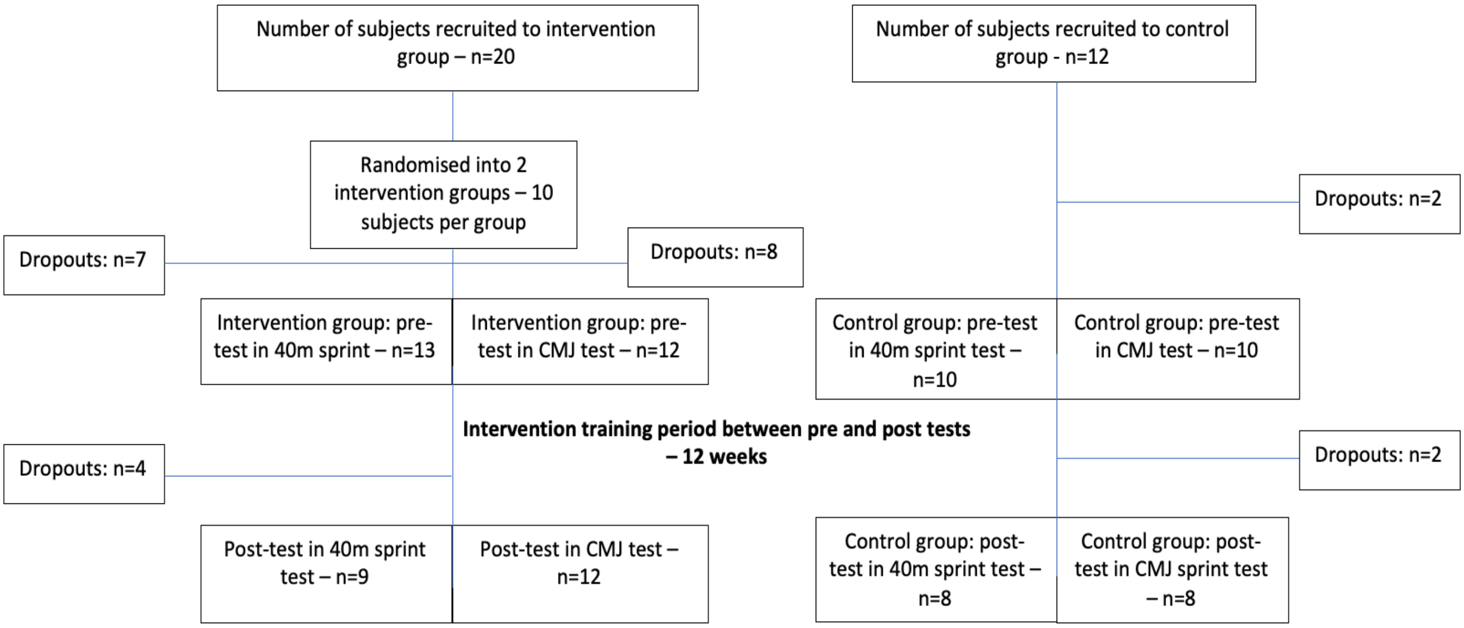
3.3. Intervention groups

This study is in collaboration with Sogndal football, with a focus on the second team built up of youth elite male football players in the age range of 16–18-years old. The selection criteria of the study were relatively limited due to one football team participating in the research project. However, the main inclusion criteria used were age, volume of training per week and being fully fit for the intervention and testing. The subjects were randomly divided into two intervention groups to avoid bias. The only difference between the groups was one group used an elastic resistance training band to control the eccentric phase of the movement, while the other group trained the NHE intervention as normal. The number of subjects recruited to this study were 20, with 10 subjects randomly divided into each intervention group. However due to various factors such as fitness, injury, Covid 19 and illness, several subjects had to withdraw from the intervention groups hence not completing the full intervention or testing. Withdrawals from the study were partially expected due to the generally high training load placed on the subjects each week. A total of seven subjects for the 40m sprint test and eight subjects for the CMJ test withdrew before pre-testing. This reduced the capacity of the study to investigate what the aim had fully intended. This study was supplementary for the players during the pre-season phase with a focus on the effect on sprint and jump performance incorporating an injury prevention exercise into their weekly schedule. After the 12-week intervention as post-tests were to take place for each test, the intervention groups had a varying number of subjects. This prevented an accurate and fair comparison between the two intervention groups. A total of eight subjects completed the intervention in the group which trained the NHE without an elastic resistance band. However, only four subjects remained in the intervention group that trained with the resistance band at post-test. A total of 12 subjects had full sets of data for the intervention groups which led to the decision of putting together each intervention group to one. This changed the aim of my study to investigate the effect of a NHE intervention program on sprint and vertical jump performance. Rather than additionally looking at the effect of training the NHE with and without an elastic resistance band during the 12-week intervention.

3.4. Control group

A control group was also created for the comparison of the data collected during testing. The aim of this study was to have a control group with similar characteristics to the intervention group. Such as total volume of football training, strength training, age, and relation to the NHE. Thus, enabling an accurate comparison between the results from the two tests in the pre/post data between the groups. Recruiting to the control group was not randomized, as subjects were selected with the inclusion criteria to match the subjects in the intervention group. In collaboration with Sogndal football the subjects were recruited to the control group from the u16 team. Other subjects from local teams in the Sogndal area were asked to participate to help build up the numbers of the control group. A total of 12 subjects were recruited to the control group, however, two had to withdraw from the study due to injury concerns prior to pre-testing. A total of 10 subjects had full data for the control group for the pre-tests. A further two subjects had to withdraw from the study during the 12-weeks simulated intervention time between pre and post-testing. This was to ensure the same conditions were instructed between testing of the pre-tests and post-tests as the intervention group to allow a fair comparison of the effects of the NHE on sprint and jump performance.

Figure 1: study protocol



The figure above shows the protocol for the subjects recruited to the study. The total number of subjects is shown at each stage of the study for both the intervention and control groups. A total of 20 subjects were randomly divided into two intervention groups. As mentioned previously the study design started with one group training the NHE with an elastic resistance band and one without. The total subjects recruited to the intervention group quickly reduced due to injury and illness. For pre-test in the 40m sprint a total of 13 subjects took part and 12 subjects took part in the CMJ test. They then trained the 12-week intervention period before completing the 40m sprint and CMJ test post-tests. During the 12-week period an unequal number of subjects was observed between the two intervention groups. The idea was to have one group training with an elastic resistance band and one group without. However, due to a lack of subjects in one of the groups, the analysis of the two intervention groups was removed from the study. Both groups and subjects were merged together and the idea of analysing the effect of training the intervention with/without an elastic resistance band was set aside. This study idea integrating NHE training with/without an elastic resistance band should be followed up in future research.

3.5. Inclusion and exclusion criteria

In research, criteria must be set to enable the reproduction of studies. Inclusion and exclusion criteria determine the characteristics of subjects or elements in the study. Inclusion criteria are characteristics of the subjects involved, such as age, gender, race, type of illness (Connelly, 2020). The inclusion criteria for my study are defined in the following paragraph. Exclusion criteria are not the opposite of inclusion criteria, they merely define attributes that would prevent a subject from being involved in a study. The balance between the two criteria must be managed carefully by researchers. If the inclusion criteria are strict and restrictive, with expansive exclusion criteria, only a narrow target group of subjects can be tested (Connelly, 2020).

Inclusion criteria defined for the intervention group were as followed, the subjects selected were players for the Sogndal second team, no underlying injuries and in the specific age range chosen for the study. The selected age ranges chosen for this study were from 16-18 years old. Exclusion criteria for this study were injuries/fitness, outside the designated age range and, football squad/team. Sogndal 2 was the chosen squad for the subjects in the intervention group. Movement of players between the first team and second team occurs often in the pre-season phase of a football season. Therefore, subjects training in both squads during the intervention were removed from participation in the study.

Before the start date for the intervention, the subjects were told by their coaches and the researchers about the study. The subjects also received an information letter and a consent form regarding the study. Those under the age of 18 years old required a parent or guardian to sign the consent form. There wasn't a fixed criteria set by the researchers on the previous experience training the specific Nordic hamstring exercise. This was due to the normal injury prevention training sessions Sogndal second team train each week. Exercises such as the NHE and the Copenhagen exercise were trained in these sessions. The subjects already had prior knowledge of the NHE, ultimately benefiting the 12-week NHE intervention. Each subject followed the same training program with the same repetitions and sets each week per training, closely instructed, and guided each session.

3.6. Intervention program

The training program consisted of training solely the Nordic Hamstring exercise over a 12-week period building up from once a week to three times a week.

The training program is linked below in table 1.

Table 1 – NH training program for the intervention group

Week	Sessions each week	Sets	Repetitions
1	1	2	2-4
2	1	2	4
3	1	2	4-6
4	2	2	4
5	2	3	2-4
6	2	3	4
7	2	3	4-6
8	3	3	2-4
9	3	3	4
10	3	3	4-6
11	3	3	6
12	3	2	4
Total	30	28	264-292

The training sessions were completed with at least 48 hours in between each session. The rest interval between each set was from 120 – 180 seconds. During the 12-week intervention, subjects followed a set number of repetitions and sets for the NHE. Total sets and repetitions increased weekly until post-testing.

Each training session for the NHE intervention was closely followed and instructed to make sure the correct measures were always followed by the subjects**.** Each subject had a total of four football training sessions each week, an average of one football match per week and two strength sessions per week. The total volume of training was therefore high, and the load of the added NHE training was adapted to morning sessions on Tuesdays, incorporated into the injury prevention and strength workout for Sogndal 2. All sessions were obligatory with absence from any form of training in the week noted down. Most absences from training were due to injury or illness.

Before both testing and training, there was a specific warm-up conducted by the researcher. 15 minutes of cycling on a spin bike was implemented before each session. Ideally all subjects used the spin bike to reduce the impact/force on the knees and ankles, however, some subjects used treadmills due to the unavailability of the spin bikes in the gym. Due to the low number of repetitions and sets each session, many subjects utilised the NHE intervention as a part of their usual strength training sessions between football sessions in the week. At each morning training session in the gym, a queue system was integrated due to the limitation of Nordic hamstring training machines present. Furthermore, the break in between each set was set from 120 – 180 seconds which created further queues.

Consequently, there was no warm down from the training sessions however, as mentioned many of the subjects continued with extra training after completion of the required sets and repetitions for the NHE. The NHE was completed using a Nordic hamstring apparatus (Pivot 618 Nordic hamstring apparatus) where the movement is independent due to the locking of the heels/feet of the subject. Once in position the subject is upright and places their hands up either side of their head. This is the start position, and the exercise begins when the subject slowly lowers their upper body down to the ground. Once the chest touches the ground the hands are used to break the fall. This exercise focuses on the eccentric phase of the movement.

Figure 2: The Nordic hamstring apparatus used during the 12-week intervention.

(*Pivot 618 Nordic Hamstring*, n.d.)

3.7. Test Procedures

The location of the study took place at the campus of Western Norway university of applied sciences. Where the subjects recruited to the study, had access to the gym, the strength lab twice for CMJ pre and post-tests and the indoor 3G football pitch. For the training, each subject was randomly placed in either the intervention group that completed the intervention with or without an elastic resistance band. Testing was conducted both before and after the intervention, at week 0 and in week 13. Accordingly, the 40m sprint test was chosen since it is a reliable indicator for acceleration and speed. Especially relevant in assessing linear sprinting skills for football players (Altmann et al., 2019). The decision of the CMJ test for jump performance was based on previous studies which have shown the reliability of the CMJ test in measuring the explosive strength (Slinde et al., 2008).

3.8. Questionnaire

Before testing the subjects filled out a questionnaire based on football experience and previous injury incidence of the hamstrings. This was completed for a general overview of injury prevalence. Body compositions were also collected during pre-testing and not in the post-tests. However, once completed the relevance of the questionnaire and body compositions to the study were questioned and therefore removed. A further in-depth study on the effect of such interventions is therefore required to investigate the effect of the NHE on hamstring injury prevalence. For this study, solely the effect of the Nordic hamstring intervention on sprint and jump performance was investigated.

3.9. The countermovement jump (CMJ) test

The countermovement jump (CMJ) test is a simple, practical, valid, and reliable measure of explosive strength in the lower body (Slinde et al., 2008). Calibration of the force platform and the ergotest software was crucial to generate reliable and valid data to the study. Here the researchers follow the calibration instructions shown on the laptop whilst standing on different parts of the force platform. Once calibrated the test procedure could go ahead. The warm-up performed by the subjects was carefully monitored by the researchers. The exercises included a 15-minutes on a spin bike, 20 repetitions of a vertical jump and three sets of squats with a barbell weighing 20kg in total. For this study, we decided to eliminate the use of an arm swing during the CMJ test as it can improve jump performance by 10% or more (Cheng et al., 2008). The removal of an arm swing also set an easier requirement of technique in the CMJ test. The subjects held their hands to their hips with their feet shoulder-width apart whilst jumping. When instructed by the test administrator, the subject jumped as high as possible and attempted to land in the same location on the platform as they took off from. Each subject performed a minimum of three jumps so that performance averages could be calculated in centimetres (cm). A set break time was implemented in between each jump to ensure reliability for the test, also ensuring maximum effort for each jump (2 minutes). The mean height jumped for each group was calculated, allowing a closer look at the performance changes in scores between pre and post-test. Each subject could perform an extra jump if necessary due to a failure in technique when executing the test. Such failures in technique include not landing correctly or using an arm swing when jumping during the CMJ test.

3.10. The 40m sprint test

The 40m sprint test was chosen as a reliable indicator of the effect on speed and acceleration. The warm-up taken by the subjects was carefully monitored by the researchers with 15-minutes on a spin bike, 15 minutes of activation exercises and five 5m sprints. Photocells (Ergotest Innovation, Statehelle, Norway) were placed at 0m, 5m, 10m, 20m, 30m and at 40m to record the acceleration of each player and top speed through the test. As each photocell is passed the data is automatically sent to the software with the time taken to run between each photocell. The test starts from a stationary position, with one foot in front of the other and the subjects decide when to start after a clear signal from the researcher. A total of three sprints was run by each subject, where a meantime from 3 sprints was calculated for analysis. All test groups (intervention both pre and post-test and the control group) wore football boots whilst running the three sprints, and the tests were performed on the same 3g football pitch surface. This was to ensure the same conditions were matched throughout the testing period for both groups. There was no requirement for an allowance of extra sprints due to the ease of completion of the 40m sprint test.

3.11. Reliability and validity

A test or study cannot be considered valid if it is not reliable. Reliability refers to the consistency and repeatability of a measure (Thomas et al., 2015). In research measurements and testing are crucial in the data gathering process. The term validity describes the degree to which a test or instrument measures what it claims to measure (2015). In quantitative studies, the term validity refers to the extent to which a test is accurately measured (Heale & Twycross, 2015). For the 40m sprint test, photocells were placed at various distances to measure the time ran. For the CMJ test, a force platform measured the height jumped for each subject, giving a valid measurement of lower body power.

3.12. Ethics

When conducting a study researchers must use research ethics, which are a set of guidelines to assist them in their ethical research (Christensen et al., 2015). Informed consent refers to informing all subjects signed up to a study about all the aspects involved in the research (2015). Protection and the well-being of the subjects, as well as their rights, is required in all forms of research (Thomas et al., 2015). Obtaining written consent was vital for this study in informing all subjects of the aspects involved in this study and confirming participation. A consent form was sent out to each individual where those aged 18 could sign under as they were deemed as an adult. Those under the age of 18 years old had to have a parent or guardian sign to allow cooperation with the study. In research, those under 18 are called minors. They are presumed to be incompetent, which means they legally cannot give consent alone (Christensen et al., 2015).

The subjects could withdraw from the study at any stage. However, this was not a problem in this study due to the motivation of these subjects as football players and their hunger to become physically fitter. A review of withdrawals from the study showed that withdrawals occurred due to injuries, covid 19 and the movement of players up to Sogndal first team. The interest in result scores was a common factor among the subjects, as they wanted to compare results from the different tests between themselves. However, this was an ethical issue as confidentiality is an important factor to consider in research. Privacy and anonymity were crucial in following the ethical guidelines of research. The subjects could receive their results one on one with the researcher after all testing was conducted. Anonymity was preserved as each subject received a test number, to ensure no names were used in the study at any point. Anonymity refers to keeping the names and identities of the research subjects hidden and unknown (Christensen et al., 2015).

The strength laboratory at the university campus was used for the CMJ test where subjects were tested in pairs to allow for efficient testing. Those who tested together could potentially see who performed better, however, no scores or results were revealed by the researcher in charge of testing. Under the 40m sprint test all subjects in the intervention groups ran in a fixed order and all subjects could observe each other between the different sprints. Rest time for each subject between the sprints was spent standing in the ordered test queue, to allow for maximum efficiency for the test. Furthermore, the results of each sprint were not revealed to the subjects after each sprint. The only indication of test performance was visual, by their own judgement of the times run per 40m sprint.

3.13. Statistical analysis of the results

Statistical analysis was performed by using Microsoft excel, the 2020 version. The aim was to analyse and compare the results of the two intervention groups, one training with and one without the elastic training resistance band. However due to withdrawals from the study, one of the intervention groups ended up with only 4 subjects. This was a low number of results to allow for a comparison between the intervention groups. Therefore, both intervention groups were set together as one, giving more data to analyse between the intervention group and the control group. In total there were 13 subjects with full data in the intervention group collected for the 40m sprint test and 12 subjects for the CMJ test at pre-testing.

For the 40m sprint test there were 3 results recorded as each subject ran a total of 3 sprints. The mean time for each subject was calculated and the mean time for each group was calculated for pre and post-test. Photocells monitored the time taken to run at different metres over the 40m sprint. Total time taken to run the 40m sprint was measured for each subject in seconds. A mean time for each group was calculated, enabling analysis of the relationship in mean time run for the 40m sprint test. Comparison of results for the intervention and control group was analysed between both pre and post-tests. For the CMJ test a total of 3 jumps were recorded in centimetres. By using this simple and effective method, the difference in height jumped could be calculated for each jump completed and a mean height in centimetres could be generated. As mentioned, the intervention group and the control group had a mean score calculated for each test at pre and post-test. This allowed a comparison within and between the groups, to fit the chosen study design of the study. Dependent T-tests were utilised in Microsoft excel for each group and each test both for pre-tests and post-tests. This reveals if the training intervention had an effect compared to the control group. Independent T-tests were then run to see if the intervention groups had a larger effect than the control groups for each test. The independent T-tests were run for both pre-tests and post-tests. Finally, an independent T-test was used focusing solely on the pre-tests for each group. To see if there were statistical differences between the different groups at baseline. The P-value was determined as $p < 0.05$. The mean time run was used for the analysis of the 40m sprint, and the mean height jumped was used for the analysis of the CMJ test. Standard deviation was calculated in excel and integrated into the bar charts for each test. The effect size was calculated using the Cohens D formula. <0.2 = trivial, 0.2 - <0.5 = small effect, 0.5 – <0.80 = medium effect, >0.8 = large effect (Lee, 2016). The data collected in excel was then transferred to Microsoft word and adapted into tables.

Total word count: 8774

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Cover letter

For my master thesis I have chosen an article based format. The chosen journal for this study is the Journal of Strength and Conditioning Research.

I would therefore like to send in this article to this journal with the following title “The effect of a 12-week Nordic hamstring training intervention on sprint and jump performance in youth elite football players”.

As described in the title, the aim of this article was to investigate the effect of using an injury preventative exercise as the primary training intervention on sprint and jump performance. This study is in collaboration with youth elite football players in the second team for Sogndal Football, a football team in the second division in Norway. This study investigates important themes within football and sport in general, which can be used in future relevant studies. The incorporation of injury preventative exercises is widespread in the modern-day sporting world. However, the effect of such exercises on crucial elements that can be determining factors within sports such as football is less researched on. The results revealed from this study show the need for more research on this topic area.

This article is original piece of research, sent to only this journal, with no other collaborations to other journals.

I hope this article is deemed interesting and can be accepted to this Journal.

Kind regards,

Oskar Bårtvedt-Payne

Article

The effect of a 12-week Nordic hamstring intervention on sprint and jump performance in youth elite football players.

Oskar Bårtvedt-Payne

University of Western Norway of Applied Sciences

Abstract

The aim of this study was to investigate the effect of a 12-week intervention using the Nordic hamstring exercise on sprint (40m sprint) and jump performance (CMJ test) in youth elite football players in the age range of 16-18 years old. The subjects were selected play and trained for Sogndal`s second team.

A total of twenty total subjects were recruited to participate and were randomized into two intervention groups. 12 further subjects were recruited to participate in the control group.
The intervention subjects were divided randomly into two intervention groups. One intervention group completed the NH intervention with elastic band whereas the other performed traditional NH without elastic band. Both/all groups trained ordinary football in addition to the NH intervention. Both intervention groups completed the same number of sets and repetitions, hence they followed the same intervention program. Due to withdrawals, the intervention groups were merged for analysis and the training effect of the elastic resistance band was removed from the study. From pre-testing to post-testing there were further withdrawals due to various factors such as injury and illness.

Between group analysis showed a 3.1% improvement for the intervention group in the 40m sprint test (5.63 ± 0.35 vs. 5.46 ± 0.32, $p = 0.004$; ES = 0.5). Jump height decreased by 13.9% for the intervention group in the CMJ test (38.98 ± 6.81vs. 33.56 ± 5.57, $p = 0.009$; ES = 0.87) The improvement of sprint performance in the intervention group highlights the use of the NHE in training routines for football players compared to the control group only training football. More research needs to be applied to the effects of the NHE in respect to other performance parameters such as jump performance.

1. Introduction

This study aimed to investigate the use of an injury preventative exercise as a viable training method for youth elite football players. By investigating the link and effect of a 12-week NHE intervention on two common elements frequent in football, jump and sprint performance.

Sprinting and acceleration activities are essential physical determinants for football players. Representing 1-4% of the total distance covered during professional football matches (Barnes et al., 2014). The hamstring muscles are crucial for sprinting leading to the argument for more focused eccentric training of the hamstrings for football players. Increased eccentric strength from a variety of hamstring exercises improved sprint performance as well as reducing hamstring strain injuries (Askling et al., 2003).

The main use of eccentric strength exercises is common for injury prevention, ultimately preventing injury and time away from sports (Schiff et al., 2010). Hamstring muscle strains are common types of injuries that athletes experience in sports where acceleration and maximal sprints are involved (Mjølsnes et al., 2004). Hamstring strains account for 12% of all lower body extremity injuries in sports (Brooks et al., 2006; Ekstrand et al., 2012). This type of injury occurs due to overstretching of the muscle during the eccentric phase where the muscle is lengthened during the swing phase of the sprint cycle (Chumanov et al., 2007). Once injured the hamstring muscles have a 20% increased injury incidence. Resulting in more severe hamstring strains with longer absences from football (Ekstrand et al., 2012). Previous research over the last 20 years has shown that the rate of hamstring injury incidence has not declined (Arnason et al., 2008; Brooks et al., 2006; Ekstrand et al., 2012). Research in the 1980s revealed ankle strains to be the most predominant injury type, followed by knee strains and hamstring strains (Ekstrand et al., 1983). Recent research indicates the prevalence of hamstring injuries in football players has increased, overtaking ankle strains, accounting for 12% of all injuries (Ekstrand et al., 2011). This reveals the need for effective and preventative rehabilitation programs to reduce injury incidence rates for the hamstring muscles. Research has shown how effective injury prevention exercises such as the NHE are in reducing hamstring strain injuries in football players (van der Horst et al., 2015). There is still no gold standard in research to the approach of preventative strategies in reducing hamstring injuries (Opar et al., 2012). Previous studies have shown the effect the NHE has on reducing the incident rates of hamstring injuries and, strengthening of the hamstring muscles (Arnason et al., 2008; van der Horst et al., 2015;

van Dyk et al., 2019). The link between the increase in eccentric hamstring strength and the positive effect on performance parameters needs to be determined. Similarly, the effectiveness of the NHE on sprint performance has been investigated in previous research (Ishøi et al., 2018; Krommes et al., 2017). However, the effects on jump performance have not been fully explored in football and should therefore be examined further.

These preventative rehabilitation programs should include eccentric training exercises, due to the positive effect of eccentric strength training on muscles such as the hamstrings (Askling et al., 2003). Eccentric strength training for the hamstring muscles is widely researched with focus on the Nordic hamstring exercise (NHE). Previous research has shown the effectiveness of the NHE in increasing eccentric strength (Arnason et al., 2008; Mjølsnes et al., 2004). Also notably increasing eccentric hamstring strength more effectively than other more traditional hamstring exercises (hamstring curl exercise) in well trained football players (Mjølsnes et al., 2004). The NHE is performed with the ankles held in place with the subjects on their knees. The exercise starts with the lowering of the upper body towards a prone position, as slowly as possible. The NHE is a simple exercise to implement in injury prevention training programs (van der Horst et al., 2015). Eccentric strength-based interventions targeting the hamstrings are methods which have shown reductions in the injury incidence of hamstring strain injuries in football (Arnason et al., 2008; Askling et al., 2003). However, the effect of such interventions needs to be researched further in their additional effect on performance factors such as sprinting and jumping for athletes.

Previous research on the effect of eccentric training for the hamstring muscles on performance of athletes in studies are relatively limited. As mentioned previously in this article the most effective eccentric training method for reducing injury incidence to the hamstring muscles is the NHE (van Dyk et al., 2019). Integration of the NHE is not widely accepted in sports such as football, and there are questions to the performance effect of the NHE (Bourne et al., 2017; Ribeiro-Alvares et al., 2018). Researching the performance effects of the NHE is limited, however, the link between the NHE and increased eccentric strength has already been proven (Higbie et al., 1996; Potier et al., 2009; Seymore et al., 2017). The next step of determining the effect of increased eccentric hamstring strength on performance parameters for football players is necessary. Eccentric training of the hamstring muscles has a positive effect on sprint performance by 2.4% (Askling et al., 2003).The focus of the study by Askling et al. (2003) was on the injury preventative effect of the NHE however, the researchers also tested isokinetic hamstring strength and maximal speed pre and post intervention. The results from this study showed the positive effect on sprint and strength performance of football players after the inclusion of a specific strength training for the hamstrings over the pre-season (Askling et al., 2003). Adopting this kind of focus in my research was necessary, as the injury preventative effect of the NHE isn't in question. I wanted to explore further the impact a NHE intervention could have on the sprint and jump performance in youth elite football players in Norway. I hypothesised that the NHE intervention would have a positive effect on sprint performance, reducing mean time to run the 40m sprint. Investigating jump performance was also implemented due to the unknown effect of the NHE on jump performance from previous research on football players. Researching this factor could create a benchmark for future research exploring the effect of the NHE on vertical jump performance in football players.

2. Methods

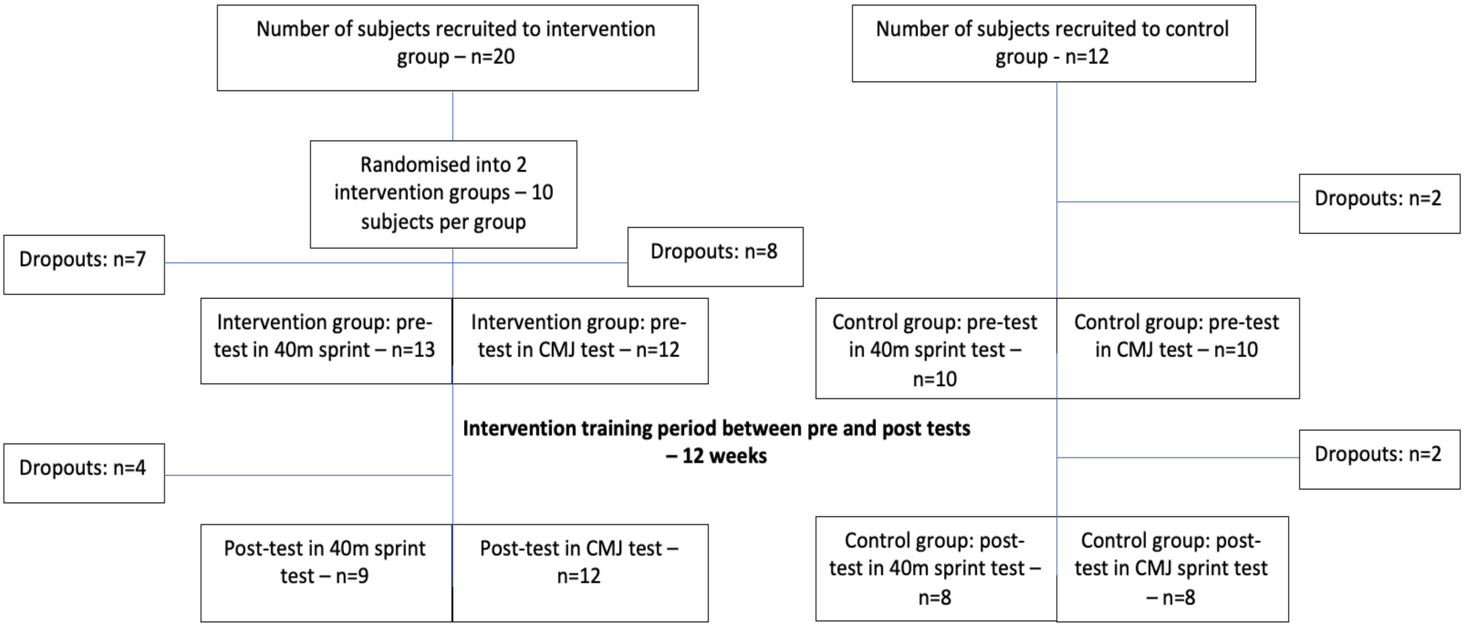
2.1. Experimental approach to the problem

This study was an intervention study which started with two intervention groups and one control group. The intervention groups followed a NH training program introduced over a 12-week period and added into the subjects' weekly football training routine alongside all other training sessions. Before the start of the 12-week intervention program, all subjects took part in a test day including completion of the 40m sprint test and CMJ test. During the intervention, all sessions of Nordic hamstring training were closely supervised to ensure the correct technique of the exercise. All data and testing were completed in the sports laboratory and football 3g pitch, to ensure matching conditions both during pre-testing and post-testing.

2.2. Subjects

A football team (Sogndal second team) collaborated and participated in the study. A total of twenty youth elite football players in the age range of 16-18 years old were recruited to be a part of this study. A total of 13 subjects were available due to seven subjects withdrawing before pre-testing. The subjects were randomly divided into two intervention groups. One group completed the intervention training the Nordic hamstring with an elastic resistance band, whilst the other completed the intervention without. The control group was also made up of football players (total of 10) from Sogndal football u16 team and another local football team in the same division as Sogndal 2. Thus, ensuring a similar level of training load per week on each subject (4 football trainings per week).

Figure 1 – overview of study protocol



Before the intervention started all subjects filled out and completed a consent form where they were informed of the study and the procedures involved. Subjects agreed to the study both orally and with written consent via consent form. Those under 18 had to have a parent or guardian sign under to be a part of the study. During the intervention, all players completed their normal weekly training and match routines. This study was deemed as a supplementary addition to their training load. The intervention training sessions took place during injury prevention sessions each Tuesday or Thursday morning with a researcher present to overview. This enabled the correct technique of the NH exercise and the correct completion of the training program in regard to the total sets and repetitions each session.

2.3. Testing procedures

All subjects recruited to the intervention group completed pre-testing, the 12-week intervention and post-testing. Subjects recruited to the control group completed pre-tests and post-tests with 12-weeks between, to simulate the same conditions for testing as the intervention group. The warmup protocol for the subjects was the same before pre and post testing as before each training session during the intervention period. The warmup included 15 minutes on the spin bike and 15 minutes of predetermined activation exercises, which the subjects used in normal football sessions and matches. Extra warmup exercises were included specific to each test such as five 5m sprints for the 40m sprint test and 20 repetitions of a vertical jump and three sets of squats with a barbell weighing 20kg in total for the CMJ test.

2.4. 40m sprint test

The testing took place at baseline before week 1 of the training intervention, and at the end of the 12-week intervention. The 40m sprint test took place on the same football pitch that the subjects trained on a daily basis. It was an artificial 3g pitch, and all players were instructed to complete the test in football boots to enable similar conditions to when running during a normal football match or training. The warmup for this test was the same as the subjects used during the intervention period. (15minute spin bike, 15-minute activation and five 5m sprints). Before pre-test, the subjects lined up in order of participant number and started the test half a meter behind the first line of photocells at 0m. Photocells (Ergotest Innovation, Statehelle, Norway) were placed at 0m, 5m, 10m, 20m, 30m and 40m to record the acceleration of each player and top speed through the test. As each photocell is passed the data is automatically sent to the software (Ergotest Innovation, Statehelle, Norway) with the time taken to run between each photocell. The test involves running a maximum sprint over 40 meters, with the end time recorded by the researcher. The test starts from a stationary position, with one foot in front of the other and the subjects themselves decide when to start after the clear signal from the researcher. A total of three sprints was run by each subject where a meantime could be measured for further analysis and comparison. Rest time in-between each sprint was the time taken for all subjects to run in order. Once a sprint was completed each subject walked back to the test queue. This enabled the same rest time for each subject between each 40m sprint.

2.5. CMJ test

The CMJ test also took place on the same day as the 40m sprint test. This test was completed at the strength laboratory at the university campus. The subjects were called in to the lab in pairs, in order of subject number. This was to ensure a minimum number of people in the lab and maximal focus on the testing ahead. Before testing the force plate and the ergotest software was calibrated. Calibration of the force platform is crucial to generate reliable and valid data within the testing. Here the researchers themselves follow the calibration instructions as shown on the laptop whilst standing on different parts of the force platform. Once calibrated the test procedure could go ahead. The warm-up (15 minutes spin bike, 15 minutes activation, 20 vertical jumps and three sets of squats with a 20kg barbell) completed by the subjects was carefully monitored by the researchers. By having a set order for testing, all subjects had an allocated time to meet up for the test. This ensured they factored in the time needed for warming up on the spin bike. Thereafter each subject completed a total of three jumps for the CMJ test. Extra jumps could be jumped if needed, due to failure of technique or equipment failure.

2.6. 12-week Nordic hamstring intervention

The intervention sessions took place at the university gym where two Nordic hamstring apparatus were set up for the study. The same warm up protocol was completed before each intervention session as in testing (15 min spin bike and 15 min activation exercise protocol). The subjects then queued up and created a set order for completion of the total number of repetitions and sets for each session. A rest time of 120-180 seconds was followed between each set completed. The researchers closely monitored each subject when performing the NHE, instructing technique and guidance for each repetition. Each session was obligatory for the subjects as the NHE intervention was incorporated into the morning sessions for the Sogndal second team. There were some subjects unable to make it to each session due to various factors, however, these subjects completed the sessions they missed at a later viable date. This ensured completion of the full 12-week NH intervention. A training log was filled out by each subject, reporting each training during the week and the intensity from a score from 1-10. This gave a more detailed picture of the training load imposed on each subject during the 12-week intervention period.

Table 1 – NH training program for the intervention group

Week	Sessions each week	Sets	Repetitions
1	1	2	2-4
2	1	2	4
3	1	2	4-6
4	2	2	4
5	2	3	2-4
6	2	3	4
7	2	3	4-6
8	3	3	2-4
9	3	3	4

10	3	3	4-6
11	3	3	6
12	3	2	4
Total	30	28	264-292

The training sessions were completed with at least 48 hours in between each session. The rest interval between each set were from 120 – 180 seconds.

The equipment used for the Nordic hamstring exercise during the intervention period was a pivot 618 Nordic hamstring machine as seen in the figure below. During the intervention the subjects were closely followed and helped through the program each session. This ensured that the correct number of sets and repetitions were performed by each subject each time they had a session in the intervention program.

Figure 1: Nordic hamstring apparatus used during the 12-week intervention.

(*Pivot 618 Nordic Hamstring*, n.d.)

2.7. Statistical analysis

For the statistical analysis of the results the Microsoft excel application was used. The 16.41 version (20091302) was used with the producer Microsoft 2020. The licence was a Microsoft 365 subscription which could be accessed via being a student at the university.
Once the tables of data collected for the results were set up on excel, using the data analysis tool in excel, descriptive statistics were configured. Dependent T-tests were used to analyse the pre-test and post-test results of the intervention group for each test. Independent T-tests were also used to analyse and compare the intervention group vs control group. The P-value was determined as $p < 0.05$.

The mean time run (seconds) was used for the analysis of the 40m sprint and the mean height jumped (cm) was used for the analysis of the CMJ test. Standard deviation was calculated in excel and integrated into the bar charts for each test. The effect size was calculated using the Cohens D formula. <0.2 = trivial, 0.2 - <0.5 = small effect, 0.5 – <0.80 = medium effect, >0.8 = large effect (Lee, 2016).

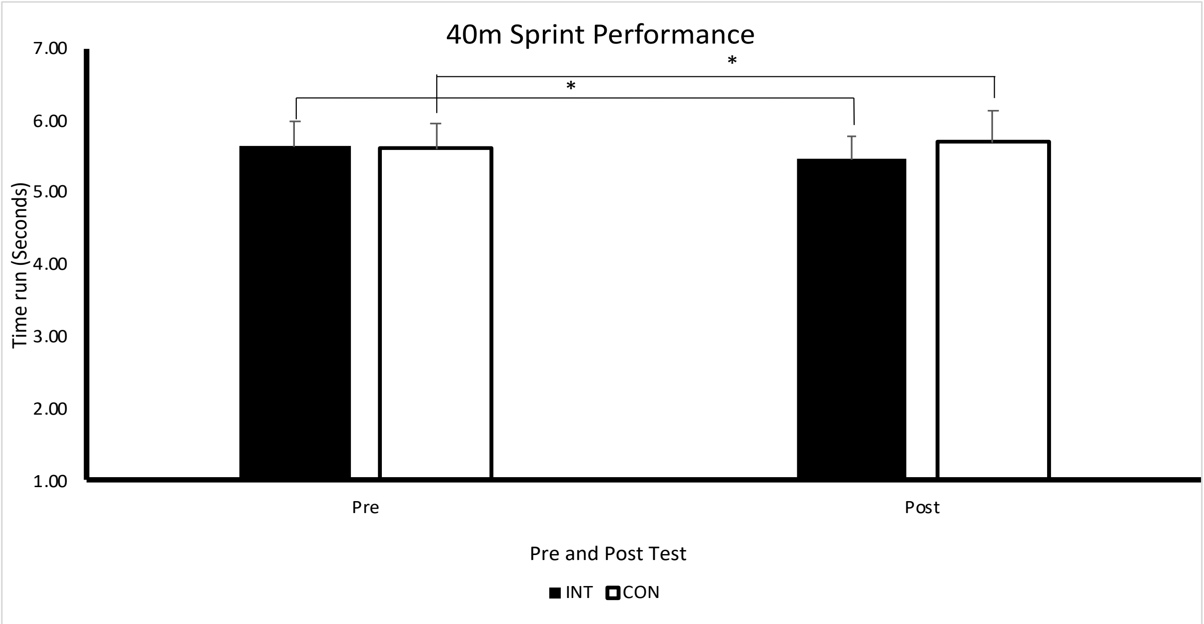
The tables from Microsoft excel were then transferred to Microsoft word to be adapted into the research article. All results are presented as mean ± standard deviation.

3. Results

In this study, the effects of a Nordic hamstring intervention on sprint and vertical jump performance were investigated. When the data produced from the intervention group was compared to the control group a significant decrease in mean time run was observed for the 40m sprint test by 3.1%. However, in the CMJ test, there was a 13.9 % decrease in the average jump height produced by the intervention group compared to the control group. Overall concluding the 12-week intervention had a positive effect on sprint performance and a negative effect on vertical jump performance in youth elite football players.

3.1. 40m sprint test

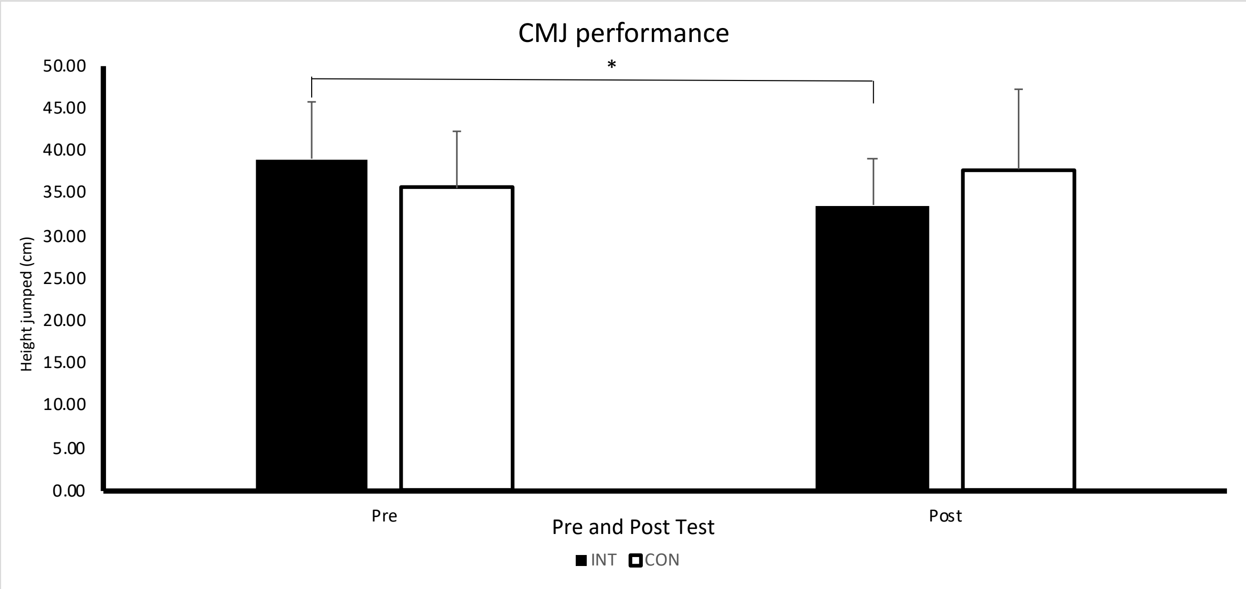
Figure 2 – 40m sprint test result



At baseline, there was no statistical difference between the subjects in the intervention group and the control group (p=0.92). The 40m sprint test results were summarised by the total mean time for both the intervention and control groups. The intervention group showed a positive effect from the NHE intervention, improving mean time run by 3.1% (5.63±0.35 seconds at pre-test to 5.46±0.32 seconds at post-test, p=0.004, ES=0.5). The control group without the NHE intervention, had a significant increase in time run by 1.6% (5.61±0.36 seconds at pre-test to 5.70±0.43 seconds at post-test, p=0.03, ES=0.22). These results provide evidence to support the positive effect of the NHE intervention on sprint performance. At post-test, the T-Test showed a not statistically significant value (p= 0.20).

3.2. Countermovement jump test

Figure 4 – Countermovement jump test results



At baseline, there was no significant statistical difference between the subjects in the intervention group and the control group (p=0.25). Mean height jumped was measured in centimetres and shown for both the intervention and control group. The intervention group showed a negative effect from the NHE intervention, decreasing height jumped by 13.9% (38.98±6.81 cm at pre-test to 33.56±5.57 cm at post-test, p=0.009, ES=0.87). The control group without the NH intervention, however showed an increase in height jumped by 6.1% (33.55±6.76 cm at pre-test to 37.74±9.48 cm at post-test, p=0.288, ES=0.27).

4. Discussion

The aim of this study was to assess the effect of the intervention (NHE) on sprint and jump performance over a 12-week training period. Previous research using similar interventions investigating the effect of the NHE on different performance factors such as sprint, jump and strength have shown varying results in performance after applying an NHE intervention (Askling et al., 2003; Freeman et al., 2018; Ishøi et al., 2018; Suarez-Arrones et al., 2019). A 10-week NHE intervention improved sprint acceleration performance with large increases in eccentric hamstring strength observed (Ishøi et al., 2018). Freeman et al, (2018) investigated the effects of sprint training and the NHE on eccentric hamstring strength and sprint performance in adolescent athletes. This was one the first studies to provide a comparison between sprint training and NHE training on eccentric hamstring strength and sprint performance. The results showed that both training groups experienced significant increases in eccentric strength (9.8% for the eccentric group and 6.2% for the sprint group). The NHE group showed a small effect on sprint performance, while the sprint training group showed moderate improvements (8.6%) (Freeman et al., 2018). Suarez-Arrones et al, (2019) found improvements in sprint performance with and without the inclusion of the NHE (Suarez-Arrones et al., 2019). However, one study using a similar intervention to my study found a reduction in time 0.074 seconds from 20-50m in a sprint from NHE training (Askling et al., 2003). The positive results from previous research led to my decision of investigating the effect the NHE has on sprint performance and vertical jump performance. I hypothesized that the experimental group training regular sessions of eccentric training for the hamstring muscles would see improvements in sprint time in the 40m sprint test. Relative few studies have investigated the effect of the NHE on performance in crucial elements specifically for football players, such as jump and sprint abilities. The main findings for my study where the positive changes in 40m sprint mean time for the intervention group, reducing sprint time by 3.1%. For the CMJ test a substantial negative effect of the NHE was observed on jump performance in the intervention group, decreasing jump height by 13.9%. There was no statistical difference at baseline between the subjects in the intervention group and control group for each test (40m sprint test: p=0.92, CMJ test: p=0.25). This is due to the recruitment of the subjects, all being youth elite football players, similar age ranges from 16-18 years old and, similar training volume each week. Enabling a fair comparison between the intervention and control groups of each test.

Previous research has shown the injury preventative effect on the hamstring muscles due to the NHE (Elerian et al., 2019; van der Horst et al., 2015). Intervention groups present in these studies all reduced injury incidence of hamstring strain injuries compared to the control groups. The reasoning for why this is important to discuss is due to the beneficial effects of the NHE on the hamstring muscles. Increased eccentric strength is a result of the NHE allowing the muscles to withstand the high lengthening force on muscle fibres (Elerian et al., 2019). NHE interventions have proven to improve strength and hypertrophy of the hamstring muscles (Freeman et al., 2018; Seymore et al., 2017). The NHE increases eccentric strength of the hamstring muscles which is considered as an essential factor for increasing in sprint performance (Mjølsnes et al., 2004). Explaining potentially why the NHE training in my study led to an improvement in speed performance for the intervention group. Perhaps an extended

NHE intervention is required to see a greater effect in sprint performance by training the NHE over a longer period.
The results of my study further back up the NHE effect on sprint performance due to the control group performing worse at post-test, increasing the mean time (0.09 seconds) to run the 40m sprint. For the intervention group in the 40m sprint test a medium effect size (0.5) was seen, showing the effect of the NHE intervention with a decrease in mean time run from pre-test to post-test (0.17 seconds). Further the p value was statistically significant in the 40m sprint performance pre to post-test (0.004). Further proving the possible strength adaptations of the hamstring muscles during the 12-week NHE intervention effecting sprint performance positively.

The other element to my study was investigating the effect of the NHE on vertical jump performance. Relative few studies have focused on the effect of the NHE on jump performance using the CMJ test. Therefore, I researched the effect of the NHE on jump height from the CMJ test using the baseline scores at pre-test to post-test scores. The results showed a negative effect of the intervention on vertical jump performance for the intervention group in the CMJ test, reducing mean jump height by 5.42cm (13.9%). The lack of a significant increase in vertical jump performance in my study was unexpected primarily due to the positive effects of the NHE on jump performance seen in previous research (Chaabene et al., 2020; Clark et al., 2005). Producing a decrease in jump performance at post-test showed a negative effect of the NHE intervention. However, the control group with no NHE intervention, experienced an increase in mean jump height (6.1%, 4.19cm) from pre to post-test. Previous research has shown a beneficial effect of a 10-week NHE intervention on CMJ test performance, improving jump height by 19% (Váczi et al., 2022). There are several factors that can have impacted these results and explain the decrease for the intervention group. Firstly, the test date could have been a determining factor, where ultimately the test conditions were not the most sufficient. Fatigue of the subjects could have played a role, with many subjects expressing the desire to have longer rest times between each jump during CMJ testing. Another explanation can be the level of fatigue of the hamstrings used in this exercise, reducing potential explosivity. The sheer training volume on the hamstrings could have affected test performance. Performing each jump without an arm swing is also an unnatural movement for football players, with several subjects having to jump more than the required 3 jumps each test due to failure in technique. In contrast to my findings Krommes et al. (2017), showed a beneficial effect of the NHE in explosive qualities of football players by testing the CMJ test. Height jumped improved by

2.1cm in the intervention group at post-test after a 10-week NHE (Krommes et al., 2017). Another study used untrained males as subjects, investigating the effect of eccentric hamstring strength training on dynamic jump performance. The results showed a significant increase in vertical jump height at post-test by 3.4cm (Clark et al., 2005). The varying results in research reveals the need for further research on the effect of the NHE on jump performance, specifically using the CMJ test as a measure of jump performance for football players.

4.1. Limitations

Recruitment to the study was a limiting factor, with a low number of total subjects available to participate. The intervention group started with a total of twenty subjects recruited. However, before pre-testing commenced a total of seven subjects dropped out of the 40m sprint test, leaving 13 total subjects. Eight subjects in the intervention group also withdrew before CMJ pre-testing. Various factors lead to withdrawals from the study at different stages, such as injuries and illness. An explanation for the level of withdrawals is due to only one squad recruited to participate in the intervention. The unavailability of subjects present in the study was impacted due to injuries in the first team, with several players being transferred up to the senior team. Withdrawals during the NHE study was a common theme as the control group also experienced injuries with two subjects dropping out of the study, leaving eight total subjects with data at post-tests. The high training volume over the pre-season phase could have been a limiting factor for the study. The number of subjects dropping out of the study indicates that potentially the training volume was too high for the subjects at that specific phase of the season. These subjects in the intervention group had a form of intense training daily. With the NHE intervention training taking place in morning sessions to allow enough time between sessions for recovery. Future interventions should be required to carefully plan out the timing and volume of training to avoid increased injuries and withdrawals from the studies.

Another potential limitation to the study was the timing of the study as mentioned previously. The phase of the season when the study was implemented was during the pre-season phase of the 2021 football season. In the pre-season phase the players have a focus on building a strong physical platform to perform during the season. In addition, players meet up to the pre-season phase generally from a break or phase with lower training volumes. This ultimately could have led to less meaningful results with lower levels of physical outputs. The unpredictability of the subjects conditioning, injuries, and the movement of players between teams were all factors to consider in analysing the results at post-test.

Testing of vertical jump performance using the NHE produced a negative effect of the intervention. This can be viewed as a limitation to the study due to the decrease in mean height jumped (cm) for the intervention group. Relative few studies have researched specifically the effect of the NHE on plyometric performance in football players. In contrast, this doesn't have to been reviewed as a limitation to my study. The effect of the hamstring muscles in jumping movements is not predominately proven compared to the effect of the quadriceps muscles. Further research is required to determine the true effects of the NHE on jump performance for football players.

Although a positive effect of the NHE was observed in relation to 40m sprint performance, the timing of the post-test was affected. Ultimately the results measured could potentially have had a greater difference in the change in mean from pre to post-test. The post-testing for the 40m sprint took place in the middle of a football training session instead of after the planned warm up and activation, as was done at pre-test. The subjects could have experienced more fatigued, leading to a potentially more negative performance when sprinting the three 40m sprints than potentially could have been observed at post-test.

For both tests in the study the mean scores were investigated for analysis of the data. However, a more intensive use of the results could have been applied. For example, investigating the different times run at different distances over the 40m sprint could have been observed. For the CMJ test the mean height in cm was recorded over three jumps. However, analysing each jump individually could have opened other aspects to analyse for my study. The results gave a relative narrow view on the effect of the NHE on jump performance so a wider and more intensive study on this topic can be deemed as necessary.

4.2. Future research

Future research should focus on the effect of the NHE on important performance parameters for football players. Using various tests focused on sprinting and vertical jumping is required to learn the effects of the NHE specific to the requirements of football players. Previous research has highlighted the eccentric strength effect of the NHE and how other exercises increase performance parameters. Wider research focused solely on the NHE should be explored. An interesting study comparing the effects of the NHE and sprint training, found that 4 weeks of sprinting increased eccentric hamstring strength, but sprinting produced more muscle fatigue than NHE (Freeman et al., 2018). Explaining the potential beneficial effects of the NHE over normal traditional sprint training for improving sprint performance in the future. A mix of methods should be explored such as a combination of sprint training with the NHE to increase eccentric hamstring strength, preventing hamstring injuries and improving athletic performance. Future research should investigate the potential effects of the NHE on a wider range of performance parameters. Incorporating injury prevention exercises is crucial for elite football players, but what other factors can these exercises impact?

5. Practical applications

The findings of this study are in line with previous research using similar NHE training interventions. Football teams should incorporate injury prevention exercises such as the Nordic hamstring exercise for their players to improve sprint performance. Implementation of a training program for the NHE can easily be applied during the pre-season phase of the season as an example. The injury preventative effects of the NHE and the evidence of increased sprint performance are proof that the use of such interventions can be beneficial to football players in impacting performance positively.

6. Acknowledgements

This study was produced for my master's thesis. I want to thank all the subjects involved in the study for complying and being motivated to follow the NHE intervention training program over the 12-weeks and the testing involved at pre-test and post-test.

7. Conclusion

Overall, this study suggests the effectiveness of a Nordic hamstring intervention on improving sprint performance despite no differences between the groups. However, in relation to the CMJ test, the intervention group revealed a negative effect of the intervention on jump performance. There are varying factors that can possibly explain the outcome of this study as previous research has shown a beneficial effect of the NHE on jump performance. This research shows the potential value of such interventions that can be adapted into regular training routines during the pre-season phase for football teams. Increasing sprint and jump performance is an important decisive factor to consider that is beneficial for improving the explosive characteristics of football players. Adapting the NHE into training routines for athletes is proven to be beneficial for injury prevention and increasing eccentric strength. The possibility of improving performance parameters highlights the importance of the NHE. However, wider research specifically targeting football players over a prolonged intervention time is required to learn the capabilities of the NHE and the effect on performance parameters such as sprinting and jumping.

Total word count: 5630

8. The journal's guidelines

1. A cover letter must accompany the manuscript and state the following: "This manuscript is original and not previously published in any form including on preprint servers, nor is it being considered elsewhere until a decision is made as to its acceptability by the JSCR Editorial Review Board." Please include the corresponding author's full contact information, including address, email, and phone number. The corresponding author assumes full ownership for all communication related to the manuscript with the journal office.

2. All authors MUST respond to the automated e-mail and complete the copyright transfer form (eCTA) during the submission process. Manuscript acceptability will not be determined until all eCTAs have been completed. Corresponding authors are strongly encouraged to supervise the completion of eCTAs from all co-authors.

3. All authors should be actively involved in the publication, be able to defend the paper and its findings, take full responsibility for all of its content, and should have signed off on the final version that is submitted. For additional details related to authorship, see "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" at http://www.icmje.org/. All authors must have made significant contributions to manuscript to justify authorship and individual author contributions may be disclosed in the Acknowledgments section. The order of authorship must be agreed upon by all authors prior to initial submission to JSCR.

4. The NSCA and the Editorial Board of the JSCR have endorsed the American College of Sports Medicine’s policies with regards to animal and human experimentation. Their guidelines can be found online at http://www.editorialmanager.com/msse/. Please read these policies carefully. Each manuscript must show that they have had Institutional Board approval for their research and appropriate consent has been obtained pursuant to law. All manuscripts must have this clearly stated in the methods section of the paper or the manuscript will not be considered for publication. Exempt studies involving human subjects (i.e. retrospective data analysis, analysis of publically available data, educational research, analysis of surveys and interviews) must include a statement of Institutional Review Board approval per journal policy.

5. All manuscripts must be double-spaced with an additional space between paragraphs. The paper should include a minimum of 1-inch margins and page numbers in the upper right

corner next to the running head. Authors must use terminology based upon the International System of Units (SI). A full list of SI units can be accessed online at http://physics.nist.gov/.

6. The JSCR endorses the same policies as the American College of Sports Medicine in that the language is English for the publication. ‘‘Authors who speak English as a second language are encouraged to seek the assistance of a colleague experienced in writing for English language journals. Authors are encouraged to use nonsexist language as defined in the American Psychologist 30:682- 684, 1975, and to be sensitive to the semantic description of persons with chronic diseases and disabilities, as outlined in an editorial in Medicine & Science in Sports & Exercise_, 23(11), 1991. As a general rule, only standardized abbreviations and symbols should be used. If unfamiliar abbreviations are employed, they should be defined when they first appear in the text. Authors should follow Webster’s Tenth Collegiate Dictionary for spelling, compounding, and division of words. Trademark names should be capitalized and the spelling verified. Chemical or generic names should precede the trade name or abbreviation of a drug the first time it is used in the text.’’

7. There are no word limitations to original studies and reviews but authors are instructed to be concise and accurate in their presentation and length will be evaluated by the Editor and reviewers for appropriateness.

8. Scientific misconduct (i.e. data fabrication, falsification, deceptive image manipulation, plagiarism, ethics violations, undisclosed conflicts of interest, duplicate publication, and human/animal research violations) will not be tolerated. Concerns of alleged scientific misconduct should be brought to the attention of the Editor-in-Chief for review using procedures established by the Committee on Publication Ethics (COPE) (publicationethics.org/resources/flowcharts). Pending review of the claims, consequential actions may include rejection of the submitted manuscript of interest, informing the authors’ institution of the alleged misconduct, retraction of a previously-published paper, and potential debarment of the author(s) from future JSCR publication. Additional scientific misconduct details may be found at http://www.icmje.org/. Acknowledgment of honest error, omission, or differences in data interpretation that do not alter the findings of a paper may occur via the Manuscript Clarification process or publication of an Erratum.

9. Attachments

9.1. Information letter and consent form for the study

Førespurnad om deltaking i forskingsprosjekt

Effekten av Nordic hamstring i fotball

Bakgrunn og hensikt

Ein hamstringstrekk er ein strekkskade som inneber heilt eller delvis ruptur av sene eller muskelfiber i ein av musklane i hamstring. Hamstringskader ein av dei vanlegaste skadetypane i fotball og skadetypane har høg grad av tilbakefall. Førebygging er og kjem til bli viktigare då aksjonar i fotball skjer oftare og hurtigare. Framtidige elitespelarar må difor vera trent for å tåle belastninga og for unngå skadar i tideleg alder. Fotball eigenart med raske vendingar og hurtig akselerasjonar gjer fotballspelarar spesielt utsett for hamstringsskadar. I både førebygging og rehabilitering, fokuserast det på både å oppretthalde eller betre normalt leddutslag samt redusere muskelsvinnet og styrketapet. Styrketrening, og spesielt eksentrisk styrketrening, har vist både ein førebyggande og effektiv til å betre styrke.

I fotball, har spelarane ein dominerande fot. Den dominerande foten nyttast til å sparke ballen. Vidar ser ein at den dominerande foten vert hyppigare nytta til bremse og gjere retningsendringar på. Over tid, fører ein einsidig dominans til eit ulike styrkeforhold mellom beina. Denne forskjellen kan vera orsaka til skadar og ein einskild risikofaktor. Unilaterale styrkeøvingar har blitt anbefalt, men ikkje alltid mogleg å gjennomføre. Difor er målet med studien å kartlegge styrkeforskjellar mellom beina og trene Nordic hamstring 2 gonger i veka gjennom oppkjøringsfasen før 2021 sesongen.

Kva inneber studien?

Før treningsintervensjonen startar må alle forsøkspersonane vert testa i ein power-profil i knebøy, styrke i Nordic hamstring og isometrisk styrke i fram- og bakside av låret samt 40m sprint. Under Nordic hamstring testinga vil du som forsøksperson bli filma frå sida, men kunn hoftepartiet og ansiktet vil difor ikkje vera med. Påfølgande kjem 12 veker med trening to i veka, etterfølgt av ein avsluttande test for å undersøkje endring frå første test. Nordic hamstring treninga vil inngå som ein av øvingane i styrketreningsprogrammet det gjennomfører til dagleg. Forsøkspersonane vil bli tilfeldig fordelt i to grupper der den einaste forskjellen mellom gruppene er at ei gruppe skal nytte strikker til avlaste motstanden i Nordic hamstring medan den andre gruppa ikkje skal nytte strikker. Treningsmotstanden vil vær individuelt tilpassa utifrå fyrste test og justert undervegs i intervensjonen.

Moglege fordeler og ulemper

Du vil få kunnskap om testing og trening av beinmuskulatur, kroppssamansetning og dine muskeleigenskapar. Testinga kan avdekke potensielle sjansar for auke skaderisiko. Ulempene er at du kan bli litt sår/øm i muskulaturen grunna treninga. Dette vil vera dei fyrste øktene då muskelvevet ikkje er vant til øvinga. Som deltakar får du ikkje trene hard styrke trening 48 timar før testing.

Kva skjer med testresultata og informasjonen om deg?

Testresultata og informasjonen som registrerast om deg skal kun brukast slik som nemnt i hensikta med studien. Alle opplysningane og resultata vil bli behandla utan namn eller andre direkte gjenkjennande opplysningar. Eit deltakarnummer knytt deg til dine resultat, Koblingsnøkkelen mellom namnet ditt og resultata vil bli låst inn i prosjektleiar sitt kontor (åtskilt frå all anna informasjon).

Det er berre autorisert personell knytt til studien som har tilgang til namnelista og som kan finne tilbake til deg. Det vil ikkje vera mogleg å identifisere deg i resultata av studien når disse publiserast.

Frivillig deltaking

Det er frivillig å delta i studien. Du kan når som helst og utan å gje nokon grunn trekke ditt samtykke til å delta i studien. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Ønsker du seinare å trekke deg eller har spørsmål til studien, kan du kontakte prosjektleder Atle Hole Sæterbakken (telefon 57676044).

Kapittel A – Utdypende forklaring på hva studien innebærer

- Testingane for alle deltakaren vil begynne i september med to tilvendingstest og en eksperimentell test
- Det settast stor pris på om deltakarane møter opp til avtalt tidspunkt for testing.

Kapittel B – Personvern og forsikring

Personvern

Opplysningar som registrerast om deg er namn, alder, vekt, kroppssamansetning, år med fotballtrening og tidelegare hamstringsskadar. Eit spørjeskjema blir brukt til å hente inn personopplysningane, og testresultata blir registrert og notert under testinga. Testresultata som vert registrert og lagre er: Power-profil i knebøy, kraftutviklinga i Nordic hamstring, isometrisk kraftutvikling i kvar fot for forside- og baksida av låret samt 40m sprint test. Etter avslutta studie blir opplysningane anonymisert, slettet eller forsvarleg oppbevart av Høgskulen på Vestlandet.

Prosjektet avsluttast 30. juni 2022. Datamaterialet anonymiserast ved at verken direkte eller indirekte personidentifiserande opplysningar framgår. Namn/koplingsnøkkel, spørjeskjema og samtykkeerklæring vert sletta. Indirekte personidentifiserande opplysningar (samanstilling av bakgrunnsopplysningar som f.eks. alder, vekt) fjernast eller grovkategoriserast slik at ingen enkeltpersonar kan gjenkjennast i materialet.

Rett til innsyn og sletting av opplysningar om deg og sletting av prøver

Viss du seier ja til å delta i studien, har du rett til å få innsyn i kva opplysningar som er registrert om deg. Du har vidare rett til å få korrigert eventuelle feil i dei opplysningane vi har registrert. Dersom du trekker deg frå studien, kan du krevje å få slettet all innsamla data om deg.

Dine rettigheitar

Så lenge du kan identifiserast i datamaterialet, har du rett til:

- innsyn i kva personopplysningar som er registrert om deg,
- å få retta personopplysningar om deg,
- få slettet personopplysningar om deg,
- få utlevert en kopi av dine personopplysningar (dataportabilitet), og
- å sende klage til personvernombodet eller Datatilsynet om behandlinga av dine personopplysningar.

Forsikring

Høgskulen på Vestlandet er sjølvassurandør.

Informasjon om utfallet av studien

Alle som er deltakarar har full rett til innsyn av utfallet i studien

Ansvarleg for prosjektet

Prosjektet vert gjennomført ved Høgskulen på Vestlandet, Fakultet for lærarutdanning, kultur og idrett, Institutt for idrett, fysisk aktivitet og kosthald, campus Sogndal.

Kontaktopplysningar for institusjons personvernombod

Høgskulen på Vestlandet sitt personvernombod er Trine Anikken Larsen og kan nåast på 55 58 76 82 eller personvernombud@hvl.no

Samtykke til deltaking i studien

Eg er villig til å delta i studien og har mottatt informasjon om prosedyrane

----

-

(Signert av prosjektdeltakar, dato)

Eg er villig til ______________________ får delta i studien og har mottatt informasjon om prosedyrane

----

-

(Signert av føresette, dato)

Eg stadfestar å ha gitt informasjon om studien

-(Signert, prosjektleiar, dato)

9.2. Training program for the 12-week NHE intervention

Week	Sessions each week	Sets	Repetitions
1	1	2	2-4
2	1	2	4
3	1	2	4-6
4	2	2	4
5	2	3	2-4
6	2	3	4
7	2	3	4-6
8	3	3	2-4
9	3	3	4
10	3	3	4-6
11	3	3	6
12	3	2	4
Total	30	28	264-292

9.3. <u>Training log example for the subjects during the 12-week intervention</u>

Example of training log from one subject in week 2 of intervention period showing total volume and perceived load from 1-10 for each session.

Mandag	**Tirsdag**	**Onsdag**	**Torsdag**	**Fredag**	**Lørdag**	**Søndag**
Skule: 1 time (2 belastning) styrke:sykling+kjer ne 1 time (4 belastning) Nordic hamstring (5 belastning)	Styrke: overkropp+skad eforebyggende 1time og 15 min (5 belastning) Fotballtrening: 1 time 15 min (belastning 4)	Fotball: Kamp 3x25min + oppvarming 90 min (belastning 7)	skule: 1 time (belastning 3) Styrke: overkropp+kj erne 75min (belastning 5) Fotball: utviklingsmål /ferdighet 40 min (belastning 2) Nordic Hamstring (belastning 4)	Fotball: teknisk/utvikl ingsmål 90 min belastning 4 Styrke: utholdenhet 30 min belastning 6	Styrke: bein+kjerne 80 min belastning 5 Fotball: ferdighet+ 16-16 8 stk 60% 60 min belastning 3	Styrke: langkøyring+ kjerne 90 min belastning 4 Fotball: utviklingsmål 60 min belastning 3