The Effect of Attentional Focus on Muscle Activation during Nordic Hamstring Exercises in Young Adults

By

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Introduction:

With their potential positive outcomes, hamstring eccentric exercises are becoming increasingly popular within training regimes, with Nordic Hamstring Exercise (NHE) being the most common. NHE is said to be a focused eccentric-type exercise and successful within training programmes to improve eccentric strength and muscle activation. The way an athlete focuses their attention when undertaking such strength-based activities, has the potential to influence strength-based developments. Where attentional focus has been referred to the process in which athletes allocate mental resources to cues, stimuli or states, it has been suggested that an external focus of attention has been beneficial in terms of movement economy. However, it has yet to be shown whether attentional focus influences muscle activation when techniques such as NHE are performed. Furthermore, the aim of the study was to compare the acute effects of attentional focus has on muscle activation and joint knee angle during a Nordic hamstring exercise.

Method: Twelve physically active recreation football players (age 25 ± 3 years) performed a 3 sets of Nordic hamstring exercises whilst undergoing 3 different attentional focus conditions, (External Muscle Contraction, External Upright Posture and Control). Measures of the Bicep Femoris and Semitendinosus were measured for peak EMG (EMGpk) and optimal knee angle (2D Video analysis) were untaken. After each condition participants were asked three specific questions designed to assess use of the respective attentional foci during task execution. Data analysis utilised SPSS (IBM, SPSS). All descriptive statistics were calculated and presented as mean ± standard deviation (SD).

Results:

All three conditions had no significant difference in muscle activation for the bicep Femoris with external upright posture (38.49 ± 9.94 EMGpk), external muscle contraction (38.67 ± 8.18 EMGpk) and the Neutral group (37.55 ± 9.35 EMGpk) When looking at the semitendinosus, again there was no significance with the three attentional focus conditions for muscle activation, External upright posture (51.89 ± 10.38 EMGpk), External muscle contraction (49.27 ± 7.56 EMGpk) and the Neutral group (49.66 ± 10.28 EMGpk). Similarly, knee angle remained constant throughout

the 3 attentional focus conditions for the Bicep Femoris, Neutral (102.71 ± 5.48°), External muscle contraction (103.16 ± 7.23°) and External upright posture (103.72 ± 4.71°) and for the Semitendinosus, Neutral (103.16° ± 5.36), External muscle contraction (103.55 ± 5.48°) and the External upright posture (104.27° ± 5.05). Post Manipulation checks highlighted that “To what extent were you focused on the movements of any part of your body?” resulted in a score of 3.83 ± 1.03, “To what extent were you focused on hamstring muscle contraction as you executed your NHE?” resulted in a scored 3.92 ± 1 and “To what extent were you focused on maintaining an upright posture as you executed your NHE?” resulted in a scored

of 3.58 ± 0.5, highlighting minimal differences noted between conditions.

Discussion: Although the findings highlighted that there were no changes in muscle activation or knee angle during the NHE, the study highlights when NHE are performed they cause a high muscle activation in both the bicep femoris and semitendinosus. The results suggest by performing this type of exercise, it can be an effective tool in injury prevention programmes, in addition to reducing the risk of injury.

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List of Abbreviations

AF – Attentional Focus

BF – Bicep Femoris

EF – External focus

EMG – Electrography

IF – Internal Focus

HII – Hamstring Injury Incidence

HSI – Hamstring Injuries

NHE – Nordic Hamstring Exercises

SEM – Semitendinosus

1.0 Introduction

1.1 Hamstring

Hamstring injuries are one of the most reported lower limb injuries, with a high incidence and re – injury rates across several sports (Bourne et 2015, Ekstrand et al, 2015, Ekstrand et al, 2016). These injuries can be typically viewed as overuse mechanism such as exposure to a high training load or volume over an extended period of time, acutely meaning a direct result of an impact or traumatic event with a sudden feeling of pain (Wing et al, 2020). A hamstring injury can be viewed as chronic or repeated injury of the same muscle site and is said to be due to a reduction of function or a lack of appropriate healing and rehabilitation of the area (Wing et al, 2020). Many hamstring injuries sustained can be serve in nature, taking longer than 28 days to recover (Ekstrand et al, 2011) and can cause a signification loss of athletes playing times, becoming detrimental to the performance of them team, and potentially a subsequent financial loss for sporting clubs (Hickey et al, 2014). Hickey et al, (2014) reported that an Australian football team estimated that hamstring injuries only could cost up to $245 ,842 per season, and increase of 71% from 2003. Due to the increasing prevalence of hamstring injury and the subsequent financial implication for teams, focus of hamstring research in the recent years has aimed at analysing the associated risks that predispose athletes to sustaining these hamstring injuries.

Hamstring injuries can be classified as either non modifiable and modifiable (Liu et al, 2012). Typically, non-modifiable risk factors associated with hamstring injuries are age, and a history of sustaining these types of injuries (Freckleton et al, 2013), whereas, modifiable risks factors are those that can be changed through training interventions which consist of fatigue, reduced eccentric strength, high-speed running load and flexibility (Wing et al, 2020). Evaluation of hamstring injuries has led to prevention programmes being developed that focus on eccentric hamstring strength, such as Nordic hamstring exercises (Seagrave et al, 2014, Van der Horst et al, 2017). Research has shown that when injury prevention programmes consist of NHE, injuries prevalence has reduced by 65% (Arnason et al, 2008), as well as a significant reduction of lost playing time (Seagrave et al, 2014).

The hamstring muscle is a biarticular muscle complex consisting of 4 different muscles: the muscle long head, bicep femoris, semitendinosus and the semimembranosus. These muscles are responsible for both knee flexion and hip extension which is vital for physical activities such as sprinting, jumping and walking (Schoenfeld et al, 2010). Moreover, this highlights the importance for athletes to have a greater hamstring muscle strength and power as this reduces the risk of weakness of the hamstrings, low – hamstring to quadricep ratio and an imbalance of activation between the different hamstring muscles which are the main causes for injury (Schoenfeld et al, 2015). Two of the main muscles in the hamstring are the semitendinosus and the bicep femoris, the bicep femoris has a physiological cross area and an intermediate fascicle length compared to other muscles in the hamstring (Woodley et al, 2005). Meanwhile the semitendinosus a much thinner physiological cross composed of long fibrils, as well as a large number of sarcomeres (Kubota et al, 2007). The semitendinosus is fusiform muscle which has long fibre lengths and a high number of sarcomeres which indicates the muscle may be well suited to produce strong eccentric contractions such as Nordic hamstring exercises (Guruhan et al, 2021). Moreover, the semitendinosus has a greater sagittal plane movement than the other hamstring muscles in the knee due to its greater moment arm biomechanics (Lieber et al, 2002). Considering each muscle in the hamstring is biomechanically and anatomically distinct this means they are expected to have different activation profiles during exercises. Therefore, it's important to have a greater understanding of the activation profiles of the different muscles to manage postinjury strengthening profiles, in addition to injury prevention programmes (Guruhan et al, 2021).

Hamstrings are known to be the most prevalent muscle group to suffer a non-contact injury within sport, with an estimated overall injury incidence of 1.2-4 injuries per 1000 hours of athlete exposure (Roe et al, 2016) and are responsible for 40% of muscle injuries within football (Askling et al, 2003). Injury intervention programmes which consist of eccentric training have been shown to have an effective reduction of injuries being sustained due to most muscles of low extremity occurring in the eccentric phase of the activity (Craddock et al, 2018).

The main cause of a hamstring injury to be sustained is when there is an excessive strain in the eccentric phase instead of force and duration of activation, and that elongation speed, before the eccentric contraction can affect the severity of the hamstring injury (Guex et al, 2013) Furthermore, the likelihood to sustain a hamstring injury becomes high during the late swing phase, as the hamstrings perform an eccentric contraction to decelerate the extension. Leading on, this has been associated with a weak eccentric strength of the muscle which increases the risk of hamstring injury when performing at high-speed running (Croiser et al, 2002).

1.2 Nordic Hamstring Exercises

Nordic Hamstring exercises in the past has been referred as the “Russian Hamstring exercise” (Askling et al, 2007). This type of exercise is partner based and can be performed with minimal equipment. Nordic Hamstring exercises involve an individual attempting to resist a forward- falling motion from a kneeling position, whilst utilising the hamstring muscles to maximise loading in the eccentric phase (Saleh et al, 2016). Nordic hamstring exercises have been shown to be an effective method to increase eccentric hamstring strength, in addition to developing higher maximal peak eccentric hamstring strength torques in comparison to traditional hamstring curls (Mjølsnes et al, 2004, Cutherbert et al, 2020).

When eccentric training is performed it causes a greater response compared to other training regimes, eccentric actions such as the Nordic hamstring exercise are more effective meaning a larger use of muscle strength with a low energy cost (Ekstrand et al, 2013). Moreover, utilising eccentric training causes an increase in muscle strength and size, in addition when eccentric loading is performed is promotes an increase in physiological working length on the muscle meaning it reduces sarcomeres to reach a critical length (Iga et al, 2012)

Further research has shown that NHE have a greater adaptive response compared to concentric training when in relation to muscle strength and architecture (Cutherbert et al, 2020). Which can be explained as the differences in adaptations between types of contraction are a result of the different mechanisms utilised to generate force, with concentric actions occurring due to active shortening of the fascicles, meanwhile eccentric movements are due to the active lengthen occurring (Franchi et al, 2017). The slow eccentric contractions that occur in NHE provide a stimulus, whereby the myosin heads are already attached to actin and are forced to detach by lengthening the cross bridges which can cause muscle damage (Franchi et al, 2017). A previous study by Opar et al, (2012) showed when NHE were implemented into a training regime throughout the season, there was a 65% reduction in hamstring injury incidents compared to teams that did not incorporate into their training sessions, attributed to an increase in eccentric strength. The increase seen within the fascicle length has been suggested to shift the angle at which peak torque occurs when eccentric contractions of the hamstring muscles are being performed (Brockett et al, 2001), a key mechanism of NHE. When a change occurs in both optimal fascicle length and force peak angle it has been shown to allow the hamstring muscle to function more effectively with a greater range of motion without an overstretch of the muscle tendon-unit (Blazevich et al, 2007). Furthermore, due to torque production it enables an improvement towards angles of less knee flexion which has been shown to be a common risk factor for hamstring injuries (Brockett et al, 2001).

Previous literature has shown that when NHE are performed there is an increase in muscle strength (Mjolnes et al 2004), there is minimal research that addresses the level of hamstring activation during performance of the NHE (Alt et al, 2023), (Van Der Tillar et al, 2017). Moreover, if the patterns of muscle activation during hamstring strength such as NHE were better characterised this would allow practitioners to better prescribe exercises for injury prevention programmes and rehabilitation sessions. In addition, the data found could enable a greater design on training programmes aimed at investigating chronic adaptations which are induced by different exercises such as the NHE.

1.3 Attentional Focus

Attentional focus in the content of exercise performance and sport, is referred to the process in which the athlete or performer allocates mental resources to stimuli, cues, or states (Neumann et al, 2019). Verbal encouragement and instruction have been extensively used in movement execution settings such as physical exercise movements associated with sports training, rehabilitation, and performance (Marchant et al, 2009, Selmi et al, 2023). Research has shown that emphasising such instructions can have a positive impact on an individual's attentional focus, in addition to the quality of their movements when in applied settings (Wulf et al, 2007). The study highlighted the importance of effective verbal instruction that is provided by practitioners and coaches when directing their clients. This research has been operationalized along the dimension of attentional direction, where attention is directed either internally directs their attention to bodily movements or sensations being produced during a movement such as technique or directs their attention away from their body and towards their desired movement outcomes such as goal targets (Wulf et al, 2001).

When instructions are explained with an emphasis on external focus it has been suggested to have a greater positive effect than internally focused instructions in guiding learning and performance in a variety of tasks and skills such as standing balance (McNevin et al, 2003) and dart throwing (Marchant et al, 2007). Previous research by Wulf et al (2001) suggested when internal foci was utilised it causes the individuals to focus and consciously control their movements which cause constraints of the motor system, as well as disrupts automatic processes. Meanwhile, external focus directs the individual's attention towards the movement effect which enables an automatic process to control the movement in conjunction with the performance outcome being focused upon (Vance et al, 2004).

Although there is a substantial amount of research which has explored the effects attentional focus has on an individual's learning and performance, there is limited research addressing it is use in strength and conditioning settings (Makaruk et al, 2014). Previous studies have investigated how attentional focus has affected movements such as jumping (Wulf et al, 2009) and exercises such as plyometric (Makaruk et al, 2012). There is currently a limited amount of research which identifies how attentional focus effects eccentric movements which aims to perform peak muscle activation.

2.0 Literature Review

2.1 Attentional Focus

Attentional focus in sport performance is commonly referred to the process in which a performer allocates mental resources to stimuli, cues and states (Neumann et al, 2019). Sport practitioners and coaches typically utilise verbal instructions and feedback to direct an athlete's attention, as well as improving performance and the learning process (Porter et al, 2010). When effective cueing is used, it must direct the focus on the attention to relevant information whilst performing motor skills (Starzak et al, 2024). An athlete’s attention can be directed into two different directions, by focusing on the body movement itself which would be regarded as an internal focus. Meanwhile when an athlete focuses on their movement in the environment this would be classed as an external focus (Starzak et al, 2024).

In recent years there has been a body of research undertaken on motor skills and perception, in addition to the effect attentional focus has on performance and how a performer learning specific sport skills (Ford et al, 2005; Wulf et al, 2007). The attentional focus research has shown that a simple adaptation in the wording of instructions and feedback can have a significant impact on the learning and performance of a motor skill (Wulf et al, 2010). Furthermore, it has been indicated that instructing performers to focus on the effects of their actions, instead of their body movements have benefitted both learning and performance (Chiviacowsky et al, 2010; Lohse et al, 2010). Chiviacowsky (2010) found when the participants attempted to balance for as long as possible the instructions directing them to the external markers rather than their feet (internal) resulted in a more effective learning. The study showed the internal group balanced for 33% of their time, meanwhile the external group were balanced for 43% of the time showing a greater time when external instructions were given. Practitioners within sport commonly utilise feedback or verbal instructions to effectively direct performers’ attention, as well as the learning process and enhancing performance (Porter et al, 2010).

Previous research has shown when using psychological strategies such as attentional focus can influence a greater rate of performance when learning a new skill or exercise (Radcliffe et al, 2015). An external focus of attention is when attention is directed away from the athlete’s body and towards desired movement outcomes, which has been reported to have an enhanced effect on motor learning and control (Wulf et al, 2007). Meanwhile an internal focus of attention directs attention directs more to the bodily movements which have been suggested to be vital to an athlete performing a movement successfully (Wulf et al, 2007). A prospective study has suggested when internal focus is utilised it can have enhanced benefits in rehabilitation programmes and movements which are concerned with an increase in muscle activity despite the less successful movement (Hunt et al, 2017).

When observing previous studies, Wolf et al, (1998) revealed the advantages of implementing an external focus in comparison to an internal focus when aiming to learn motor skills. When looking at external focus it consists of concentration on the intended effect of the movement such as the motion of implement such as tennis racquet, hitting a target such as a bullseye in darts, in addition an image such as pendulum type motion of a golf club (An et al, 2024). Meanwhile, an internal focus consists of a concentration on the body movements such as how an individual moves their wrists, hips and arms (An et al, 2024). When analysing the effect of attentional focus when performing a golf swing, a study undertaken by Bell et al, (2012) revealed when external focus was utilised there was a greater level of performance in relation to the accuracy and flight of the shot compared to when internal focus was used. Moreover, when looking at the effect attentional focus has on dart throwing it has been demonstrated external focus causes greater accuracy of the throw, particularly when the focus is more distal such as focusing on the bullseye rather than proximal such as the trajectory of the dart (Mckay et al, 2012).

In the study undertaken by Wulf et al, (1998) the individuals learnt the balancing tasks more efficiently when an external que was given. Moreover, the subjects were informed to focus their attention on the wheels of a ski simulator which caused them to have more of an effective learning than the internal focus instructions to focus on their feet. Furthermore, in the 2nd experiment in within the study the participants were told to concentrate on keeping the markers in front of their feet when led to an increased balance learning compared to the internal instructions to keep their feet horizontal. These findings are in agreement with a comprehensive meta-analysis which confirmed the superiority of an external focus in comparison to an internal focus for both immediate performance and learning (Chua et al, 2021). In addition, this study revealed that the benefits that occurs when external focus is utilised is independent of health conditions, age, and the level of expertise an individual attains.

When analysing the optimal theory of motor learning, an external focus has been shown to be one of three vital factors that influence the effectiveness of motor skill learning, as well as performance (Wulf et al, 2016). The other two factors that are proposed are autonomy support and enhanced expectancies for performance. When all three factors are present it has been suggested they contribute to the fluidity with which the proposed movement goal is transferred into action and also contribute to goal action coupling (Wulf et al, 2016). These results are similar to a study undertaken by Kal et al, (2013) which indicated an external focus not only enhances movement accuracy compared with an internal focus but also improves movement fluency which results in a greater neuromuscular efficiency (Greig et al, 2014).

A potential explanation for a faster rate of motor skill learning for the participants as well as greater performance could be external focus may have positive motivational consequences. Wulf et al, (2016) proposed "Movement success resulting from an external focus can cause an enhanced expectancy for future success". Therefore, this suggests by implementing an external focus over an internal focus it can result in an increased level of confidence due to a successful performance which could potentially lead to a virtuous cycle of good performance, which will then lead to an increase in self-efficacy (Wulf et al, 2016). The participants thoughts and feelings about future performance including self-efficacy expectations are a main focus of human motivation (Bandura et al, 1977). Furthermore, when external focus is implemented, this can increase the level of performance thus a greater expectation of performance which can cause additional benefits to motor skill learning and performance (Jenkins et al, 2020).

In this present study the aim was to see the feasibility of utilising more than one external instruction against no instructions given. Most studies have examined the utilisation of a single internal focus instruction with a comparable external focus instruction (Chua et al, 2021). However, the acquisition of a movement such as a jump, or a throw requires the attention of the individual to be direct at the proper movement form, in addition to the performance outcome. Moreover, it’s uncommon when trying to learn a new skill that only a singular instruction will be utilised. Therefore, by utilising more than one external attentional focus its suggested it will promote a greater progression when then Nordic hamstring exercise is performed.

2.2 Nordic Hamstring Exercises

Nordic hamstring exercises have been used in many sport training environments such as rugby union and football as a method of increasing eccentric hamstring strength which aims to reduce the incidence of hamstring injuries (Iga et al, 2012), (Small et al, 2009). A Nordic hamstring exercise is a bodyweight only exercise, which requires the performer to lower their upper body towards the ground whilst at a kneeling position with a device or partner holding down their ankles which is known as the descent phase (Marshall et al, 2015). After this process the performer utilises their upper body to provide propulsion for returning to the starting position of the exercise which is known as the ascent phase (Marshall et al, 2015). The use of NHE is increasing in training environments as it doesn’t require any specialist equipment (Marshall et al 2015).

Nordic Hamstring exercises have become a popular strategy for hamstring injury prevention programmes in football players (Meurer et al, 2017). NHE has been shown to be an effective tool to increase eccentric hamstring strength, in addition to developing higher maximal eccentric hamstring strength torques compared to regular hamstring curls (Mijolsnes et al, 2004). Arnason et al, (2008) demonstrated when Nordic hamstring exercises were involved in a 10-week injury prevention programme it enhanced the eccentric knee flexor strength of football players. In the study five out the 10 Icelandic football teams and six of the 14 Norwegian teams utilised Nordic hamstring exercises in their strength training program as well as their warmups for the 2002 football season. Arnason et al, (2008) revealed there we no hamstring injuries reported during eccentric strength training, in addition to hamstring strains were 65% lower among the teams that utilised eccentric exercises compared to the teams that did not use the program. In addition to this, research conducted by Lovell et al (2018) and Ishoi et al, (2018) revealed when Nordic hamstring exercises were incorporated into the injury prevention programme it caused a positive strength response with the football players involved. According to a meta- analysis conducted by Al Attar et al (2018) training programmes that utilise Nordic hamstring exercises reduce the rate of injuries by 51% for football players from different competitive levels, which supports the inclusion of this type of exercise in injury prevention programmes. The muscular strengthening provided by Nordic hamstring exercises is one of the main mechanisms responsible for the reduction in hamstring injury strains in football (Marshall et al, 2015).

A study undertaken by Petersen et al, (2011) conducted a strength and condition programme for amateur footballers which consisted of Nordic hamstring exercises which decreased the rate of new and recurrent hamstring injuries by 60% and 80%. These findings are further supported by Van Der Horst et al, (2015) which examined hamstring injuries in amateur football players aged 18-40 years in which they added Nordic hamstring exercises to an experimental group whilst a group performed their regular training routine. The study found when this was performed over 13 weeks there was a significantly lower hamstring injury incidence in the experimental group than the group that was undertaking the normal training regime.

2.3 Hamstring Muscle Activation

Electromyography (EMG) is well used tool for non-invasive assessment of muscle function that consists of recording and quantifying the electrical activity associated with contracting skeletal muscle fibres (Beck et al, 2005). EMG recordings have a variety of clinical and biomedical applications that can be utilised t0 examine factors relating to motor control strategies associated with force production as well as neuromuscular fatigue. The amplitude contents of EMG signal enable information related to muscle activation to be provided and are influenced by the level of motor unit recruitment, synchronisation and firing rate (Basmakian et al, 2014).

There have been several studies that have investigated how muscle activation is affected in the hamstrings when performing different leg movements such as Nordic Hamstring exercises. However, there’s still a lack of evidence to show the proposed effectiveness that Nordic hamstring exercises have for preventing hamstring injuries which compare the differential level of muscle activation in the hamstring muscles throughout the open knee angles (Monjati et al, 2017). Previous research undertaken by Ditrolio et al, (2013) revealed there was a higher amount of muscle activation in the bicep femoris during Nordic hamstring exercises compared to a traditional maximal eccentric exercise. In this study the Bice femoris was the only hamstring muscle analysed.

Moreover, a study undertaken by Marshall et al, (2015) reported there was a significant decrease in bicep femoris muscle activation but an increase in semitendinosus during 6 sets of 5 repetitions when Nordic hamstring exercises were performed by football players. Following on, Zebris et al, (2013) found when comparing Nordic hamstring exercises to the glider exercise muscle activation was significantly higher. The study found when the Nordic hamstring exercise is performed the movement across the knee joint causes a greater muscle activation in the semitendinosus compared to the bicep femoris, which is consistent with another previous study (Bourne et al, 2016).

2.3.1 Nordic Hamstring Exercises and Muscle Activation

Nordic Hamstring exercises are a field-based exercise with a focus on eccentric action of knee flexor muscles (Brockett et al, 2001). A study undertaken by van Dyk et al, (2019) which utilised a female and male football team revealed when Nordic Hamstring exercises were implemented in a pre-training programme this reduced the hamstring injury rates by half. This preventive measure is related by an increase in muscle activation in the hamstrings which as there was an increase in fascicle length, as well as eccentric knee flexor strength (Medeiros et al, 2020). Likewise, a pre training programme that was conducted for 12 weeks that included Nordic hamstring exercises decreased injury risk by 82% for all lower limbs' injuries (Al Attar et al, 2017). The study had similar results which showed an increase in muscle activation in the hamstrings which led to an increase in eccentric muscle strength, as well as an increase in muscle length.

Furthermore, a more recent study undertaken by Elerian et al, (2019) measured 34 active male footballers that utilised Nordic hamstring exercises within the pre- training programme. The results from the study had comparable results to the previous two studies as it indicated a greater muscle activation than the control that did their usual training regime. The research indicated the players that performed Nordic hamstring exercise had a higher eccentric strength which meant the players could withstand the high lengthening force on muscle fibres (Van Hooren et al, 2017). However, there is still a limited amount of research into the use of Nordic Hamstring exercises in pre training regimes, therefore more research is needed comparing the effect of Nordic hamstring exercises has on muscle activation compared to concentric hamstring exercise in injury prevention programmes.

Although Nordic Hamstring injuries have been shown to elicit adaptations that reduce the risk of a hamstring injury, however the compliance of Nordic hamstring exercises in professional football teams are low despite a high occurrence of hamstring injuries in football. A reason for low compliance in football teams could be due to the high dosages that are prescribed in the interventions that have been conducted. Moreover, in professional football for men, fewer than one fifth of team's report being compliant with the hamstring injury prevention programme that consists of NHE (Bahr et al, 2015), (Chesterton et al, 2021). Many teams utilise a programme of a shorter duration, in addition to lower training volume which facilitates the implementation in the busy periods of the season (Amundsen et al, 2022).

2.3.2 Attentional Focus and Muscle Activation

Attentional focus is a well-known aspect of motor learning and has been shown to have implications to the fitness professional. Research has indicated that performance-oriented tasks are enhanced when external focus of attention is adopted by an individual (Schoenfeld, 2016). Wulf et al (2007) analysed over 50 studies which represented more than 90% of the studies showed superior movements in motor learning with the participants used an external focus compared to an internal focus. In addition, the studies highlighted there were additional benefits seen across a variety of outcome measures and activities which lends strong support for the utilisation of external focus when the aim is to enhance performance (Schoenfeld, 2016).

When evaluating resistance training, the performance- based superiority of an external focus has contributed to an enhanced economy of movement which has been associated with a greater force production, however it has been shown to reduce muscular activity (Marchant et al, 2009). This can be explained as the study did not record the EMG of the triceps, meanwhile previous research demonstrated associated increases in EMG activity in the triceps is in correlation with the bicep EMG activity when an internal attentional strategy is utilised. Therefore, such effects show an interference between the agonist and antagonist muscle groups during such movements (Vance et al, 2004). Moreover, a more economical movement pattern has been shown to facilitate a better skill acquisition, and it may not enhance muscle development (Schoenfeld, 2016). When the target for the individual is to have a greater muscle activation, indirect evidence has suggested internal focus may be the best method for this. When athletes perform strength training it has been suggested there is an importance of developing a “mind muscle connection” when training (Marchant et al, 2009). Therefore, this method utilises internal focus which consists of visualizing the target muscle, whilst directing the neural drive to the muscle when the athlete is performing the movement. A number of studies have revealed a greater muscle activation when participants were coached to use an internal focus of attention (Wolf et al, 2007; Lewis et al, 2009; Karst et al, 2004; Schoenfeld, 2016).

A study undertaken by Lewis et al, (2009) suggested when young women were instructed to adapt an internal focus, they were able to achieve a greater mean EMG activity of the gluteus maximus when performing a hip extension. The instruction utilised in the study was “use your gluteal muscles to lift your leg whilst keeping your hamstring muscles relaxed”. Following on from this, the timing of the muscle activation was altered so the gluteus maximum of the participants was activated significantly earlier during the hip extension. Likewise, a study undertaken by Bressel et al, (2009) showed that peak EMG amplitude and were increased significantly in the abdominal musculature as the participants were told to “brace themselves as they were going to punched in the stomach” when performing a squat. The evidence shown, suggests when performing a singular movement such as the Nordic Hamstring exercise that an internal focus approach will enhance muscle activation than if no instructions or an external focus was implemented.

3.0 Aims and Hypothesis

3.1 Aims

The aim for this present study was to investigate the influence attentional focus instructions have on muscle activation when performing a Nordic Hamstring exercise, addressing the utility of attention focus cues on an exercise setting. This study aims to evaluate whether utilising external focused instructions can be beneficial to enable muscle activation to be more efficient which was previously stated by Vance et al, (2004). In, addition, an aim of the study was to evaluate whether attentional focus would affect the angle at which muscle activation was highest.

3.2 Hypotheses

The hypothesis of the study is when the activation of the hamstring occurs it will be the greatest when Nordic hamstring exercises are performed at the more extended knee joint positions. Moreover, when the attentional focus conditions are utilised prior to each Nordic Hamstring exercise the muscle activation will be higher than the controlled condition where no verbal instructions have been provided.

4.0 Methods

4.1 Participants

Twelve physically active recreational male football players (age: 25, ± 3 years) participated in this study (characteristics in table 1). Participants were excluded from the study if they had sustained a lower limb injury in the previous six months, or if they had any feeling of muscle illness or pain that could reduce their effort in performing the Nordic Hamstring exercise. The participants in the study were asked to refrain from any lower body strength training during 48 hours before testing to ensure that the participants did not have the risk of fatigue. Participants provided full informed consent and completed a health screening questionnaire prior to commencement of the session.

Table 1: Characteristics of Participants

Age (Years)	25 ± 3
Height (CM)	1.78 ± 0.08
Body Mass (KG)	84.87 ± 11.84
Body mass index (kg/m2)	26.67 ± 3.41

Data is presented as mean ± SD

4.2 Study Design

The study implemented a multimodal design with some observational analysis to assess the primary aim along with a repeated measures design to assess the secondary aim. The observational component assessed the knee angle associated with maximal hamstring muscle activation during the performance of Nordic Hamstring Exercise. The secondary repeated measures component then explored how different attentional focus (three levels: neutral, external upright posture, and external muscle contraction) can affect hamstring muscle activation during the Nordic Hamstring Exercise. This study involved 2 study visits each lasting approximately 2 hours.

4.3 Experimental Protocol

The participants were required to attend the strength and conditioning suite at Leeds Trinity University on 2 occasions separated by a minimum of 24 hours. Participants were required to refrain from consuming ergogenic supplements, in addition to alcohol 24 hours before the main trail commenced. The participants were informed to not perform strenuous exercises for the lower body 24 hours prior to the main trial taking place.

4.3.1 Visit One

On arrival at the strength and conditioning suite the study was explained in detail, and participants were offered the opportunity to ask any questions. Participants then provided written informed consent. Following this body mass and stature were recorded (See section 4.4.1).

Participants were then setup for EMG and video analysis, with relevant markers and electrodes placed in situ (as per the details below). Once the participant was ready, they were asked to undertake a standard RAMP protocol warm up (See 4.4.2) and then they were asked to complete a maximal voluntary contraction (MVC) which was used to normalise the main trial data (as per the details below). The participants then conducted the Nordic Hamstring Exercise protocol (as detailed below) and electrical activity of the bicep femoris and semitendinosus, as well as the angular displacement of the knee joint of the dominant subject leg were recorded for subsequent later analysis. The first set of Nordic Hamstring Exercises that were conducted as a familiarisation to the protocol, this was included to prevent a learning effect being present which could affect the main trial results, as well as allowing the study to maintain validity (Currell et al, 2008). As there we no requirements in the study for participants to have experience in performing Nordic Hamstring exercises, it was vital they have an opportunity to become familiar with the exercises before main trial testing had begun. Following a rest period, participants then completed their first set of experimental Nordic Hamstring Exercises (each participant was randomly allocated to a set of attentional conditions per trial to eliminate order effect, explained below).

4.3.2 Visit Two

Following a minimum period of 24 hours, participants revisited the strength and conditioning suite at Leeds Trinity University to undertake the remaining 2 attentional focus sessions. Participants were asked to attend this session in the same state that the attended visit one.

Participants were then setup for EMG and video analysis (detailed below), with relevant markers and electrodes placed in situ. Once the participant was ready, they were asked to undertake a standard RAMP protocol warm up and then they were asked to complete an MVC. The participants then conducted their second set of Nordic Hamstring Exercises and electrical activity of the bicep femoris and semitendinosus, as well as the angular displacement of the knee joint of the dominant subject leg were recorded for subsequent later analysis. Following a rest period, participants then completed their final set of experimental Nordic Hamstring Exercises.

On completion of this trial participants completed a post experimental manipulation questionnaire which consisted of them being asked the following items: (a) To what extent were you focused on the movements of any part of your body (e.g., legs, torso, arms, hands or head) as you executed your Nordic Hamstring exercise? (b) To what extent were you focused on your hamstring muscle contraction as you executed your Nordic Hamstring exercise? (c) To what extent were you focused on maintaining an upright posture as you executed your Nordic Hamstring exercise? Responses to all manipulation check questions were provided via a Likert scale ranging from 1 (not at all) to 5 (very much so).

The participants were randomly allocated into one of three different subgroups regarding attentional focus. The first study visit occurred 24 hours before the second experimental study visit (visit 2), which involved a familiarisation session. The familiarisation session was included to prevent a learning effect being present which could affect the main trial results, as well as allowing the study to maintain validity (Currell et al, 2008). As there we no requirements in the study for participants to have experience in performing Nordic Hamstring exercises, it was vital they have an opportunity to become familiar with the exercises before main trial testing had begun.

4.4 Experimental Procedures

4.4.1 Anthropometric measures

The participant's standing height was measured using HM200P stadiometer (Charter Electronic Co, LTD, Taichung, Taiwan). To record measurements of the participant's height they were instructed to stand with their back, buttock and heels against the stadiometer, which was checked to ensure this was completed correctly by the researcher. The stadiometer headboard was lowered onto the top of the participants head compressing their hair. Following on, the height was measured to the nearest 0.1cm. The participant's body mass was measured using a Seca- digital floor scale (Seca, LTD, Birmingham, UK) to the nearest 0.05kg. The measurements for both body mass and height were made with the participants wearing light sportswear and without wearing shoes.

4.4.2 RAMP Warm Up

The participants completed a standardised warmup which consisted of a ten-minute submaximal cycle at an intensity of 10-12 on the RPE scale. Once completed the participants performed 8 repetitions of dynamic stretching exercises which included legs swings, hip curls and backward and side hip bending followed by 10 repetitions of strength body weight exercises consisted of heels rises, squats, jack-knife sit ups, hip bridges, and hip extensions (Sarabon et al, 2019).

4.4.3 Electromyography (EMG)

Surface Electromyography (EMG) was utilised within this study which is the recording of electrical activity in the skeletal muscle.

4.4.3.1 Electromyography Acquisition

Prior to the placement of the electrodes, the site was prepared by removing excess hair to avoid physical interference of the ionic exchange and reduce background noise, similar to methods recommended by Delsys (Konrad et al, 2006, Reaz et al, 2006). Once this process has been completed, the participant's dominant leg was fitted with wireless surface EMG sensors (Delsys Trivingo Avanti). The EMG sensors were placed upon the bellies of the bicep femoris and semitendinosus muscles of the dominant leg via palpitation of the relevant muscle groups. The sensors were placed on the participant's leg with an interelectrode distance of 2cm in accordance with SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles). The electrodes were placed parallel to the longitudinal axis of muscle fibres on the participant's contracted muscle taking muscle migration during the exercise into consideration. The sites selected were the midpoint on the line between ischial tuberosity and the medial epicondyle of the tibia for the semitendinosus. While the other electrode was placed on the midpoint on the line between the ischial tuberosity and the lateral epicondyle of the tibia.

The EMG system was run at a sampling rate of 2000Hz over a wireless network, connected to a host laptop for real-life time display, as well as storage of the results for data analysis. The signals of the sensor were amplified with a low pass frequency of 20hz and a high pass frequency of 400hz with a common mode rejection ratio of 92 dB. The filtering frequency limits were based on the recommendations of DeLuca et al (2010) to limit any intrinsic and extrinsic noise which could affect the signal.

4.4.3.2 EMG data processing

When the data was collected, the EMG data was analysed using Delsys EMGworks analysis. The EMG data from the movement of the Nordic Hamstring exercise were put through an amplitude analysis which rectified the raw EMG signal and converted all negative amplitudes into positive amplitudes which provided a data set that mean values were taken from instead of having a raw signal with a mean of 0. Therefore, this showed the peak amplitude of muscle activation for each repetition the participant performed. Following on, the data analysis was to filter the data using a Butterworth filter with a 5 Hz cut off frequency, as well as a band pass filter as this was most suitable for the data. Therefore, this enabled RMS analysis to be undertaken using an MVIC trial which normalised the data, which resulted in the data to be displayed as a percentage instead of volts which enabled a comparison between participants to occur. The signals were smoothed by utilising a low frequency Butterworth filter, with a 5 Hz cut-off frequency (Bartlett et al, 2007). Furthermore, the participants performed five repetitions of Nordic hamstring exercises for two sets. The joint torques were calculated using a (2D) inverse dynamic model which will be built with a segmental method (Winter et al, 2009). This generated the EMG outcome variables.

4.4.3.3 Electromyography analysis

Following the collection of the EMG during the main procedures, each electromyogram had its mean offset subtracted to limit any contamination which could have been caused by background noise. In addition, each graph was analysed for any further sign of contamination such as motion artifacts and crosstalk. These methods that were utilised were in accordance with previous research (DeLuca, 2010, Halaki et al, 2012). If a motion artifact appeared which typically occurs during EMG acquisition as stated by De Luca et al, (2010), then the false peak was cropped out of calculation window, meaning it was ignored during the assessment of peak muscle activation. In the study EMG peak was utilised, as motion artifacts were manually ignored instead of using moving averages which have been shown by Konrad et al (2006) to be at a higher risk of contamination of motion artifacts.

4.4.4 Two- Dimensional Video Analysis

4.4.4.1. Camera set up

Two- dimensional (2D) video analysis was utilised to establish the knee angle of the dominant leg at the point of maximum muscle activation. A Casio EX- ZR700 was used to record the movement. The camera was placed at side of the participant’s dominant leg and was positioned parallel (90 degrees) to the movement frame to avoid distortion or error in video processing. The frame rate used for the camera was 240 fps, meanwhile the sampling rate was 1/1000.

4.4.4.2 Video preparation

Each participate was required to wear 3 limb markers throughout the protocol. These were placed on the knee (lateral condyle of tibia), the hip (greater trochanter) and the ankle (lateral malleoli), to allow for joint angle of the knee to be determined. The participants were required to wear sports clothing such as shorts which enabled access to the relevant joint centres. If the participants could not wear shorts, then tight-fitting clothing was used if it did not distort the marker from the true limb movement.

4.4.4.3 Video data processing

The collected video files were uploaded into the Dartfish 22 analysis software (Dartfish, Switzerland). The knee angle was measured at the time point of peak muscle activation which was determined by the start of the movement when the knee starts to bend, and it ended when the participant's hands made contact with the ground which is typically between 6-10 seconds. Furthermore, the hip, knee, and ankle markers to create the outcome variables. This was repeated for each of the participant dominant leg muscles for each Nordic Hamstring Exercise.

4.4.5 Maximum Voluntary Isometric Contractions

Maximum Voluntary Isometric contraction (MVIC) is a standardised, objective, and sensitive tool for the measurement of muscular strength (Meldrum et al, 2007). A MVIC is a used commonly in research as a reference point for EMG amplitude and for force production (Burden et al, 2010). This method monitors levels of isometric strength and was utilised to identify maximal voluntary muscle activity to normalise EMG data.

An MVIC for the participant's hamstrings were performed following the warmup (see section 4.4.2). The MVIC that was utilised, required the participants to lie face down on the floor whilst pulling as hard as they could with their dominant leg on a tightened ratchet that was attached to an immoveable structure at 130-degree flexion. The contractions were performed with an adjustable dynamometer (Konrad, 2006). Each participant performed preparation contractions at 50% and 75% of their maximal effort, before performing a 5 second maximal contraction. One repetition for the MVIC was performed, where verbal encouragement was provided throughout the however no attentional focus was utilised. The MVIC for the participants were obtained on both days of testing to ensure a suitable baseline recording could be gathered.

4.4.6 Nordic Hamstring Protocol

The following protocol was used for this specific study, based upon the method utilised by Mjolsnes et al, (2004). The participants started the exercise in a knelt position while securing their legs by the ankle. After the participant began to lean forward at the knees whilst maintaining their hip joint in an extended position. Participants were told to resist the falling motion for as long as possible by engaging their hamstring muscles. However, if a participant couldn't do this then they were told to maintain the tension in their hamstrings even if they were falling or had fallen. The participants were then asked to utilise their hands to both break their fall and return their torso to the starting position which aimed to minimise the concentric contraction of the hamstring during the movement. First the participants performed an identical exercise protocol to the one that will be used within in the study. This gave the participants an exposure to the perform the Nordic hamstring exercise to enable them to become familiar with the technique which enabled the study to be valid and prevent a learning effect (Currell et al, 2008). Once completed the main protocol was measured and performed for 3 sets of 5 repetitions. There were 10 minutes seated rest period between sets. During each set, participants undertook 1 of the attentional foci activities (as described above).

4.4.7 Attentional focus

The respective attentional foci were induced via explicit instruction (Bell and Hardy, 2008). The content of the experimental treatment package differed across focuses groups. The explicit instructions were drawn heavily from Wulf et al, (2000), whereby the participants were asked to concentrate on one specific aspect of skill execution. In addition, the intervention package borrowed heavily from Beilock et al, (2002), where attempts were made to induce attentional foci by posting pertinent questions during the testing phase.

Each participant undertook 3 attentional focus conditions (described in 4.4.7.1), these were randomly assigned to an order for each participant to ensure that there was no order effect. On visit 1 participants completed 1 condition with the remaining 2 conditions completed on visit 2.

4.4.7.1 Attentional Focus Conditions

4.4.7.1.1 Neutral Condition

During this condition, no coaching instructions were given, allowing the participants to perform a neutral attention (Wulf et al, 2013). The participants were informed of the purpose of the exercises, although they were instructed to perform the exercise as hard possible.

4.4.7.1.2 External focus condition - Contraction of Muscle

During this condition, participants were explicitly instructed to focus on contraction of hamstring muscles when undertaking the Nordic Hamstring Exercises. Participants within this group were also asked to repeat the phrase hamstring muscle activation further promote an external focus. They were reminded of these instructions after every third rep.

In accordance with recommendations from Beilock et al. (2002), once participants had completed their external focus condition, they were asked on a scale of 1 (not at all) to 5 (very much so) “to what extent did you focus on hamstring muscle activation during that exercise?”

4.4.7.1.3 External Focus Condition – Upright Posture

During this condition, participants were explicitly instructed to focus on maintaining an upright posture when completing the Nordic Hamstring Exercise. In addition, participants were asked to repeat the phrase maintain posture. They were reminded of these instructions after every third rep.

Once participants had completed their external focus condition, they were asked on a scale of 1 (not at all) to 5 (very much so) “to what extent did you focus on maintaining an upright posture during that exercise?”

4.4.7.2 Post Experimental Manipulation Check

As per Bell & Hardy (2008), participants were asked three specific questions designed to assess use of the respective attentional foci during task execution. More precisely, all participants answered the following items:

(a) To what extent were you focused on the movements of any part of your body (e.g., legs, torso, arms, hands, or head) as you executed your Nordic hamstring exercise?

(b) To what extent were you focused on hamstring muscle contraction as you executed your Nordic hamstring exercise?

(c) To what extent were you focused on maintaining an upright posture as you executed your Nordic hamstring exercise?

Responses to all manipulation check questions were provided via a Likert scale ranging from 1 (not at all) to 5 (very much so).

4.5 Data Analysis

Once the outcome variables were measured and they were analysed using SPSS (IBM, SPSS). All descriptive statistics were calculated and presented as mean ± standard deviation (SD). Prior to any formal analysis the statistical assumptions for normality and homogeneity of variance were assessed. Following this the primary outcome, assessing the association between maximal hamstring muscle activation and knee angle was assessed using a paired sample analysis. In addition to this the effect of attentional focus on maximal hamstring activation (across 3 levels) was assessed using a repeated measures ANOVA analysis with a Bonferroni adjustment. Mean differences were presented with adjusted 95% confidence intervals (CI) with significance being assessed at $P < 0.05$. As part of this analysis, the association between the post experimental manipulation check and maximal hamstring muscle activation was assessed using linear regressions to assess how the quality of the of the attentional focus manipulation affect.

5.0 Results

5.1 Attentional Focus on Muscle Activation

The results of the effects of attentional focus strategy of had on the three kinetic variables are reported in figures 5.1, 5.2, 5.3. The post manipulation check is reported in figure 4. There were no significant differences for peak muscle activation during the three attentional focus conditions for the bicep femoris (p=0.88). In addition to this, there was no significant differences for peak muscle activation during the three conditions for the semitendinosus (p=0.55). All three conditions had no significant difference for the bicep femoris with external focus = 38.49 ± 9.94 EMGpk External focus muscle contraction = 38.67 ± 8.18 EMGpk and the Neutral group = 37.55 ± 9.35 EMGpk When looking at the semitendinosus, again there was no significance with the three attentional focus conditions, External focus upright posture= 51.89 = ± 10.38 EMGpk, External focus muscle contraction = 49.27 ± 7.56 EMGpk and the Neutral group = 49.66 ± 10.28 EMGpk.

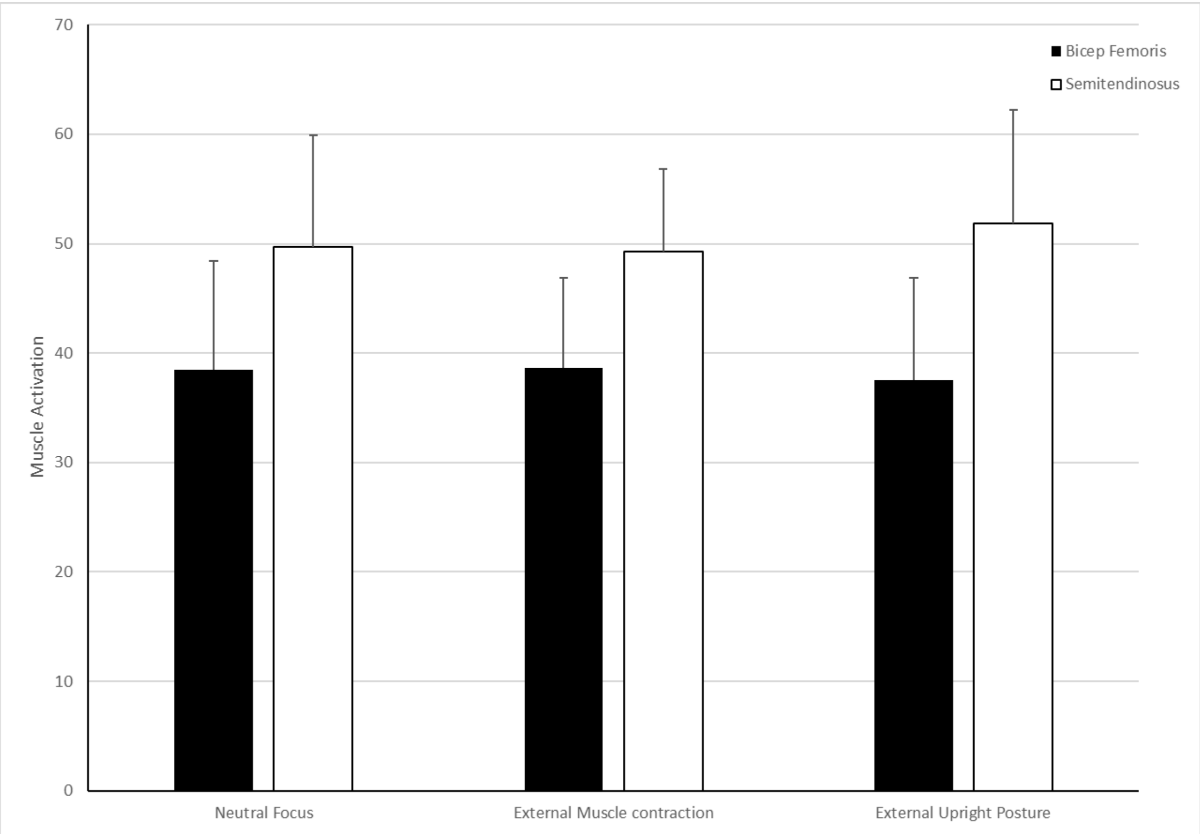

Figure 1: The effects of attentional focus strategy on peak muscle activation

5.2 Attentional Focus on Joint Angle

When utilising pairwise comparisons this revealed there was no significant difference for the joint angle when peak muscle activation occurs for all three attentional focus conditions for the bicep femoris (p=0.79). Following on, from this when using pairwise comparisons this showed there no significant different for the joint angle when peak muscle activation occurs for all three attention focus conditions for the semitendinosus (p=0.67). The results revealed there no significant difference for all three attentional focus conditions for the bicep femoris, Neutral group =102. 71 ± 5.48°, External group = 103.72 ± 4.71° and the Internal group = 103.16 ± 7.23° This was similar with all three conditions for the semitendinosus, Neutral group = 103.16 ± 5.36°, External group = 104.27 ± 5.05°, Internal group = 103.55 ± 5.48°

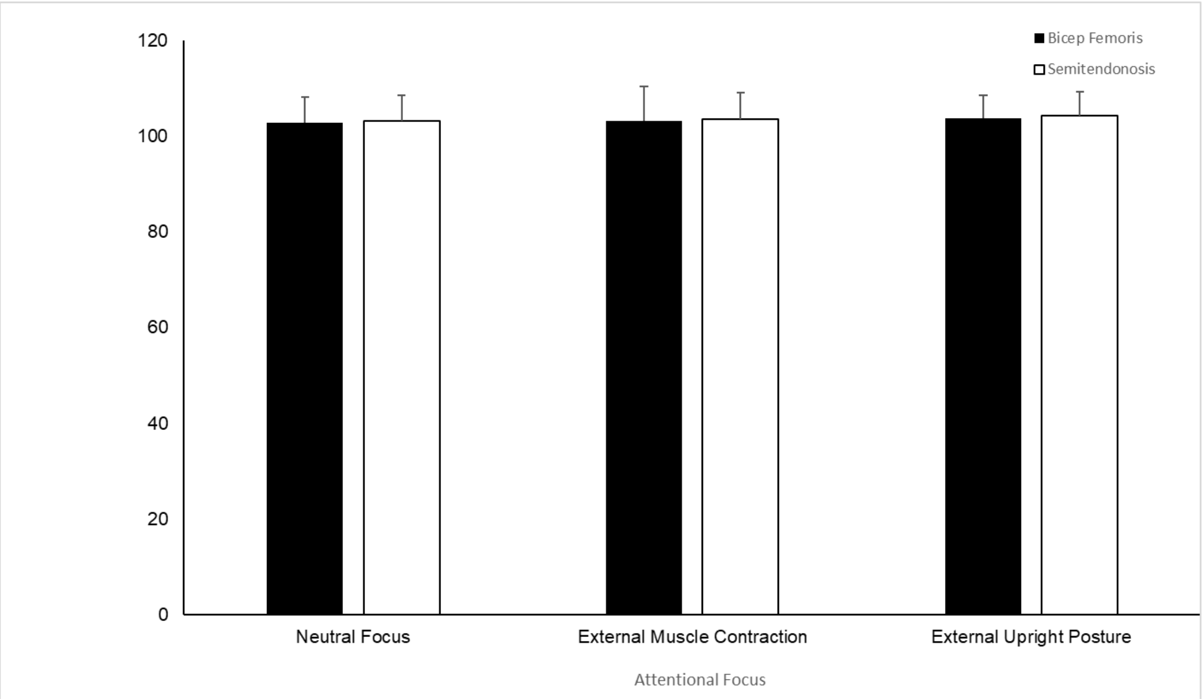

Figure 2: The effects of attentional focus strategy on peak joint angle

5.3 Order Effect of Muscle activation

When analysing the data there was no significant difference between the three conditions for the order effect (p=0.31).

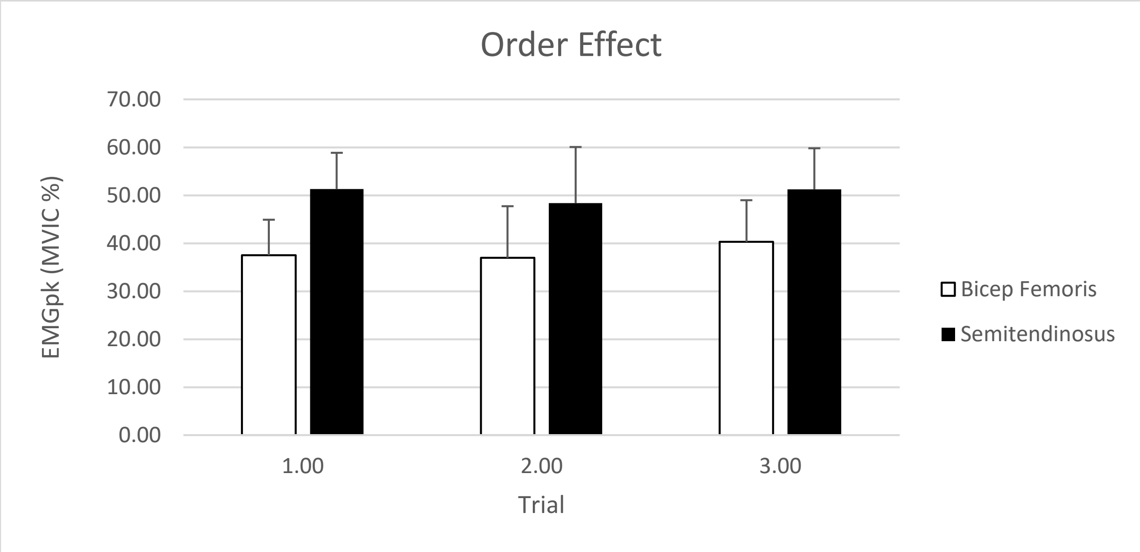

Figure 3: The order effect of muscle activation on the attentional focus conditions

5.4 Attentional Focus Manipulation

All the participants within the study reported to what extent they had completed the task (Nordic Hamstring exercises) as the combined attention –oriented intervention package outlined. In addition, the participants were asked three specific questions designed to assess the use of the respective attentional foci during Nordic Hamstring exercises. The participants answered the following questions after the five repetitions of each condition and the responses to all the manipulation check questions were provided by via the Likert scale ranging from 1 (not at all) to 5 (very much so).

Table 4: Mean responses to question of the post experimental manipulation check

QUESTION	**SCORE**
TO WHAT EXTENT WERE YOU FOCUSED ON THE MOVEMENTS OF ANY PART OF YOUR BODY? (E.G., LEGS, TORSO, ARMS, HANDS OR HEAD) AS YOU EXECUTED YOUR NHE?	3.83 ± 1.03

TO WHAT EXTENT WERE YOU FOCUSED ON HAMSTRING MUSCLE CONTRACTION AS YOU EXECUTED YOUR NHE?	3.92 ± 1
TO WHAT EXTENT WERE YOU FOCUSED ON MAINTAINING AN UPRIGHT POSTURE AS YOU EXECUTED YOUR NHE?	3.58 ± 0.51

Results presented as mean ± standard deviation.

6.0 Discussion

6.1. Study Aims and Findings

6.1.1 Aims

The purpose of this study was to test two competing focus of attentional focus theories proposed by Beilock et al, (2004) and Wulf et al, (2001) utilising young active adults performing Nordic Hamstring exercises. The main aim of the study was to observe the influence attentional focus instructions had on muscle activation when performing a Nordic Hamstring exercise, whilst addressing the utility of attention focus cues on an exercise setting. In addition, the study aimed to evaluate whether utilising external focused instructions can be beneficial to enable muscle activation to be more efficient as previously proposed by Vance et al, (2004). Moreover, the study aimed to see if attentional focus cues effect the angle at which muscle activation was greatest. For this to occur, each participant completed three trials of the prescribed task under each of the three conditions (i.e., external, internal and neutral) which totalled 15 trials per person. Based on the findings of Wolf et al, (2001) the study predicted that directing external attentional focus rather than minimal instructions given would cause a greater muscle activation when performing Nordic Hamstring exercises compared to performing this in a neutral condition.

6.1.2 Findings

The results of the research do not support the hypothesis predicted by Wolf et al, (2001) which proposed that adopting an external focus que should elicit results that are superior to trials that were performed in the control group. Many of the trials performed failed to demonstrate a robust effect of the external focus which is inconsistent when previous research (Ducharme et al, 2016; Porter et al, 2010). This could be explained by the order effect as the attentional focus conditions were implemented in the research, a randomisation process was undertaken where the three focus conditions were randomly assigned to enable an unbiased comparison of the three focus conditions. Moreover, it suggests the participants performed the exercise more frequently, leading them to become more familiar with the testing environment which could have affected the different conditions (Milley et al, 2021).

In a study undertaken by Cerrah et al, (2014), muscular activation differences between amateur players and professional football players were assessed when performing a countermovement jump, revealing that the professional footballers had a greater muscle activation than the amateur players due to a greater knee flexor and stronger hamstrings when performing the countermovement jump and suggested this was due to the professional players having a greater exposure to the exercise. When analysing the data it revealed when the participants were taking off to jump there is when peak muscle activation occurred for the bicep femoris in both groups. However, in the take off stage the professional players had an average of 20% MVIC meanwhile the amateur players recorded 12-15% MVIC which shows a higher result for the professional players. Therefore, this can explain why the muscle activation in the third trials were higher as they had previously performed the Nordic Hamstring exercise which caused the participants to be more familiar with the technique of the exercise.

Although there was no significant difference with muscle activation (as seen in Figure 1) in the three conditions the post task questionnaire provides an insight into the participant's experiences of the instructions that were provided in table 4. The three types of attentional focus utilised did not influence the physical demands or levels of perceived mental during the exercise. However, the external muscle instructions were rated higher compared to the neutral group, within post manipulation checks, suggesting the external instructions were easier to follow meaning there was difficulties when minimal instructions were given in the neutral group which scored lower. These findings do agree with previous research which highlights preferences for external focus instructions (Wulf et al, 2001). It's suggested that utilising internal and minimal instructions constraints the motor system by interfering with natural control processes, meanwhile external instructions seem to enable automatic control processes to regulate their movements (Wulf et al, 2001)

From a practical perspective, the results within the study may be of substantial practical importance for athletes that compete in strengthening exercise such as Nordic hamstring exercises. The findings from the study suggest that adopting an external muscle contraction instruction may enhance the muscle activation of the participants which can directly the impact the strengthening of the hamstrings which would reduce the incidence of an injury to occur (Grgic et al, 2020). In addition, the findings of the study highlight the importance of utilising cue standardisation when performing muscular strength exercises (Grgic et al, 2020). If the researcher used different cues during the research this could impact the participants muscle activation and could subsequently change the correct interpretation of the data recorded.

Although, it could be argued the nature of the task could potentially influence the participant’s experiences and preferences (Marchant et al, 2007). Tasks such as weightlifting and eccentric exercises require fewer external instructions compared to alternative exercises such as target based performance and movements of apparatus (Marchant et al, 2007). This can make the comparison between external and internal focuses difficult in these types of settings, and it could be argued internal instructions could be found easier to comply with because of the salience of muscular contractions and exertion (Marchant et al, 2009). Furthermore, it may be useful for practitioners such as coaches and trainers to develop more concise and accurate external instructions to reduce the differences. An example of this could be the use of a metaphor or an analogy to induce an appropriate imagery to manipulate an external focus when the movement of the does not have obvious effects of the environment (Wulf et al, 2007). In addition, it has also been shown in regard to body- related techniques specially adopting external focus instructions can lead to greater learning outcomes and motor performance compared to internal focus (Chua et al, 2021).

During the three conditions there was relatively low levels of mean muscle activation (≤60%, as seen in figure 1) when performing Nordic hamstring exercises, however the findings from this study indicate the semitendinosus was activated significantly more than the bicep femoris when the Nordic Hamstring exercise was performed. The muscle activation for the bicep femoris for all three conditions averaged at 38.2 EMGpk meanwhile the average muscle activation for the semitendinosus was 50.27 EMGpk . Typically, the maximum force generating capacity of the skeletal muscle of the hamstring is dependent on the muscles’ physiological CSA, therefore pennate muscles are usually stronger than fusiform muscles (Lieber et al, 2002). Moreover, the study indicated that the semitendinosus which is a fusiform muscle and built long and thin was more active during Nordic Hamstring exercises than the bicep femoris which is generally a bulkier pennate muscle (Woodley et al, 2005). The results are in agreement with a previous study by Bourne et al, (2015) which analysed different muscle activation patterns in uninjured and injured active men. Although there is a lack of evidence to show the mechanism for the selective recruitment of the semitendinosus when Nordic hamstrings exercises are performed, it could be explained that the differences between hamstring muscle moment arms played a role. When looking at the knee, the semitendinosus has a larger sagittal plane moment arm than the bicep femoris, which suggest the semitendinosus has a greater mechanical advantage which causes a preferential recruitment during the Nordic hamstring exercise at the join (Thelen et al, 2005).

A study undertaken by Ono et al, (2010) revealed preferential recruitment of the semitendinosus was observed when the subjects performed an eccentric exercise utilising a leg curl machine. This suggests when exercises that involve knee movements while the hip joint is in a fixed position is associated to the characteristic of hamstring recruitment. Therefore, these previous studies which is an agreement with the results from this current study, suggest that when the Nordic Hamstring exercise is utilised there is a minimal activation of the bicep femoris compared to the semitendinosus that this exercise may not be an optimal exercise for injuries relating to running injuries.

This exercise can increase muscle activation and strength of the hamstrings (Delahunt et al, 2016; Bourne et al, 2016). Bourne et al (2016) showed when performing Nordic Hamstring exercises it promoted the elongation of the fascicles of the bicep Femoris long head, suggesting if there’s an increase in the bicep Femoris long head for every 0.5cm increase in the fascicle there is a reduction of 74% probability a football player will sustain a hamstring injury (Bourne et al, 2016). These results correlate with a study undertaken by Lovell et al, (2018) which indicated when the participants completed Nordic hamstring exercises over a 12 twelve week period the fascicle length of the bicep Femoris increase by 1.58cm. Based on the two findings, it reveals when the fascicle length is increase it causes an increase in eccentric strength in the hamstring which will lead to a higher level of muscle activation and can result in a significant reduction in hamstring injury.

However, they indicated it did not promote hypertrophy in the bicep Femoris as they found this develops in the semitendinosus. This is in accordance with this present study as it represents that muscle activation levels in the semitendinosus nearly reached almost 60%, meanwhile the bicep Femoris only reached 30% of the eccentric MVIC. In the study undertaken by Delahunt et al, (2016) the results found were similar with the average EMG levels for the semitendinosus were 65% of the eccentric MVIC. Although, when six weeks of Nordic Hamstring training the participants increased the percentage to 80% of the eccentric MVIC (Van Der Tillaar et al, 2017). In this present study some of the participants had experience of performing Nordic Hamstring exercises, whilst others had minimal or no experience with this exercise. Therefore, this may have influenced the muscle activation between the participants within the three conditions during the exercise. However, a study undertaken by Ribeiro – Alvares et al, (2023) found when utilising a four-week NHE training programme for amateur adult footballers there was an increase in their eccentric knee flexor, in addition to an increase in muscle strength. Moreover, this suggest although the players were at an amateur level there has been an increase in muscular strength which decreases the risk of hamstring injury.

During the first phase of the Nordic Hamstring exercise where the movement is controlled, the hamstring muscles are resisting knee extension, in addition to decelerating the downward movement of the trunk (Monajati et al, 2017). Therefore, this causes the hamstring to become highly activated, as well as an eccentric controlled muscle action which peaked at 103.2 ± 7.14 degrees is within the bicep Femoris. Meanwhile the joint angle was 103.66 ± 7.03 degrees when peak muscle activation occurred within the semitendinosus. In addition, when performing the Nordic hamstring exercise, the participants perform the exercise slowly and smoothly against gravity and must have control of their torso while attempting to resist the fall by contracting the muscles, which can explain why the first phase of the Nordic hamstring exercise when the downward motion occurs, muscle activation is at its highest. (Guruhan et al, 2020). This data represents there is no significant difference between the two hamstring muscles as the highest muscle activation occurs approximately at the same knee angle (Ditroilo et al, 2013). One possible mechanism that was suggested by Hegyi et al, (2019) is the hamstring muscle activation is higher when the body is trying to maintain an upper body for a shallow knee angle which supports this study’s results. In addition, it has been suggested the hamstring muscles may generate internal hip extension torque to keep the upper trunk and pelvis straight during the Nordic hamstring exercises (Narouei et al, 2018). By performing Nordic Hamstring exercises at a shallow knee flexion, it could assist performers to perform eccentric exercise in lengthened positions which has been shown to have a positive effect of preventing hamstring injury severity (Askling et al, 2013). Furthermore, the findings of this present study may provide suggestions for a progressive prevention injury programme for the hamstrings. A recent study suggested when utilising a progressive training intervention with a shallow knee flexion it can cause an increase in eccentric strength meaning a lower hamstring injury severity (Presland et al, 2018).

6.2 Strengths, Limitations and Assumptions

A strength of the study was the study used a control group, which enabled an effect of attentional focus had on muscle activation whilst performing Nordic hamstring exercises which made the findings more reliable and valid. Another strength of the study was there was minimal research regarding the effect attentional focus has on muscle activation when eccentric exercises such as Nordic hamstring exercises are utilised. Therefore, this research has given us a greater insight into the relationship between the conditions which can be used for future research.

One limitation of the study was the participants that were recruited where between ages 20-30 meaning it was young sample. Therefore, future research could recruit older participants to observe if there is a difference between the three attentional focus conditions when Nordic hamstring exercises are performed. Another limitation of the study was it used a young male sample size that are the typical recreational footballers and therefore whilst important for this population group to understand the role of attentional focus on movements such as the Nordics and the role of muscle activation it limits the scope of the study and therefore further research would be needed to apply the findings to larger sample populations. In addition to this, the sample size utilised in the study was 12 participants which is a low size. Furthermore, by doing this it could have had an insufficient statistical power as it may minimize the spurious findings meaning the results may not be a true representation of the population.

When analysing the use of the EMG, one limitation was when surface EMG is utilised it can be prone to cross talk from nearby muscles especially between the bicep femoris and semitendinosus (French et al, 2014). In addition, one limitation is when a normalisation was used similar to the one in this study this can affect the results from the hamstring muscles as it’s not entirely clear whether the MVIC flexion can elicit the similar activity for the semitendinosus and the bicep femoris (Rutherford et al, 2010). Moreover, another limitation of the study was many eccentric repetitions of the same muscle in a single session could lead to a significant level of fatigue, which could affect peak torque or the EMG activity that was seen in the results. Therefore, this suggests that the study needs to be verified in an experiment that consists of trained athletes with a high level of NHE strength. When evaluating the EMG activity, it was lower than expected this could be due to hamstring muscle selection as only the bicep femoris and the semitendinosus were used when measuring muscle activation, however the semimembranosus was not utilised meaning the results do not show a true representation of the hamstring muscle activity.

6.3 Further Research

For future research it would be recommended to extend upon the research regarding the potential benefits of utilising the different attentional focus and build upon the body of work assessing both the internal and external foci. Most recent studies have conducted single session designs, therefore long-term benefits for attentional focus could also be explored (Wulf et al, 2007; Christina et al, 2014), this in turn will build upon the application to implement within the applied setting. In addition to this, transfer effects need to be established to determine if attentional focus is beneficial when practicing Nordic hamstring exercises in the laboratory can transfer into real life training as there wasn't an effect when performing in a lab- based setting, again building on the understanding of how the work can translate into the 'real world approach'. This in turn will develop the literature and enhance the understanding of NHE and their benefit to injury prevention programmes.

Moreover, previous research undertaken by Porter et al (2012) consisted of a survey of attentional focus strategies utilised in strength and conditioning settings which provides a unique outlook of current attentional focus practises used. Therefore, additional research could similarly survey what strategies are utilised for lower limb single exercises as this can enable a greater understanding of apparent effects of attentional focus on exercise performance, as well as help increase awareness of using focus cues in similar settings. Moreover, a future direction would be to compare the effect an external focus and internal focus has on NHE, as previous research has suggested when an internal focus is utilised when learning a new skill, it has shown a greater learning effect than an external focus (Schonefield et al, 2016).

When analysing the muscle activity of the hamstring it would be recommended to measure the activity for all 4 biarticular muscles within the muscle as this will show a true representation of muscle activation which may suggest different findings compared to the ones found in this present study.

For future direction it would be recommended that participants that are experienced in Nordic hamstring exercises should be utilised instead of amateur participants as this will reduce the likelihood of a learning effect to occur. Moreover, within this study muscle activation became higher the more the participants performed the exercise which could be argued is because they became more familiar with performing the exercise the more repetitions that were completed.

6.4. Conclusion

For several years there have been many studies that have investigated the effect attentional focus can have on skilled performance. As stated previously studies investigated the effects attentional focus can have on whole body movements such as the standing long jump (Porter et al, 2010) and vertical jumping (Wulf et al, 2007). The results of the previous research revealed that performance under an external focus caused the best measures for the participant compared to the other two conditions. As Nordics are a new exercise modality and with the growing demand to utilise exercises such as this within sporting settings, it is key to explore this novel area further. To the best of our knowledge, this present study is the first to test the effect external focus has compared to an internal focus and neutral for the task of performing Nordic hamstring exercises. However, the results for the effect of the attentional focus conditions were not agreeing with the hypothesis as there were no significant differences seen for peak muscle activity between the three conditions.

In addition, the results of the study reveal when Nordic Hamstring exercise are performed at shallow knee angle causes muscle activation to occur in the hamstrings at high levels and has been shown to be similar in joint angles when peak muscle activation occurred when sprinting (Van der Tillar et al, 2017). Therefore, the results in this present study can partly explain potential methods that can be utilised in future hamstring prevention programmes. However, joint angles at which the Nordic

Hamstring exercise is performed should be studied further before being implemented into future injury prevention programmes.

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