EFFECT OF ADDING MINI-SQUAT EXERCISES AT DIFFERENT ANGLES TO LEG PRESS EXERCISE ON QUADRICEPS AND HAMSTRING STRENGTH AND H:Q RATIO IN ATHLETES

1-3-2025

A Protocol Submitted in Partial Fulfillment of The Requirements
for the Master's Degree in Physical Therapy
for Musculoskeletal Disorders and its Surgery
Faculty of Physical Therapy
Cairo University
2025

CHAPTER I

INTRODUCTION

Football is a demanding sport requiring a combination of explosive strength, speed, and endurance. The nature of the game involves repeated high-intensity actions, such as sprinting, jumping, tackling, and rapid changes in direction, all of which place heavy demands on the lower limbs **(Hammami et al., 2018).** For optimal performance and injury prevention, football players need well-developed neuromuscular coordination and muscle strength, particularly in the quadriceps, hamstrings, and gluteal muscles **(Filho et al., 2023).** These attributes are often developed through structured strength training programs that include both free-weight and machine-based exercises **(Wirth et al., 2023)**.

Closed kinetic chain (CKC) exercises are movements in which the distal segment of the limb remains fixed against a stable surface, causing simultaneous motion at multiple joints and promoting integrated muscle activation **(Pamboris et al., 2024).** This configuration enhances joint stability through co-contraction of agonist and antagonist muscles, facilitates functional movement patterns, and reduces excessive shear forces across joints compared to open kinetic chain (OKC) exercises **(Ahmed at al., 2023**). CKC exercises such as the leg press and squat are widely implemented in both rehabilitation and performance training due to their capacity to strengthen multiple muscle groups, improve neuromuscular coordination, and support functional carryover to daily activities and sport-specific tasks **(Immanuel & Muthukrishnan, 2025).**

Mini squats, characterized by shallow knee flexion angles (typically between 30°–60°), are commonly integrated in rehabilitation and foundational strength programs due to their low mechanical demand on the knee joint and their effectiveness in activating the quadriceps without excessive joint strain

(Kubo et al., 2019). They offer a safer alternative to deeper squats, especially for individuals with mobility restrictions or those returning from injury **(Straub & Powers, 2024).** However, mini squats alone may not provide sufficient mechanical load or range-specific strength adaptations necessary for explosive movements like sprinting and vertical jumping, which are essential in football **(Skratek et al., 2024).**

The leg press exercise complements squat-based training by enabling athletes to apply heavy loads to the lower limbs in a more stable, controlled environment. This allows for targeted muscle activation without overloading the spine or requiring advanced balance and coordination skills. Research has shown that the leg press elicits high quadriceps activation and allows for safe manipulation of joint angles and foot positioning, making it valuable for both strength development and injury prevention **(Wirth et al., 2019).** When used in conjunction with squats, especially mini squats at varying angles, the leg press can provide a more complete stimulus to the muscles involved in key football movements **(Schoenfeld et al., 2017).**

Emerging evidence suggests that combining machine-based and free-weight resistance exercises produces more comprehensive adaptations than either modality alone. For example, **Rossi et al. (2018)** found that a combined squat and leg press training regimen over 10 weeks resulted in improved strength, balance, and vertical jump performance. Additionally, **Ben Brahim et al. (2021)** showed that integrating resisted sprinting and strength training (including squats and leg presses) enhanced both sprint speed and ball-striking power in young elite football players more than soccer training alone. These findings support the idea that a multi-modal training approach targeting various joint angles and loading patterns may better reflect the complex demands of football **(Shuzhen et al., 2025).**

The hamstring-to-quadriceps (H:Q) ratio is an important indicator of knee joint stability, reflecting the balance between knee flexors and extensors. In healthy individuals, a conventional H:Q ratio of about 0.5–0.6 is typical, whereas elite athletes often display higher ratios due to sport-specific adaptations and targeted strength training **(Çelebi et al., 2018).** Sports involving explosive actions, rapid decelerations, and frequent directional changes place high demands on both muscle groups, making balanced strength essential for performance and injury prevention. Regular monitoring and tailored conditioning programs are therefore recommended to enhance performance and reduce injury risks **(Baroni et al., 2020).**

One critical aspect of lower limb strength balance in football players is the (H:Q) ratio, which reflects the relationship between the knee flexor and extensor muscles. A low H:Q ratio, where quadriceps strength disproportionately exceeds that of the hamstrings, has been strongly associated with a higher risk of hamstring strains and non-contact anterior cruciate ligament (ACL) injuries due to reduced dynamic knee joint stability during high-speed movements **(Grygorowicz et al., 2017).**

Statement of problem:

This study will try to answer the following question:

Will adding mini-squat exercises at different angles (30°,45°, and 60°) to leg press exercise influence quadriceps and hamstring strength and H:Q angle in football players?

Purposes of the study:

The purposes of this study are to

1. To investigate the difference between adding knee flexion mini-squat exercise at different angles (30°, 45°, and 60°) to leg press exercise on quadriceps strength in football players.
2. To investigate the difference between adding knee flexion mini-squat exercise at different angles (30°, 45°, and 60°) to leg press exercise on hamstrings strength in football players.
3. To investigate the difference between adding knee flexion mini-squat exercise at different angles (30°, 45°, and 60°) to leg press exercise on the hamstring-to-quadriceps (H:Q) ratio in football players.

Significance of the study:

Football is a high-intensity sport that places repeated stress on the lower limbs, especially the knee joint. Lower limb strength, joint stability, and muscle balance are critical for optimal performance and injury prevention in football players **(Brito et al., 2010).** Among the most common injuries in football are those affecting ACL and hamstring strains, which are often linked to imbalances between the quadriceps and hamstrings, typically assessed using the H:Q ratio **(Croisier et al., 2008).** A low H:Q ratio is associated with poor neuromuscular control and increased injury risk, particularly during sprinting, deceleration, and cutting movements **(Baroni et al., 2020).**

Mini squats and leg press exercises are widely used in sports rehabilitation and conditioning programs to strengthen the lower extremities. Performing mini squats at specific knee flexion angles may help target muscle activation more precisely and improve motor control and joint loading strategies **(Escamilla et al., 2012).** While leg press exercises focus on maximal strength and power, adding mini squats at varying angles may improve joint mechanics, increase proprioception, and support functional training in football athletes. Despite their individual benefits, limited research has examined the combined effect of angle-specific mini squats and leg press exercises on lower limb performance and muscle balance in football players **(Zhao et al., 2023)**.

Recent studies have highlighted the importance of exercise selection and angle specificity in resistance training, showing that different knee angles result in varied activation patterns in the quadriceps and hamstrings. However, current literature offers limited insight into the effects of integrating mini squat exercises with leg press training on injury prevention and functional outcomes in athletic populations. In particular, there is a lack of literature on how such a combined leg press and mini squat exercise at different angles influences the H:Q ratio, lower limb neuromuscular control, and performance in young male football players. Therefore, the present study aims to examine whether incorporating mini squats performed at varying knee flexion angles into a leg press training program can improve muscle balance and lower limb strength in football players. The findings may provide valuable guidance for physiotherapists, coaches, and sports scientists in developing evidence-based, angle-specific exercise protocols tailored to the functional demands of athletes. **(Watanabe et al., 2020).**

Delimitation:

This study will be delimited to the following:

1. Male football players aged between 18–30 years **(Scoz et al., 2021)**.
2. Body Mass Index (BMI) between 18.5 and 24.9 kg/m² **(Walsh et al., 2018 & Sattar& Lean, 2009).**
3. Participants will receive 18 training sessions, conducted three days per week, over six successive weeks

Basic assumptions:

1. Participants understood and followed the given instructions during assessment and treatment procedures.
2. Participants did not receive any additional medical or physical therapy treatment during the study period.

Hypotheses will be:

1. There is no statistically significant difference between adding 30°, 45°, and 60° knee flexion mini-squat exercises to leg press exercise and leg press exercise alone on quadriceps strength in football players.
2. There is no statistically significant difference between adding 30°, 45°, and 60° knee flexion mini-squat exercises to leg press exercise and leg press exercise alone on hamstrings strength in football players.
3. There is no statistically significant difference between adding 30°, 45°, and 60° knee flexion mini-squat exercises to leg press exercise and leg press exercise alone on the hamstrings-to-quadriceps H:Q ratio in football players.

Definitions of terms

Hamstring-to-quadriceps ratio H:Q ratio:

The H-Q ratio refers to the relative strength of the hamstring muscles compared to the quadriceps, typically measured under isokinetic conditions (at the same angular velocity). It is calculated as the maximal concentric knee flexion strength divided by maximal concentric knee extension strength. A conventional ratio of around 0.6 (hamstrings at least 60 % as strong as quadriceps) is commonly regarded as a threshold for reducing injury risk, particularly to the ACL **(Grygorowicz et al., 2017).**

Leg press exercise:

The leg press is a closed kinetic-chain, compound weight-training exercise in which the individual pushes a weighted platform or sled away from the body using the legs, typically seated or reclined. It targets the quadriceps primarily, with secondary involvement of the hamstrings, gluteus maximus, and calves, and is frequently used in athletic training and rehabilitation due to its controlled motion and safety features **(Da Silva et al., 2008).**

Mini squat exercise:

A mini-squat is a partial squat movement performed in a standing position, where the knees and hips are flexed to approximately 45°–60°, significantly less than in a full-depth squat. The movement is executed by bending the knees as if sitting into a chair and then extending back up, often performed with hands supported for balance. Mini-squats are used to strengthen the quadriceps and gluteal muscles and to enhance functional movement such as sit-to-stand or stair-climbing, while minimizing stress on the joints **(Escamilla, 2001).** Some authors, however, consider mini-squats to begin from 15-20° of knee flexion, typically ranging between 30° and 60° **(Daşkapan et al., 2013)**.

CHAPTER II

LITREATURE REVIEW

The review of related literature will cover the following topics: (1) Anatomy of the quadriceps muscle, (2) Anatomy of the hamstrings muscle, (3) Strength training in athletes, (4) Biomechanics of squat exercises, (5) Effect of mini squats on quadriceps strength, (6) Effect of mini squats on hamstring strength, (7) Effect of mini squats on H:Q ratio, (8) Leg press exercise: purpose and muscle activation, (9) Effect of leg press exercise on quadriceps strength, (10) Effect of leg press exercise on hamstring strength,(11) Effect of leg press exercise on the H:Q ratio, and(12)Assessment of muscle strength and H:Q ratio

1-**Anatomy of quadriceps muscle:**

The quadriceps femoris is the primary extensor of the knee joint and one of the most powerful muscle groups in the human body. It is composed of four muscles: rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius, all of which converge into the quadriceps tendon that inserts into the patella and continues as the patellar ligament to the tibial tuberosity **(Standring, 2016)**. Among these muscles, the rectus femoris is unique as it spans both the hip and knee joints, enabling it to contribute to hip flexion in addition to knee extension, while the vasti muscles function primarily in knee extension **(Moore et al, 2018)** (figure 1).

The origins of these muscles vary, with the rectus femoris arising from the anterior inferior iliac spine, the vastus lateralis from the greater trochanter and linea aspera, the vastus medialis from the medial linea aspera and intertrochanteric line, and the vastus intermedius from the anterior and lateral surfaces of the femoral shaft **(Standring, 2016)**. Together, these muscles form a layered tendon complex that allows for the efficient transfer of force during knee extension. Recent anatomical studies have described the presence of an additional slip, the tensor vastus intermedius, which contributes to the structural complexity of the quadriceps tendon **(Grob et al, 2016)**.

Functionally, the quadriceps plays a vital role in locomotion and daily activities such as rising from a chair, climbing stairs, running, and jumping **(Herzog, 2017)**. Within the group, the vastus medialis obliquus (VMO) is particularly important for stabilizing the patella during movement and preventing lateral displacement, thereby reducing the risk of patellofemoral pain syndrome **(Powers, 2010)**. Innervation of the quadriceps arises from the femoral nerve (L2–L4), while its vascular supply is derived from branches of the femoral artery and the lateral circumflex femoral artery **(Moore et al., 2018)**.

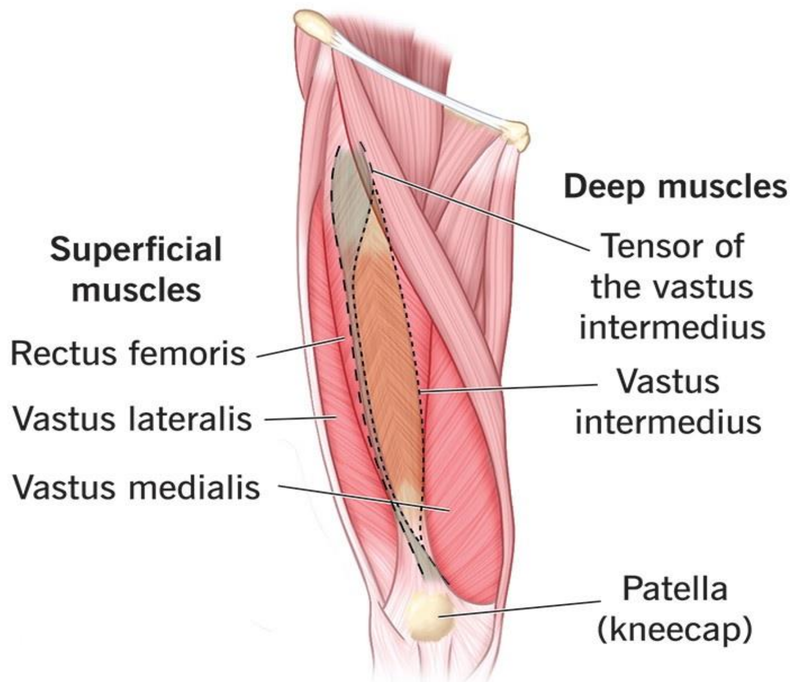

Fig 1: Anatomy of quadriceps muscle (adopted from Senghas, 1990).

2-Anatomy of hamstrings muscle:

The hamstring muscles are located in the posterior compartment of the thigh and consist of the biceps femoris (long and short heads), semitendinosus, and semimembranosus. These muscles share a common origin at the ischial tuberosity, except for the short head of the biceps femoris, which originates from the femoral shaft. They extend distally to insert on the tibia and fibula: the semitendinosus inserts on the medial tibia, the semimembranosus inserts on the medial tibial condyle, and the biceps femoris attaches to the head of the fibula **(Standring, 2016; Moore et al., 2018)** (figure 2).

Functionally, the hamstrings act as powerful hip extensors and knee flexors. During gait, they play an essential role in decelerating knee extension at the end of the swing phase and contribute to hip extension during stance, making them critical for sprinting and explosive activities **(Schache et al., 2012)**. Their biarticular nature, spanning both the hip and knee joints, increases their susceptibility to injury, particularly under eccentric loading conditions such as high-speed running **(Askling et al., 2007)**.

The hamstrings are innervated by the sciatic nerve, with the tibial division supplying all except the short head of the biceps femoris, which is innervated by the common fibular division **(Moore et al., 2018)**. Their blood supply is derived mainly from perforating branches of the profunda femoris artery, with additional contributions from the inferior gluteal artery **(Standring, 2016)**.

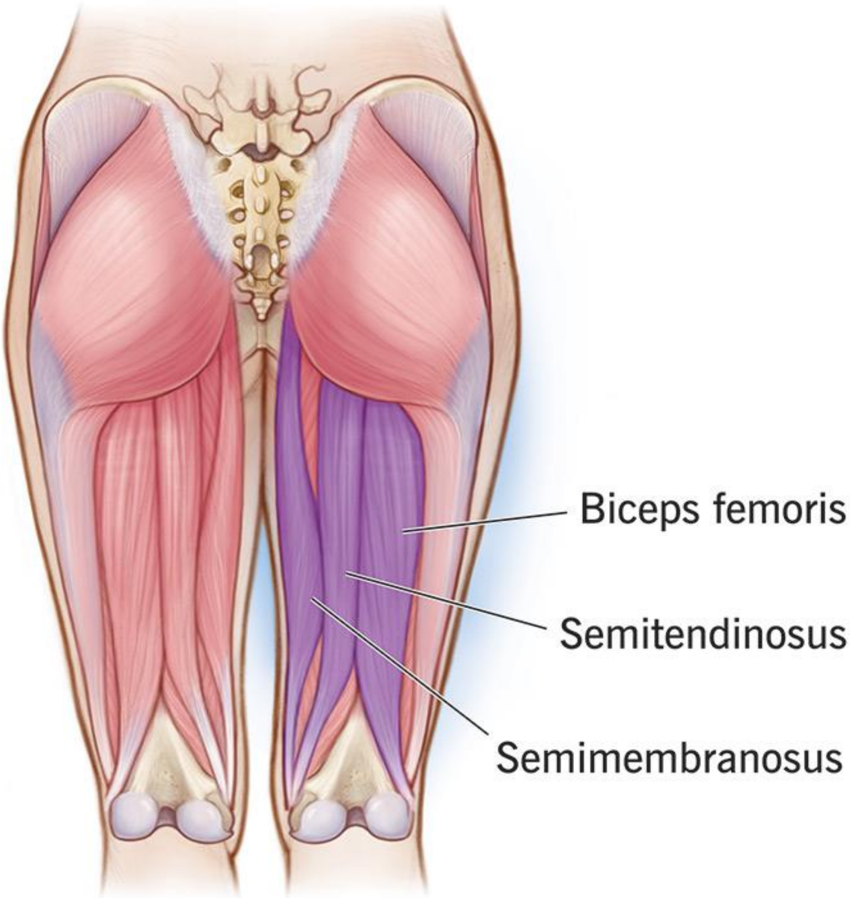

Fig 2: Anatomy of hamstrings muscle (adopted from Senghas, 1990).

3-Strength Training in Athletes:

Strength training is a fundamental component of athletic conditioning, particularly for sports that require explosive power, speed, and agility, such as football. Football involves rapid acceleration, deceleration, jumping, cutting, and high-impact collisions, all of which demand optimal muscular strength and neuromuscular coordination **(Comfort et al., 2014).** Strength training improves the functional capacity of athletes by enhancing force production, neuromuscular efficiency, and joint stability key factors for high-level performance in football **(Suchomel et al., 2016).**

Research indicates that well-structured resistance training programs can significantly increase sprinting speed, vertical jump height, and change of direction ability in football players **(Turner et al., 2014).** These improvements are attributed to enhanced muscle cross-sectional area, increased motor unit recruitment, and improved rate of force development (RFD). Moreover, strength training enhances the robustness of movement patterns, allowing athletes to generate force more efficiently and reduce energy expenditure during match-play activities **(Cormie et al., 2011).**

The lower extremities, particularly the hamstrings, quadriceps, and gluteal muscles, are prone to both strength imbalances and overuse injuries in football players. One of the most commonly observed deficits is the (H:Q) strength ratio imbalance. An insufficient H:Q ratio may predispose athletes to hamstring strains and ACL injuries due to reduced dynamic knee stability **(Croisier, 2004).** Additionally, repeated eccentric loading of the lower limb muscles, especially during sprinting and deceleration, increases the risk of muscle damage if not properly conditioned through strength training **(Schache et al., 2012).**

Knee valgus, patellofemoral pain, and Achilles tendinopathy are also frequently reported among athletes with poor muscular strength or control in the lower extremities **(Myer et al., 2008).** Strength training, particularly exercises targeting the posterior chain and hip abductors, has been shown to correct biomechanical deficiencies and lower the incidence of non-contact injuries **(Zebis et al., 2009).**

Resistance training provides a broad spectrum of physiological and performance-related benefits for athletes. From a muscular perspective, it promotes hypertrophy, enhances tendon stiffness, and strengthens connective tissues all crucial for absorbing high forces during dynamic sports movements It also improves joint proprioception and stability, contributing to better coordination and control under competitive conditions. **(Wirth, Hartmann, Mickel, Szilvas, & Keiner, 2016).**

Functionally, resistance training improves maximal strength, explosive power, muscular endurance, and resilience to fatigue, making it indispensable for both elite and amateur football players **(Kraemer & Ratamess, 2004)**. It further enables athletes to tolerate higher training volumes and intensities, thereby accelerating performance adaptations and supporting long-term athletic development **(Suchomel et al., 2016).**

Importantly, targeted resistance exercises such as squats, lunges, and leg press specifically develop the prime movers of the hip, knee, and ankle joints. These movements simulate key phases of sprinting, kicking, and tackling in football, making them not only preventive but also highly specific to the demands of the sport **(Del Monte et al, 2020).**

4- Biomechanics of Squat Exercises:

Squats are typically classified based on the depth of descent, which is defined by the angle at the knee joint and the position of the hip relative to the knee. A mini squat (also called a quarter squat) involves knee flexion of approximately 40°–50°, while a parallel squat reaches around 90° of knee flexion, and a deep squat exceeds 110°–130°, often going until the thighs are below parallel to the floor Each variation targets specific muscle groups to different extents and places varying levels of mechanical stress on joints and tissues. **(Caterisano et al., 2002).**

Mini squats are often used in early rehabilitation phases and for athletes with limited mobility or knee issues, as they minimize compressive forces on the patellofemoral joint and reduce anterior shear at the knee. In contrast, deep squats recruit a larger range of motion and activate a greater portion of musculature, but they also increase joint loading, particularly at the hips and knees **(Hartmann et al., 2013).**

Squat exercises primarily engage the quadriceps femoris, hamstrings, gluteus maximus, and adductor magnus, along with stabilizing contributions from the erector spinae, core musculature, and calves. The level of activation for each muscle group is strongly influenced by squat depth, foot positioning, trunk angle, and external load placement **(Escamilla, 2001).**

In general, quadriceps activation is highest during the concentric (ascending) phase of the squat and increases as knee flexion deepens. The gluteus maximus becomes more active at greater hip flexion angles, especially during deep squats, contributing significantly to hip extension in the upward phase **(Schoenfeld, 2010).** Although the hamstrings are not primary movers in squats, they act synergistically with the glutes to stabilize the hip and counter anterior tibial translation, especially in posterior chain–focused squat variants like box squats **(Yavuz et al., 2015).**

The adductor magnus also plays a key role during squatting, particularly in deep squats, by assisting in hip extension and providing frontal plane stability. The erector spinae and core muscles (e.g., rectus abdominis and obliques) contribute to spinal stiffness and postural control, especially when heavier loads are applied **(McKean et al., 2010).**

The depth of the squat significantly alters the distribution of forces and muscle recruitment patterns. As squat depth increases, so does the range of motion at the hip and knee joints, which in turn results in greater activation of the posterior chain. Research using surface electromyography (EMG) has consistently shown that deeper squats result in higher activation of the gluteus maximus and adductor magnus compared to shallow squats **(Bryanton et al., 2012).**

Deeper squats also lead to higher compressive and shear forces at the knee, particularly on the patellofemoral and tibiofemoral joints. However, these forces remain within tolerable physiological limits for healthy individuals and are offset by the increased activation of stabilizing muscles at shallower angles (mini squats), quadriceps activation dominates, while gluteal and hamstring contributions are relatively lower. This makes mini squats more quadriceps-focused and less functional for activities requiring powerful hip extension. **(Schoenfeld, 2010).**

Furthermore, joint angle affects length-tension relationships, which influence force output. At deeper angles, muscles operate closer to their optimal length for force production, particularly the glutes and adductors. The use of different squat depths can therefore be strategically programmed to emphasize specific performance outcomes or to manage loading during rehabilitation phases **(Hartmann et al., 2013).**

Importantly, joint angle and depth also have a direct influence on the torque demands placed on the knee and hip joints. As knee flexion increases, the external moment arm acting on the knee becomes longer, thereby increasing torque requirements for the quadriceps. Simultaneously, the hip extensors must generate more force to overcome the increased hip flexion, especially in athletes performing squats with a forward lean or deeper descent **(Swinton et al., 2012).**

5-Effect of Mini Squats on Quadriceps Strength:

Mini squats, typically performed between 0°–60° of knee flexion, are widely recognized for their effectiveness in strengthening the quadriceps while minimizing stress on the knee joint structures. This partial range of motion specifically engages the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius, with greater activation of the vastus medialis oblique (VMO), which plays a crucial role in patellar stabilization and knee extension mechanics **(Escamilla et al., 2012).**

The reduced depth of the squat makes it a safer option for athletes recovering from injury, as it reduces compressive and shear forces across the tibiofemoral and patellofemoral joints compared to deep squats **(Caterisano et al., 2002).** Furthermore, progressive training with mini squats has been shown to significantly enhance quadriceps torque and functional performance in both healthy and injured populations, making it a valuable addition to rehabilitation and athletic conditioning programs **(Earl & Hoch, 2011; Isear et al., 1997).**

6-Effect of Mini Squats on Hamstring Strength:

While squats are primarily quadriceps-dominant, mini squats also recruit the hamstring muscles, albeit to a lesser extent compared to exercises involving deeper knee flexion or hip extension **(Caterisano et al., 2002).** The hamstrings function as stabilizers during the squatting motion by controlling anterior tibial translation and assisting in hip extension **(Escamilla et al., 2001).**

Electromyographic studies indicate that hamstring activation increases with the load and the degree of knee flexion; however, even in partial squats, the hamstrings remain active to provide dynamic stabilization, particularly when maintaining proper trunk posture **(Schoenfeld, 2010).** Strengthening the hamstrings through mini squats may not be as pronounced as through exercises such as Romanian deadlifts or Nordic hamstring curls, but their role in co-activation during squatting tasks is vital for balanced knee mechanics and reducing injury risk in athletes **(Ebben et al., 2009).**

7-Effect of Mini Squats on H:Q Ratio:

The hamstring-to-quadriceps ratio (H: Q) is a critical indicator of knee joint stability, particularly in athletic populations where knee injuries, such as ACL tears, are common **(Croisier et al., 2008).** Mini squats, by simultaneously engaging both quadriceps and hamstrings, contribute to improving neuromuscular balance around the knee. Although mini squats are more quadriceps-dominant, the co-activation of hamstrings during the exercise enhances the functional stability of the joint, supporting a healthier H:Q ratio **(Aagaard et al., 1998).**

Studies have suggested that athletes with low H:Q ratios are at greater risk of non-contact ACL injuries, and integrating closed-chain exercises like mini squats into training can reduce such risks by promoting balanced muscular adaptation **(Hewett et al., 2005).** Additionally, combining mini squats with other hamstring-dominant exercises has been shown to optimize the H:Q ratio, thereby improving both performance and injury prevention outcomes in sports settings **(Coombs & Garbutt, 2002; Myer et al., 2008).**

8- Leg Press Exercise: Purpose and Muscle Activation:

The leg press is a closed kinetic chain resistance exercise primarily designed to develop lower limb strength through a controlled movement pattern. It typically involves pushing a platform upward or outward with the feet while the back remains supported against a padded seat or backrest. Unlike the squat, which requires the body to move around the barbell in free space, the leg press constrains the path of movement to a fixed trajectory. The two most common types are the 45-degree incline leg press and the horizontal leg press, both of which allow for a relatively high external load with reduced axial compression on the spine **(Escamilla et al., 2001).**

During the leg press, force is generated primarily in the sagittal plane, involving hip and knee extension and ankle plantarflexion. The movement begins with the knees flexed and the feet positioned shoulder-width apart on the platform. As the platform is pushed away, the knees and hips extend simultaneously, mimicking a squatting-type motion. The joint angles, foot placement, and seat inclination all influence the mechanical demand placed on different lower limb muscles Unlike the squat, the leg press significantly reduces the balance and stabilization requirements, making it a safer and more accessible option for individuals with limited motor control or during early rehabilitation. **(Martínet al., 2020).**

The leg press primarily activates the quadriceps femoris group, including the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. It also recruits the gluteus maximus, hamstrings (particularly the biceps femoris and semitendinosus), and gastrocnemius and soleus muscles at the ankle joint **(Da Silva et al., 2008).**

The leg press exercise elicits varying patterns of muscle activation depending on load, depth, and foot positioning, making it a versatile lower limb strengthening tool. During the knee extension phase, the quadriceps muscles—particularly the vastus lateralis and vastus medialis demonstrate the highest electromyographic (EMG) activity, especially under heavier loads or when the knees are in greater degrees of flexion **(Escamilla et al., 2001).** As the movement approaches full knee extension, quadriceps engagement peaks, ensuring efficient force production. The gluteus maximus becomes progressively more involved as hip flexion increases, a pattern often accentuated when the feet are positioned higher on the platform. This upward placement shifts the mechanical load proximally, encouraging greater hip extensor involvement Although the hamstrings are not primary movers in the leg press compared to hip-dominant exercises, they contribute to hip extension and co-contract with the quadriceps, thereby enhancing knee joint stability throughout the push phase. **(Paoli et al., 2009).**

Additionally, calf muscles such as the gastrocnemius and soleus play a supportive role, especially during the terminal phase of the movement. When the toes exert pressure against the platform, these muscles facilitate ankle plantarflexion, contributing to full lower limb extension. The muscle recruitment pattern is highly dependent on foot placement: a higher foot position increases gluteal and hamstring activation, a lower placement emphasizes the quadriceps, while a wider stance preferentially recruits the adductor magnus This adjustability allows the leg press to be tailored to specific muscular targets or to accommodate athletes with limited joint range of motion, making it particularly useful in rehabilitation and performance conditioning programs. **(Escamilla et al., 2001; Paoli et al., 2009).**

The leg press and the squat both target similar muscle groups and movement patterns, yet they differ considerably in terms of biomechanical loading, neuromuscular activation, and risk profile. The leg press allows for greater external loads due to the fixed machine path and reduced stability requirements. However, higher loads on the leg press do not always equate to greater functional strength because the body's stabilizers are underutilized compared to free-weight squats **(Wirth et al., 2016).**

The leg press exercise typically allows for greater peak force output compared to the squat, largely due to the external support provided by the machine, which minimizes the requirement for postural stabilization **(Hoffman et al., 2009).** In contrast, squatting involves axial loading of the spine and requires substantial activation of the core musculature and spinal erectors to maintain balance and proper alignment throughout the movement **(McBride et al., 1999).** Force plate analyses and electromyographic (EMG) studies suggest that although the leg press elicits higher quadriceps activation especially under heavy loads—the squat offers a more holistic recruitment pattern involving the gluteus maximus, hamstrings, and trunk stabilizers This comprehensive activation pattern enhances neuromuscular efficiency and full-body strength, which are key components in athletic performance. **(Escamilla, 2001).**

From a biomechanical perspective, the leg press imposes significantly less axial compression on the spine compared to the squat, making it a preferred choice for individuals with spinal limitations or during rehabilitation phases **(Callaghan & McGill, 2001).** However, improper form during deep leg press particularly excessive knee flexion combined with posterior pelvic tilt can increase shear forces on both the lumbar spine and the posterior structures of the knee joint. These risks underscore the importance of maintaining neutral spine alignment and controlled depth when executing the leg press. Conversely, when squats are performed with proper technique and load management, they offer a more functional distribution of joint forces. Squats facilitate full kinetic chain involvement, promoting joint stabilization and alignment through dynamic control **(Escamilla, 2001).**

In terms of functional carryover to athletic activities, squats are superior due to their demand on dynamic stability, proprioception, and postural control. These qualities are critical for sport-specific tasks such as sprinting, jumping, and rapid changes in direction particularly in football where multidirectional agility and explosive power are essential **(Thomas et al., 2009).** On the other hand, the leg press provides value in isolating specific muscle groups and enhancing maximal force capacity, particularly at targeted joint angles. It is especially effective during early phases of strength training or when addressing unilateral or muscular imbalances **(Paoli et al., 2009).**

9-The effect of Leg Press Exercise on Quadriceps Strength:

The leg press exercise is one of the most widely utilized resistance training movements for targeting the quadriceps due to its ability to isolate and load the knee extensors in a controlled, closed-kinetic-chain position. By allowing the individual to push against a fixed platform, the exercise emphasizes knee extension torque while minimizing balance demands, making it effective for both rehabilitation and performance enhancement **(Escamilla et al., 2001).**

During the concentric phase, the quadriceps are primarily activated to extend the knee, while the eccentric phase requires them to control the descent of the load. Repeated performance of the leg press leads to hypertrophy and increased maximal voluntary contraction of the quadriceps, which contributes to enhanced lower-limb strength and improved functional performance in athletes **(Schoenfeld, 2010).** Furthermore, the closed-chain nature of the exercise has been shown to replicate functional movement patterns more closely than open-chain exercises, thereby offering benefits in terms of sports specificity and joint stability **(Pincivero et al., 2004).**

10-The effect of Leg Press Exercise on Hamstring Strength:

Although the leg press is often regarded as a quadriceps-dominant exercise, the hamstrings play a supportive role during execution. They are primarily engaged during hip extension and act synergistically with the gluteal muscles to stabilize the pelvis and assist in the upward phase of the movement **(Wright et al., 1999).**

Electromyographic (EMG) studies have demonstrated moderate activation of the hamstrings during leg press performance, especially at deeper knee flexion angles, where greater hip extension demand is imposed **(Escamilla et al., 1998).** While the hamstrings are not the primary movers, regular performance of the leg press can indirectly improve hamstring strength through stabilization and co-contraction with the quadriceps, which is important for injury prevention and overall muscular balance **(Solomonow et al., 1987).** However, compared to direct hamstring exercises such as Romanian deadlifts or leg curls, the hypertrophic and strength gains in the hamstrings from leg press alone remain relatively limited (Ebben et al., 2009).

11-The effect of Leg Press Exercises on H: Q Ratio:

The leg press is a closed kinetic chain exercise that predominantly targets the quadriceps due to the knee extension component of the movement. As a result, long-term exclusive reliance on the leg press may disproportionately increase quadriceps strength compared to the hamstrings, leading to a reduced H:Q ratio and elevating the risk of knee injuries, particularly ACL tears and patellofemoral pain. A reduced H:Q ratio reflects insufficient hamstring strength to counterbalance quadriceps dominance, which compromises knee joint stability during high-demand activities such as sprinting, cutting, or jumping **(Croisier et al., 2008).**

However, research indicates that the contribution of hamstrings during the leg press varies depending on technique and joint positioning. For example, performing the leg press with greater hip flexion angles or deeper ranges of motion increases posterior chain recruitment, allowing the hamstrings and gluteal muscles to contribute more effectively. Additionally, tempo variations, unilateral leg press, and eccentric-focused training have been suggested to enhance co-activation of the hamstrings, thereby helping maintain a healthier H:Q ratio **(Jaric, 2002).**

To optimize muscle balance, leg press training should not be performed in isolation but rather integrated with targeted hamstring-dominant exercises such as Nordic hamstring curls, Romanian deadlifts, or stability ball leg curls. Combining these exercises ensures proportional development between the knee extensors and flexors, preserving an optimal H:Q ratio and reducing the likelihood of muscular imbalances and knee-related pathologies **(Alonso-Cortés et al., 2022; Aagaard et al., 1998).**

12-Assessment of muscle strength, H:Q ratio, and ROM:

- **Assessment of muscles strength:**

Manual Muscle Testing (MMT) represents the most basic method for evaluating quadriceps and hamstring strength, relying on the examiner's subjective judgment of resistance to applied force. Although widely implemented in clinical settings due to its simplicity and cost-effectiveness, MMT demonstrates limited validity and reliability, particularly for detecting subtle strength deficits or in individuals with high levels of muscular strength **(Cuthbert & Goodheart, 2007).**

Handheld dynamometry (HHD) provides a more objective alternative by quantifying force output of the knee extensors and flexors. Reported reliability values for HHD are generally strong, with intraclass correlation coefficients (ICCs) ranging from 0.76 to 0.96 for both quadriceps and hamstrings **(Thorborg et al., 2013).** Nonetheless, outcomes are influenced by examiner strength, stabilization strategies, and patient positioning, which reduce its consistency compared with isokinetic assessment, particularly in athletic populations **(Mentiplay et al., 2015).**

Isokinetic dynamometry, most commonly performed using systems such as the Biodex, is considered the gold standard for assessing quadriceps and hamstring performance. It provides dynamic, objective, and reproducible measures of torque during concentric and eccentric contractions under controlled angular velocities **(Drouin et al., 2004).** In addition to peak torque, this method yields further performance parameters including total work, power, and fatigue index that offer a comprehensive understanding of muscular capacity **(Impellizzeri & Marcora, 2009).**

A distinct advantage of isokinetic dynamometry lies in its ability to assess the H:Q ratio. The conventional H:Q ratio is defined as the relationship between concentric hamstring and concentric quadriceps peak torque, whereas the functional H:Q ratio compares eccentric hamstring to concentric quadriceps torque **(Aagaard et al., 1998).** These indices are valuable for evaluating muscular balance across the knee joint, informing injury risk assessment, rehabilitation progress, and return-to-sport readiness **(Coombs & Garbutt, 2002).**

The validity of isokinetic dynamometry is well established. Torque is measured directly via the device's lever arm at predefined angular velocities, demonstrating strong criterion validity in comparison with other strength assessment methods. Furthermore, the ability to isolate joint movements and regulate contraction speed enhances construct validity, making it particularly suitable for both clinical practice and research applications **(Feiring et al., 1990).**

Reliability has been consistently confirmed across studies. Test–retest reliability of isokinetic quadriceps and hamstring strength has shown excellent results, with ICCs ranging from 0.85 to 0.99 depending on contraction mode and angular velocity **(Maffiuletti et al., 2007; Impellizzeri & Marcora, 2009**). H:Q ratio measurements similarly demonstrate strong reproducibility, with ICCs typically reported between 0.82 and 0.95 **(Ayala et al., 2012).** The standard error of measurement (SEM) for peak torque generally falls between 5–8%, indicating minimal variability due to measurement error **(Dirnberger et al., 2012).** Moreover, Biodex dynamometers have demonstrated high inter-device reliability, ensuring consistent outcomes across different testing sites **(Feiring et al., 1990).**

- **Assessment of range of motion ROM:**

Range of motion (ROM) assessment of the knee joint is commonly performed using different clinical and laboratory-based tools, with the goniometer being the most widely applied method in both research and clinical practice. The universal goniometer is inexpensive, portable, and easy to use, making it a gold standard in routine physiotherapy assessments. Previous studies have shown that the universal goniometer demonstrates excellent intra-rater reliability, with intraclass correlation coefficients (ICC) ranging from 0.90 to 0.99 for knee flexion and extension **(Brosseau et al., 2001).** Inter-rater reliability has also been reported as high, with ICC values between 0.85 and 0.95, depending on examiner experience **(Gogia et al., 1987).** Its validity in comparison to radiographic measurements has been established, showing strong correlations (r = 0.93–0.97) between goniometric and radiographic values for knee joint angles **(Sadeghi et al., 2015).**

Digital inclinometers and smartphone-based goniometric applications have been introduced as alternatives. Digital inclinometers have demonstrated excellent intra-rater reliability (ICC = 0.97) and inter-rater reliability (ICC = 0.94) for knee flexion measurements, with validity coefficients up to r = 0.96 compared to radiographic standards (**Kolber & Hanney, 2012).** Smartphone-based applications have also shown promising results, with studies reporting ICC values of 0.85–0.95 for knee ROM compared to the universal goniometer. These emerging tools provide greater accessibility, although they remain complementary rather than replacements for traditional goniometry in clinical trials **(Ockendon & Gilbert, 2012).**

Radiographic imaging and 3D motion analysis systems are considered reference standards for ROM assessment, particularly in research contexts. Radiographic assessment demonstrates nearly perfect validity, as it directly visualizes joint angles; however, its practicality is limited by cost and radiation exposure. Three-dimensional motion capture systems, though resource-intensive, have been reported to achieve validity coefficients above 0.95 compared to radiographic assessment, and inter-rater reliability exceeding 0.90 for dynamic knee ROM. Despite these advances, goniometry remains the most practical and reliable method in routine clinical and sports settings due to its balance between validity, reliability, and accessibility **(Windolf et al., 2008).**

CHAPTER III

SUBJECTS, MATERIALS AND METHODS

The current study aims to investigate whether incorporating mini squat exercises at different knee flexion angles into a leg press training program enhances hamstring- quadriceps ratio H:Q ratio in football players.

Design of the study:

This study will follow a randomized controlled trial (RCT) design.

Study setting

The study will be conducted at the outpatient physical therapy clinic of Jazan University Hospital, kingdom of Saudi Arbia.

Sample size:

The sample size for this study was determined using G*Power version 3.1.9 (Heinrich-Heine-University, Düsseldorf, Germany). An a priori power analysis was conducted for a repeated measures MANOVA with between-subject factors, setting the alpha level (α) at 0.05, desired power ($1 - \beta$) at 0.80, Pillai's trace (V) at 0.1989, and effect size $f^2(V)$ at 0.2877, targeting isometric muscle strength across four independent groups. The analysis indicated a minimum required sample size of 48 participants, allocating 12 per group. To compensate for possible dropouts, the total sample was increased to 60 participants, with 15 individuals per group **(Wirth et al., 2016)** (figure 3).

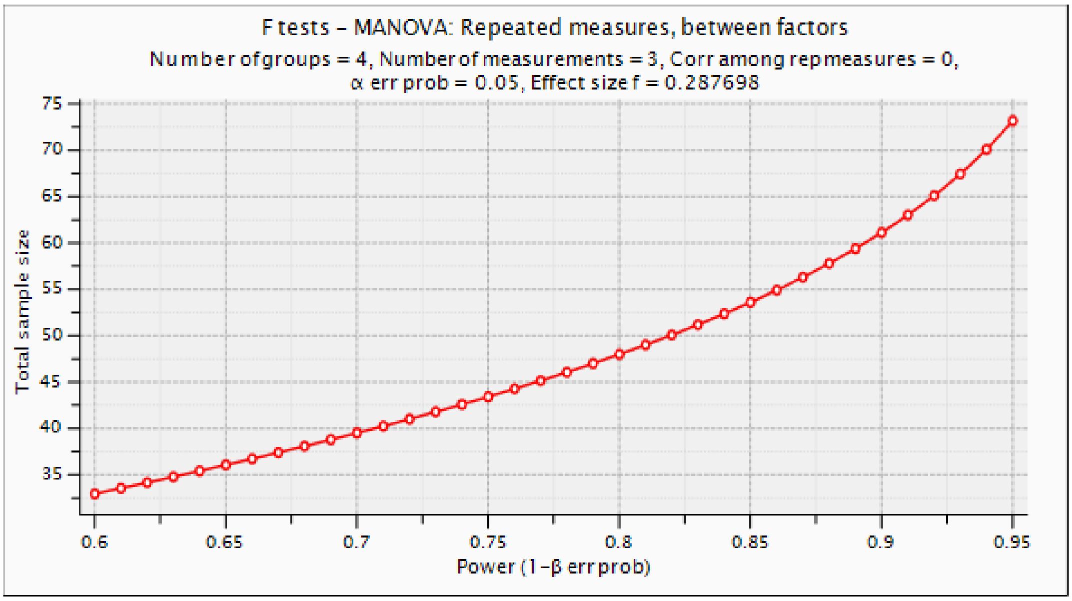

***Fig 3*:sample size calculation using G power**

Randomization, allocation concealment, and blinding

The enrolled participants will be randomized in a simple randomization way using (www.randomizer.org/links/) by another participant not involved in the data collection. Allocation concealment will be ascertained using sealed, opaque, sequentially numbered envelopes. The participants will be blinded to the assigned intervention group.

Participants

Sixty male football players from Al-Ahli and Al-Ittihad football clubs in the Kingdom of Saudi Arabia. Participants will be asked to sign a written informed consent that includes participation in the experimental trial, permission to use data and/or pictures, and informing them of their right to withdraw at any time **(Appendix I).**

Participants will be randomized into 4 equal groups: an experimental group (A, B, and C), and a Control group (D).

Experimental groups (A, B, and C)

Group A: Fifteen participants will receive mini-squat exercises at 30° knee flexion and leg press exercises

Group B: Fifteen participants will receive mini-squat exercises at 45° knee flexion and leg press exercises

Group C: Fifteen participants will receive mini-squat exercises at 60°and leg press exercises

Control group D: Fifteen participants will receive leg press exercise program only.

Inclusion criteria:

Participants having the following criteria will be included in the study:

1. Male football players aged between 18–30 years **(Scoz et al., 2021)**.
2. Body Mass Index (BMI) between 18.5 and 24.9 kg/m² **(Walsh et al., 2018 & Sattar& Lean, 2009).**
3. Currently training or playing with a registered football club/team.
4. Hamstring-to-Quadriceps (HQ) strength ratio of ≥ 0.6 **(Çelebi et al., 2018)**.
5. Having no oral or injectable non-steroidal anti-inflammatory drugs (NSAID), 2weeks before starting study.
6. Having no oral injectable corticosteroids 3 months before starting the study.

Exclusion criteria:

Participants having any of the following criteria will be excluded from the study:

1. History of acute or chronic injury to the knee, hip, or ankle joint
2. Undergoing any other rehabilitation or physical therapy programs during the six weeks before starting the study
3. Diagnosed with neurological or systemic disorders affecting muscle function or balance

4. Participation in competitive sports or high-intensity training outside the study protocol during the study period
5. Presence of any contraindication to exercise, such as uncontrolled hypertension or heart conditions.
6. Clinically free from lower limb injuries.
7. Having no history of neurological, cardiovascular, or musculoskeletal disorders.

Instrumentation:

a. Isokinetic dynamometry:

Isokinetic dynamometry (**Biodex System 4 Pro)** is considered the gold standard for assessing muscle strength and HQ ratios, offering valid and reliable measurements through controlled torque assessment during concentric and eccentric contractions. Its criterion validity is well established, and reliability is consistently high, with ICCs ranging from 0.85 to 0.99. Furthermore, its ability to calculate both conventional and functional H:Q ratios provide a reproducible measure of knee muscle balance, making it highly valuable for evaluating injury risk, rehabilitation outcomes, and return-to-sport readiness **(Ayala et al., 2012)** **(**figure 4).

Fig 4**: Isokinetic dynamometry device (Biodex System 4 Pro, Biodex Medical Systems, Inc., Shirley, NY, USA) (adopted from Sinacore et al. 2017).**

b. leg press machine (FL1801 Isolateral Leg Press):

Fig 5: Leg press machine (FL1801 Isolateral Leg Press, BodyKore Inc., Garden Grove, CA, USA) (adopted from BodyKore Inc., 2025).

c. Goniometer (Jamar Plus+ Digital 8):

Digital goniometers provide more precise joint range of motion (ROM) measurements than traditional goniometers by offering direct electronic readouts, reducing examiner error. They have demonstrated excellent reliability and validity, with intra-rater ICC values up to 0.96 for knee flexion and 0.92 for extension, and inter-rater ICCs ranging from 0.88 to 0.94. These results highlight their accuracy and reproducibility, making them particularly useful in research and advanced clinical practice **(Kolber & Hanney, 2012)** (figure 6).

Fig 6: Goniometer (Jamar Plus+ Digital 8” Goniometer, China) (adopted from Jeon et al., 2024).

Assessment procedures:

Participants will be interviewed, and they will be checked for eligibility according to pre-mentioned inclusion criteria. Participants who will be eligible for the study will sign a written consent form, and demographic data regarding height, weight, and BMI will be calculated and recorded. The pretest will be performed 3 days after a familiarization test, which included the same tests in the same order. The same tests will be carried out again 3 days after the last training session.

The assessment procedure will include the following:

1-Measurenent of quadriceps strength:

- The participant will be seated on the isokinetic dynamometer chair, with proper posture and alignment ensured.
- The chest, pelvis, thigh, and ankle will be stabilized using adjustable straps to minimize compensatory movements.
- The lateral femoral epicondyle (the anatomical axis of the knee joint) will be aligned with the mechanical axis of the dynamometer arm.
- The lever arm of the dynamometer will be securely attached to the participant’s lower leg, just above the ankle, using a padded cuff.

- Test Parameter Settings will be:
  - Mode: Concentric contraction.
  - Velocity: Commonly set at 60°/s for maximal strength.
  - The range of motion (ROM): between 90°knee flexion to full knee extension.
  - Repetitions: 3–5 maximal repetitions.
- The participant will be allowed to perform a submaximal warm-up trial to become familiar with the movement and resistance.
- The participant will be instructed to perform maximal knee extension against the resistance of the device, moving from a flexed to an extended position.
- The test will be conducted unilaterally, assessing one leg at a time.
- The participant will be encouraged to exert maximal effort during each repetition.
- The isokinetic device will record key outcome measures including peak torque (Nm), average power, and total work for each repetition. These values will be used to quantify quadriceps strength (figure 7).

2- Measurement of hamstrings muscle strength:

All previously described quadriceps muscle evaluation procedures will be applied for the hamstrings muscle strength test; however, the range of motion will be set from full knee extension, and the participant will be instructed to actively bend the knee against the resistance of the device to 90°.

3-Hamstring to quadriceps H:Q ratio calculation:

H:Q ratio will be calculated by use this formula:

$$\boldsymbol{H:Q\ Ratio} = \left(\frac{\boldsymbol{Hamstring\ Peak\ Torque\ (Nm)}}{\boldsymbol{Quadriceps\ Peak\ Torque\ (Nm)}}\right)$$

- Value interpretation:

- < 0.5: hamstring weakness.
- 0.5-0.7: normal range.
- 0.8-1: strong hamstring.

Fig 7: quadriceps and hamstring muscles strength measurement by isokinetic dynamometer device (adopted from Sinacore et al. 2017).

Treatment procedures:

1) Control group D: The participant will receive 18 sessions of leg press exercise using a leg press machine, conducted over a six-week period. Each training session will consist of 7 sets of 10 repetitions, with inter-set rest intervals of 90 seconds **(Wirth et al., 2016 a)** Before starting the leg press program, a standardized warm-up consisted of 5 min of submaximal cycling on an ergometer and 2 to 3 sets of moderate loaded squats with 6 repetitions each.

10 Repetition Max (10RM) Test:

The 10-repetition maximum (10RM) test will be conducted to determine the initial training load as a following:

- The machine will be loaded with a light weight (approximately 25–30% of the participant's body weight).
- The participant will perform 10 repetitions using proper form.
- The weight will be increased gradually (by 5–10 kg) after each successful attempt.
- This process will continue until the participant reaches a weight they can complete for 10 repetitions with good form, but with difficulty during the final 2 reps.
- That weight will be recorded as the participant's 10 Repetition Maximum (10RM).
- Strength training will then begin at 75–85% of the determined 10RM **(Piper et al., 2021).**

Leg Press Exercise:

1. The seat and backrest of the leg press machine will be adjusted to position the participant's hips and knees at approximately 90 degrees of flexion to ensure a comfortable and standardized starting posture.
2. The participant's feet will be positioned shoulder-width apart on the footplate, with the toes slightly externally rotated and the heels in full contact with the platform.
3. The participant will maintain full contact with the backrest throughout the exercise, with the head and spine supported. The side handles will be grasped to enhance postural stability and balance.

4. The exercise will commence from a flexed knee position, with particular attention given to maintaining proper knee alignment over the feet, avoiding any medial or lateral deviation.
5. The participant will extend the knees and hips to press the platform upward, taking care to avoid full knee lockout at the end of the movement.
6. The platform will then be returned to the initial position in a controlled manner through knee flexion, maintaining proper form throughout the eccentric phase (figure 8).

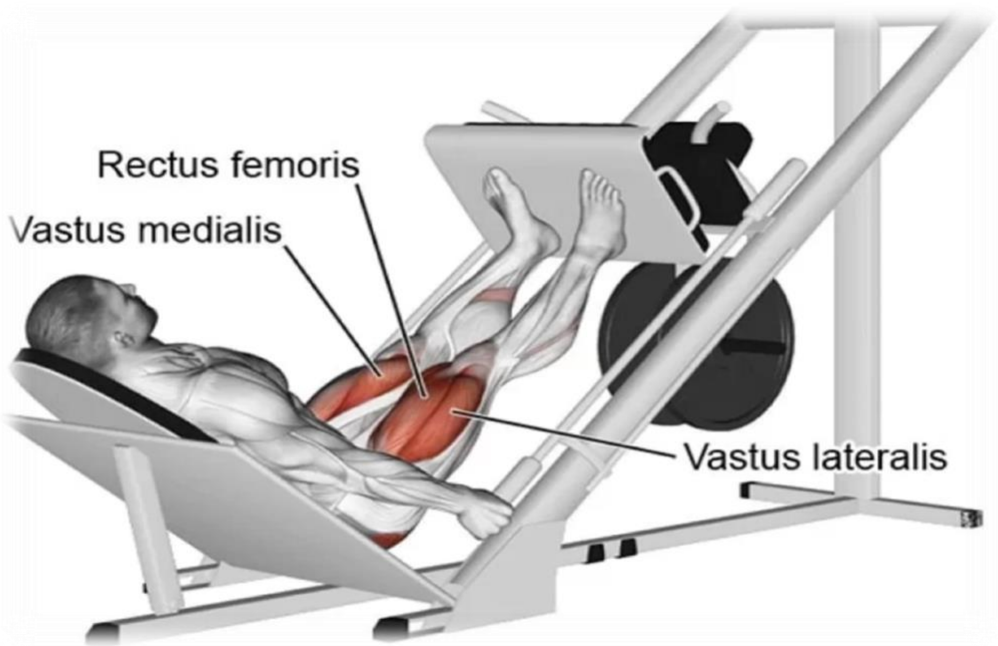

Fig 8: Leg press exercise adopted from (adapted from Martín et al., 2020).

2) Experimental groups: The participant in each subgroup (A, B, and C) will perform the same leg press exercise protocol applied for group D followed by mini squat exercise program with 5 min of submaximal cycling on an ergometer between 2 treatment programs. A total of 18 sessions will be conducted over a six-week period as follows:

1. **Group A:** participants will receive mini-squat program at 30° in addition to leg press program
2. **Group B:** participants will receive mini squat program at 45° in addition to leg press program

3. **Group C:** participants will receive mini-squat at 60° in addition in addition to leg press program

Mini-squat program:

1. Participants will stand barefoot or wear flat training shoes on a stable surface, placing their feet shoulder-width apart with toes slightly pointed outward.
2. A goniometer will be used during the first session to measure the target knee flexion angle (30° for group A, 45° for group B, and 60° for group C) demonstrated once by the examiner on one leg while the participant stands still. This will be followed by passive guidance into the used angles to help the participant recognize the posture and depth, with instructions to remember the sensation for future sessions; goniometer use will be repeated in later sessions only if corrective feedback is required.
3. Mini-squat session will last 10 minutes. Squat will be performed in a slow and controlled manner (approximately 2 seconds down and 2 seconds up), with short rests of 15–30 seconds allowed every 1–2 minutes as needed. Approximately six minutes of active squatting will be completed per session, with the remaining time allocated for brief rests and transitions **(adapted from Hartmann et al., 2016)** (figure 9).

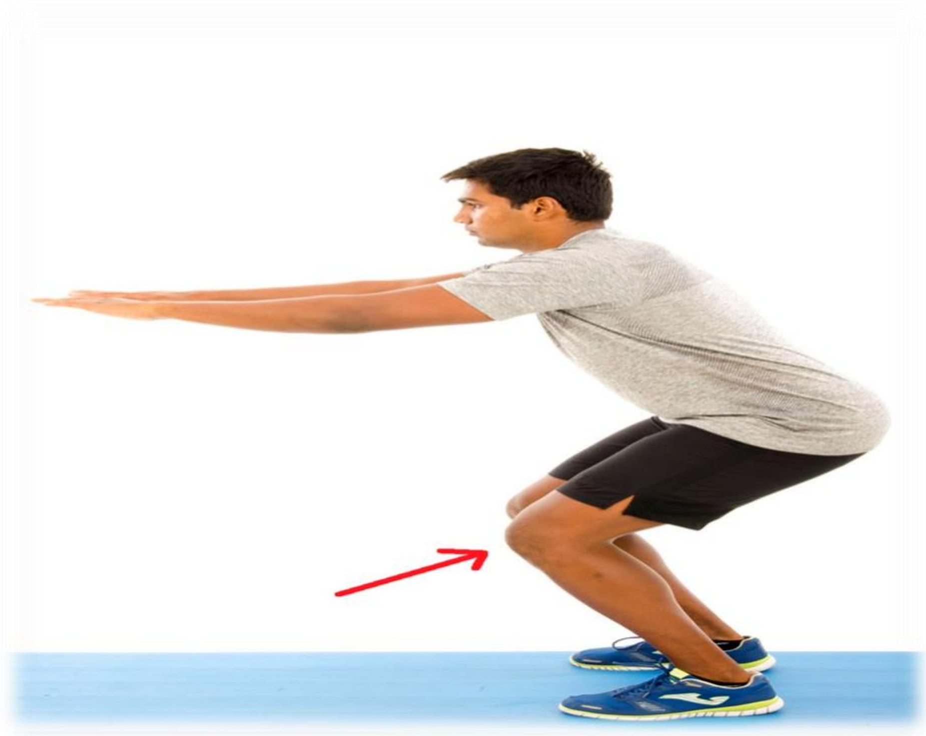

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Fig 9: Mini squat exercise (adopted from Prentice, 2024).

Statistical analysis

All analyses were carried out using IBM SPSS Statistics version 27 (IBM Corp., Chicago, IL, USA).

- Subject characteristics will be analyzed using ANOVA, while the Chi-squared test will be used to compare the distribution of the affected side among the groups
- The Shapiro-Wilk test assessed the normality of the data, followed by Levene’s test to verify the homogeneity of variances across groups.
- A mixed MANOVA will be conducted to evaluate the effects of group on the dependent variable(s).
- Post-hoc multiple comparisons were performed with Bonferroni correction to adjust for Type I error.
- Statistical significance was determined at a threshold of $p < 0.05$.

REFERENCES

Aagaard, P., Simonsen, E. B., Magnusson, S. P., Larsson, B., & Dyhre-Poulsen, P. (1998). A new concept for isokinetic hamstring:quadriceps muscle strength ratio. *American Journal of Sports Medicine, 26*(2), 231–237. https://doi.org/10.1177/03635465980260021201

Aagaard, P., Simonsen, E. B., Trolle, M., Bangsbo, J., & Klausen, K. (1998). Isokinetic hamstring/quadriceps strength ratio: Influence from joint angular velocity, gravity correction, and contraction mode. Acta Physiologica Scandinavica, 163(3), 287–293. https://doi.org/10.1046/j.1365-201X.1998.00378.x

Ahmed, F., Hossain, K. A., Islam, M. S., Hassan, M. N., Nahid, Z. B. S., Uddin, M. K., ... & Haque, M. O. (2023). The effects of closed kinetic chain exercise on pain and physical function in patients with knee osteoarthritis: a narrative review. Bulletin of Faculty of Physical Therapy, 28(1), 48.https://doi.org/10.1186/s43161-023-00161-8

Alonso-Cortés, D., Rodríguez-Rosell, D., Beato, M., & Pareja-Blanco, F. (2022). Strength balance of hamstrings-to-quadriceps ratio in professional football players. Biology of Sport, 39(1), 123–131. https://doi.org/10.5114/biolsport.2022.102003

Askling, C. M., Tengvar, M., Saartok, T., & Thorstensson, A. (2007). Acute first-time hamstring strains during high-speed running: A longitudinal study including clinical and magnetic resonance imaging findings. The American Journal of Sports Medicine, 35(2), 197–206. https://doi.org/10.1177/0363546506294679

Ayala, F., De Ste Croix, M., Sainz de Baranda, P., Santonja, F., & Tillar, R. (2012). Criterion-related validity and reliability of isokinetic and isometric tests of hamstring strength. *Journal of Strength and Conditioning Research, 26*(3), 827–836. https://doi.org/10.1519/JSC.0b013e31822a5cb5

Baroni, B. M., Ruas, C. V., Ribeiro-Alvares, J. B., & Pinto, R. S. (2020). Hamstring-to-quadriceps torque ratios of professional male soccer players: A systematic review. The Journal of Strength & Conditioning Research, 34(1), 281-293. DOI: 10.1519/JSC.0000000000002609

Ben Brahim, M., Bougatfa, R., Makni, E., Gonzalez, P. P., Yasin, H., Tarwneh, R., Moalla, W., & Elloumi, M. (2021). Effects of combined strength and resisted sprint training on physical performance in U-19 elite soccer players. Journal of Strength and Conditioning Research, 35(12), 3432–3439.

BodyKore Inc. (2025). FL1801 Isolateral Leg Press Machine [Product description]. Retrieved August 12, 2025, from https://www.bodykore.com

Brito, J., Figueiredo, P., Fernandes, L., Seabra, A., Soares, J. M., Krustrup, P., & Rebelo, A. (2010). Isokinetic strength effects of FIFA's "The 11+" injury prevention training programme. Isokinetics and Exercise Science, 18(4), 211–215. https://doi.org/10.3233/IES-2010-0386

Brosseau, L., Balmer, S., Tousignant, M., O'Sullivan, J. P., Goudreault, C., Goudreault, M., & Gringras, S. (2001). Intra- and intertester reliability and criterion validity of the parallelogram and universal goniometers for measuring maximum active knee flexion and extension of patients with knee restrictions. *Archives of Physical Medicine and Rehabilitation, 82*(3), 396–402. https://doi.org/10.1053/apmr.2001.19778

Bryanton, M. A., Kennedy, M. D., Carey, J. P., & Chiu, L. Z. F. (2012). Effect of squat depth and barbell load on relative muscular effort in squatting. Journal of Strength and Conditioning Research, 26(10), 2820–2828. https://doi.org/10.1519/JSC.0b013e31826791a7

Callaghan, J. P., & McGill, S. M. (2001). Low back joint loading and kinematics during standing and unsupported sitting. Ergonomics, 44(3), 280–294. https://doi.org/10.1080/00140130118276

Caterisano, A., Moss, R. F., Pellinger, T. K., Woodruff, K., Lewis, V. C., Booth, W., & Khadra, T. (2002). The effect of back squat depth on the EMG activity of 4 superficial hip and thigh muscles. Journal of Strength and Conditioning Research, 16(3), 428–432.

Çelebi, M. M., Akarçeşme, C., & Dalbayrak, B. E. (2018). Evaluation of postural balance and hamstring/quadriceps peak torque ratios according to leg dominancy in Turkish female volleyball players. Spor Hekimliği Dergisi, 53(3), 123-130. DOI: 10.5152/tjsm.2018.100

Comfort, P., Stewart, A., Bloom, L., & Clarkson, B. (2014). Relationships between strength, sprint, and jump performance in well-trained youth soccer players. Journal of Strength and Conditioning Research, 28(1), 173–177. https://doi.org/10.1519/JSC.0b013e318291b8c7

Coombs, R., & Garbutt, G. (2002). Developments in the use of the hamstring/quadriceps ratio for the assessment of muscle balance. Journal of Sports Science and Medicine, 1(3), 56–62.

Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing maximal neuromuscular power: Part 1—biological basis of maximal power production. Sports Medicine, 41(1), 17–38. https://doi.org/10.2165/11537690-000000000-00000

Croisier, J. L. (2004). Factors associated with recurrent hamstring injuries. Sports Medicine, 34(10), 681–695. https://doi.org/10.2165/00007256-200434100-00005

Croisier, J. L., Ganteaume, S., Binet, J., Genty, M., & Ferret, J. M. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. The American Journal of Sports Medicine, 36(8), 1469–1475. https://doi.org/10.1177/0363546508316764

Cuthbert, S. C., & Goodheart, G. J. (2007). On the reliability and validity of manual muscle testing: A literature review. *Chiropractic & Osteopathy, 15*(1), 4. https://doi.org/10.1186/1746-1340-15-4

Da Silva, E. M., Brentano, M. A., Cadore, E. L., De Almeida, A. P. V., & Kruel, L. F. M. (2008). Analysis of muscle activation during different leg press exercises at submaximum effort levels. The Journal of Strength & Conditioning Research, 22(4), 1059-1065.

Daşkapan, A., KÜLÜNKOĞLU, B., Özünlü Pekyavaş, N., Tüzün, E., Nur Coşar, S., & Karataş, M. (2013). Comparison of mini-squats and straight leg raises in patients with knee osteoarthritis: A randomized controlled clinical trial Diz osteoartritli hastalarda mini squat ve düz bacak kaldırma egzersizlerinin karşılaştırılması: Randomize kontrollü klinik çalışma. Turkish Journal of Rheumatology, 28(1). DOI: 10.5606/tjr.2013.2392.

Del Monte, A., Requena, B., Martínez-Ruiz, E., & Cappa, D. (2020). Effects of a six-week resistance training program on lower limb muscle strength and soccer kick performance. Journal of Human Kinetics, 72(1), 37–47. https://doi.org/10.2478/hukin-2019-0115

Dirnberger, J., Wiesinger, H. P., & Kösters, A. (2012). Reproducibility of isokinetic muscle strength measurements in the knee and ankle joint. *Isokinetics and Exercise Science, 20*(3), 149–153. https://doi.org/10.3233/IES-2012-0461
DOI: 10.1519/JSC.0000000000003829

Drouin, J. M., Valovich-McLeod, T. C., Shultz, S. J., Gansneder, B. M., & Perrin, D. H. (2004). Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. *European Journal of Applied Physiology, 91*(1), 22–29. https://doi.org/10.1007/s00421-003-0933-0

Earl, J. E., & Hoch, A. Z. (2011). A proximal strengthening program improves pain, function, and biomechanics in women with patellofemoral pain syndrome. American Journal of Sports Medicine, 39(1), 154–163. https://doi.org/10.1177/0363546510379967

Ebben, W. P., Fauth, M. L., Garceau, L. R., & Petushek, E. J. (2009). Electromyographic analysis of hamstring and quadriceps muscle activation during plyometric exercises. Journal of Strength and Conditioning Research, 23(3), 703–709. https://doi.org/10.1519/JSC.0b013e31819b79bd

Ebben, W. P., Feldmann, C. R., Dayne, A. M., Mitsche, D., & Alexander, P. (2009). Muscle activation during lower body resistance training. International Journal of Sports Medicine, 30(1), 1–8. https://doi.org/10.1055/s-2008-1038785

Escamilla, R. F. (2001). Knee biomechanics of the dynamic squat exercise. Medicine & Science in Sports & Exercise, 33(1), 127–141. https://doi.org/10.1097/00005768-200101000-00020

Escamilla, R. F., Fleisig, G. S., Zheng, N., Barrentine, S. W., Wilk, K. E., & Andrews, J. R. (2001). Effects of technique variations on knee biomechanics during the squat and leg press. *Medicine and Science in*

Sports and Exercise, 33(9), 1552–1566. https://doi.org/10.1097/00005768-200109000-00020

Escamilla, R. F., Fleisig, G. S., Zheng, N., Barrentine, S. W., Wilk, K. E., & Andrews, J. R. (1998). Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. Medicine and Science in Sports and Exercise, 30(4), 556–569. https://doi.org/10.1097/00005768-199804000-00014

Escamilla, R. F., MacLeod, T. D., Wilk, K. E., Paulos, L., & Andrews, J. R. (2012). Anterior cruciate ligament strain and tensile forces for weight-bearing and non-weight-bearing exercises: A guide to exercise selection. Journal of Orthopaedic and Sports Physical Therapy, 42(3), 208–220. https://doi.org/10.2519/jospt.2012.3768

Feiring, D. C., Ellenbecker, T. S., & Derscheid, G. L. (1990). Test-retest reliability of the Biodex isokinetic dynamometer. *Journal of Orthopaedic & Sports Physical Therapy, 11*(7), 298–300. https://doi.org/10.2519/jospt.1990.11.7.298

Filho, M. E., Silva, A. F., Clemente, F. M., Beck, W., & Amorim, S. (2023). Strength, plyometric and combined training improve power and speed characteristics in highly trained soccer players: A systematic review and meta-analysis. Sports Medicine, 53, 187–203. https://doi.org/10.1007/s40279-023-01944-8

Gogia, P. P., Braatz, J. H., Rose, S. J., & Norton, B. J. (1987). Reliability and validity of goniometric measurements at the knee. *Physical Therapy, 67*(2), 192–195. https://doi.org/10.1093/ptj/67.2.192

Grob, K., Ackland, T., Kuster, M. S., & Filgueira, L. (2016). New insight into the architecture of the quadriceps tendon. Journal of Experimental Orthopaedics, 3(1), 32. https://doi.org/10.1186/s40634-016-0068-y

Grygorowicz, M., Michałowska, M., Walczak, T., Owen, A., Grabski, J. K., Pyda, A., ... & Kotwicki, T. (2017). Discussion about different cut-off values of conventional hamstring-to-quadriceps ratio used in hamstring injury prediction among professional male football players. PLoS One, 12(12), e0188974.

Hammami, M., Negra, Y., Billaut, F., Hermassi, S., Shephard, R. J., & Chelly, M. S. (2018). Effects of lower-limb strength training on agility, repeated sprinting, leg peak power, and neuromuscular adaptations in soccer players. Journal of Strength and Conditioning Research, 32(1), 37–47. DOI: 10.1519/JSC.0000000000001813

Hartmann, H., Wirth, K., Klusemann, M., Dalic, J., Matuschek, C., & Schmidtbleicher, D. (2013). Influence of squatting depth on jumping performance. Journal of Strength and Conditioning Research, 27(5), 1355–1362. https:// DOI: 10.1519/JSC.0b013e31824ede62

Herzog, W. (2017). The problem with skeletal muscle series elasticity. BMC Biomedical Engineering, 1(1), 1–9. https://doi.org/10.1186/s42490-017-0002-6

Hewett, T. E., Myer, G. D., & Ford, K. R. (2005). Reducing knee and anterior cruciate ligament injuries among female athletes: A systematic review of neuromuscular training interventions. Journal of Knee Surgery, 18(1), 82–88.

Hoffman, J. R., Ratamess, N. A., Cooper, J. J., Kang, J., Chilakos, A., & Faigenbaum, A. D. (2009). Comparison of loaded and unloaded jump squat training on strength/power performance in college football players. Journal of Strength and Conditioning Research, 19(4), 810–815.

Immanuel, S., & Muthukrishnan, P. (2025). Effectiveness of combined open and closed kinetic chain exercises for treating shin splints in football players. International Journal of Life Sciences Biotechnology and Pharma Sciences, 21(1), Article 178. https://ijlbps.net/index.php/ijlbps/article/view/178

Impellizzeri, F. M., & Marcora, S. M. (2009). Test validation in sport physiology: Lessons learned from clinimetrics. *International Journal of Sports Physiology and Performance, 4*(2), 269–277. https://doi.org/10.1123/ijspp.4.2.269

Isear, J. A., Erickson, J. C., & Worrell, T. W. (1997). EMG analysis of lower extremity muscle recruitment patterns during an unloaded squat. Medicine and Science in Sports and Exercise, 29(4), 532–539. https://doi.org/10.1097/00005768-199704000-00016

Jaric, S. (2002). Muscle strength testing: Use of normalisation for body size. Sports Medicine, 32(10), 615–631. https://doi.org/10.2165/00007256-200232100-00002

Jeon, E. Y., Jang, H. J., & Nam, Y. G. (2024). A Study on The Reliability and Validity of Measuring The Range of Motion of The Knee Joint Using A Universal Goniometer and A Smartphone Application-Based Goniometer. Korean Society of Physical Medicine, 19(4), 59-65.

kinetic chain exercises in ACL rehabilitation on knee joint pain, laxity, extensor muscle strength, and function: A systematic review with meta-analysis. Frontiers in Sports and Active Living, 6, Article 1416690. https://doi.org/10.3389/fspor.2024.1416690

Kolber, M. J., & Hanney, W. J. (2012). The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: A technical report. *International Journal of Sports Physical Therapy, 7*(3), 306–313. [No DOI available — open access link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3404631/]

Kraemer, W. J., & Ratamess, N. A. (2004). Fundamentals of resistance training: progression and exercise prescription. Medicine & Science in Sports & Exercise, 36(4), 674–688. https://doi.org/10.1249/01.MSS.0000121945.36635.61

Kubo, K., Ikebukuro, T., & Yata, H. (2019). Effects of squat training with different depths on lower limb muscle volumes. European Journal of Applied Physiology, 119, 1933–1942. https://doi.org/10.1007/s00421-019-04181-y.

Maffiuletti, N. A., Bizzini, M., Desbrosses, K., Babault, N., & Munzinger, U. (2007). Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. *Clinical Physiology and Functional Imaging, 27*(6), 346–353. https://doi.org/10.1111/j.1475-097X.2007.00758.x

Martín-Fuentes, I., Oliva-Lozano, J. M., & Muyor, J. M. (2020). Evaluation of the lower limb muscles' electromyographic activity during the leg press exercise and its variants: a systematic review. International journal of environmental research and public health, 17(13), 4626. https://doi.org/10.3390/ijerph17134626.

Martín-Fuentes, I., Oliva-Lozano, J. M., & Muyor, J. M. (2020). Muscle activation and kinematic analysis during the inclined leg press exercise in young females. International Journal of Environmental Research and Public Health, 17(22), 8698.

Martín-Fuentes, I., Oliva-Lozano, J. M., & Muyor, J. M. (2022). Influence of feet position and execution velocity on muscle activation and kinematic parameters during the inclined leg press exercise. Sports Health, 14(3), 317-327. https://doi.org/10.1177/19417381211016357

McBride, J. M., Triplett-McBride, T., Davie, A., & Newton, R. U. (1999). A comparison of strength and power characteristics between power lifters, Olympic lifters, and sprinters. Journal of Strength and Conditioning Research, 13(1), 58–66.

McKean, M. R., Dunn, P. K., & Burkett, B. J. (2010). Quantifying the movement and the influence of load in the back squat exercise. Journal of Strength and Conditioning Research, 24(6), 1671–1679. DOI: 10.1519/JSC.0b013e3181d8eb4e.

Mentiplay, B. F., Perraton, L. G., Bower, K. J., Adair, B., Pua, Y. H., Williams, G. P., & Clark, R. A. (2015). Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: A reliability and validity study. *PLoS ONE, 10*(10), e0140822. https://doi.org/10.1371/journal.pone.0140822

Moore, K. L., Dalley, A. F., & Agur, A. M. R. (2018). Clinically oriented anatomy (8th ed.). Wolters Kluwer.

Myer, G. D., Ford, K. R., & Hewett, T. E. (2008). Neuromuscular training techniques to target deficits before return to sport after anterior cruciate ligament reconstruction. Journal of Strength and Conditioning Research, 22(3), 987–1014. https://doi.org/10.1519/JSC.0b013e31816a86cd

Ockendon, M., & Gilbert, R. E. (2012). Smartphone apps for measuring joint range of motion: A clinical evaluation of accuracy and reliability. *BMJ Open, 2*(6), e001556. https://doi.org/10.1136/bmjopen-2012-001556

Paoli, A., Marcolin, G., & Petrone, N. (2009). The effect of stance width on the electromyographical activity of eight superficial thigh muscles during back squat with different bar loads. Journal of Strength and Conditioning Research, 23(1), 246–250. DOI: 10.1519/JSC.0b013e3181876811.

Pincivero, D. M., Gandhi, V., Timmons, M. K., & Coelho, A. J. (2004). Quadriceps femoris electromyogram during concentric, isometric and eccentric phases of fatiguing dynamic knee extensions. Journal of Biomechanics, 37(5), 713–720. https://doi.org/10.1016/j.jbiomech.2003.09.011

Piper, T. J., Furman, S. M., Smith, T. J., & Waller, M. A. (2021). Establishing normative data for 10RM strength scores in college-aged males. International Journal of Strength and Conditioning. https://doi.org/10.47206/ijsc.v1i1.40

Powers, C. M. (2010). The influence of abnormal hip mechanics on knee injury: A biomechanical perspective. Journal of Orthopaedic & Sports Physical Therapy, 40(2), 42–51. https://doi.org/10.2519/jospt.2010.3337

Prentice, W. E. (2024). Open vs Closed Kinetic Chain Exercise in Rehabilitation. In Rehabilitation Techniques for Sports Medicine and Athletic Training (pp. 305-328). Routledge.

Rossi, F. E., Schoenfeld, B. J., Ocetnik, S., Young, J., Vigotsky, A., Contreras, B., & Cholewa, J. M. (2018). Strength, body composition, and functional outcomes in the squat versus leg press exercises. Journal of Sports Medicine and Physical Fitness, 58(3), 263–270

Sadeghi-Demneh, E., Shamsi, F., & Sadeghi, T. (2015). Validity and reliability of goniometric measurements of the knee in the clinical setting: Comparison with radiographic measurements. *Journal of Research in Medical Sciences, 20*(6), 540–545. https://doi.org/10.4103/1735-1995.163979

Sattar, N., & Lean, M. (Eds.). (2009). *ABC of Obesity*. John Wiley & Sons.

Schache, A. G., Dorn, T. W., Blanch, P. D., Brown, N. A., & Pandy, M. G. (2012). Mechanics of the human hamstring muscles during sprinting. Medicine & Science in Sports & Exercise, 44(4), 647–658. https://doi.org/10.1249/MSS.0b013e318236a3d2

Schoenfeld, B. J. (2010). Squatting kinematics and kinetics and their application to exercise performance. Journal of Strength and Conditioning Research, 24(12), 3497–3506. https://doi.org/10.1519/JSC.0b013e3181bac2d7

Schoenfeld, B. J. (2010). The mechanisms of muscle hypertrophy and their application to resistance training. Journal of Strength and Conditioning Research, 24(10), 2857–2872. https://doi.org/10.1519/JSC.0b013e3181e840f3

Schoenfeld, B. J., Grgic, J., Ogborn, D., & Krieger, J. W. (2017). Strength and hypertrophy adaptations between low-vs. high-load resistance training: a systematic review and meta-analysis. The Journal of Strength & Conditioning Research, 31(12), 3508-3523. DOI: 10.1519/JSC.0000000000002200

Scoz, R. D., Alves, B. M. O., Burigo, R. L., Vieira, E. R., Ferreira, L. M. A., da Silva, R. A., Hirata, R. P., & Amorim, C. F. (2021). Strength development according with age and position: a 10-year study of 570 soccer players. BMJ open sport & exercise medicine, 7(1), e000927. https://doi.org/10.1136/bmjsem-2020-000927

Senghas, Richard E. M.D... Atlas of Human Anatomy. The Journal of Bone & Joint Surgery 72(3):p 477, March 1990.

Shuzhen Ma, Yanqi Xu, Simao Xu. (2025) Effects of Physical Training Programs on Healthy Athletes' Vertical Jump Height: A Systematic Review With Meta-Analysis. Journal of Sports Science and Medicine (24), 236 - 257. https://doi.org/10.52082/jssm.2025.236

Sinacore, J. Anthony, Andrew M. Evans, Brittany N. Lynch, Richard E. Joreitz, James J. Irrgang, and Andrew D. Lynch. (2017). "Diagnostic Accuracy of Handheld Dynamometry and 1-Repetition-Maximum Tests for Identifying Meaningful Quadriceps Strength Asymmetries." The Journal of Orthopaedic and Sports Physical Therapy 47 (2): 97–107. https://www.jospt.org/doi/10.2519/jospt.2017.6651.

Skratek, Josua & Kadlubowski, Björn & Keiner, Michael. (2024). The Effect of Traditional Strength Training on Sprint and Jump Performance in 12- to 15-Year-Old Elite Soccer Players: A 12-Month Controlled Trial.

The Journal of Strength and Conditioning Research. Online first. 10.1519/JSC.0000000000004890.

Solomonow, M., Baratta, R., Zhou, B. H., Shoji, H., Bose, W., Beck, C., & D'Ambrosia, R. (1987). The synergistic action of the anterior cruciate ligament and thigh muscles in maintaining joint stability. The American Journal of Sports Medicine, 15(3), 207–213. https://doi.org/10.1177/036354658701500302

Standring, S. (2016). Gray's anatomy: The anatomical basis of clinical practice (41st ed.). Elsevier.

Straub, R. K., & Powers, C. M. (2024). A biomechanical review of the squat exercise: implications for clinical practice. International Journal of Sports Physical Therapy, 19(4), 490. doi: 10.26603/001c.94600

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The importance of muscular strength in athletic performance. Sports Medicine, 46(10), 1419–1449. https://doi.org/10.1007/s40279-016-0486-0

Swinton, P. A., Lloyd, R., Keogh, J. W. L., Agouris, I., & Stewart, A. D. (2012). A biomechanical comparison of the traditional squat, powerlifting squat, and box squat. Journal of Strength and Conditioning Research, 26(7), 1805–1816. https://doi.org/10.1519/JSC.0b013e3182577067

Thomas, K., French, D., & Hayes, P. R. (2009). The effect of two plyometric training techniques on muscular power and agility in youth soccer players. The Journal of Strength & Conditioning Research, 23(1), 332-335.

Thorborg, K., Bandholm, T., & Holmich, P. (2013). Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *British Journal of Sports Medicine, 47*(9), 593–598. https://doi.org/10.1136/bjsports-2012-091036

Walsh, J., Heazlewood, I. T., & Climstein, M. (2018). Body Mass Index in Master Athletes: Review of the Literature. Journal of lifestyle medicine, 8(2), 79–98. https://doi.org/10.15280/jlm.2018.8.2.79

Watanabe, K., Kouzaki, M., & Moritani, T. (2020). Muscle activation during squat exercises at different angles measured by EMG: Influence on performance and safety. European Journal of Applied Physiology, 120(1), 211–221.

Windolf, M., Götzen, N., & Morlock, M. (2008). Systematic accuracy and precision analysis of video motion capturing systems—Exemplified on the Vicon-460 system. *Journal of Biomechanics, 41*(12), 2776–2780. https://doi.org/10.1016/j.jbiomech.2008.06.024

Wirth, K., Hartmann, H., Mickel, C., Szilvas, E., & Keiner, M. (2016 a). The impact of back squat and leg-press training on maximal strength and speed-strength parameters. Journal of Strength and Conditioning Research, 30(5), 1205–1212. https://doi.org/10.1519/JSC.0000000000001215

Wirth, K., Keiner, M., Hartmann, H., Sander, A., & Mickel, C. (2016 b). Effect of 8 weeks of free-weight and machine-based strength training on strength and power performance. Journal of human kinetics, 53, 201–210. https://doi.org/10.1515/hukin-2016-0023

Wright, G. A., Delong, T. H., & Gehlsen, G. (1999). Electromyographic activity of the hamstrings during performance of the leg curl, stiff-leg deadlift, and back squat movements. Journal of Strength and Conditioning Research, 13(2), 168–174.

Yavuz, H. U., Erdag, D., Amca, A. M., & Aritan, S. (2015). Kinematic and EMG activities during front and back squat variations in maximum loads. Journal of Sports Sciences, 33(10), 1058–1066. https://doi.org/10.1080/02640414.2014.984240

Zebis, M. K., Andersen, L. L., Bencke, J., Kjaer, M., & Aagaard, P. (2009). Identification of athletes at future risk of anterior cruciate ligament ruptures by neuromuscular screening. American Journal of Sports Medicine, 37(10), 1967–1973. https://doi.org/10.1177/0363546509335000

Zhao, X., Turner, A. P., Sproule, J., & Phillips, S. M. (2023). The effect of unilateral and bilateral leg press training on lower body strength and power and athletic performance in adolescent rugby players. Journal of Human Kinetics, 86, 235–246. https://doi.org/10.5114/jhk/159626

Appendix I
Informed consent form

I am Mr / Misses / …………………………………… freely and voluntarily consent to participate in research study titled:” **Effect of adding mini-squat exercises at different angles to leg press exercise on quadriceps and hamstring strength and H:Q ratio in athletes**” under the direction of researcher / . A thorough description of the procedure has been explained, and I understand that I may withdraw my consent and discontinue participation in this research at any time without prejudice to me.

Participant Name: **Signature:** **Date:**