SELINUS UNIVERSITY
OF SCIENCES AND LITERATURE

THE EFFECTIVENESS OF MUSCLE ENERGY TECHNIQUE AND HAMSTRING NORDIC LOWER IN HAMSTRING TIGHTNESS AMONGST YOUNG ATHLETES OF PAKISTAN"

By
Abdul Haseeb Bhutta

A DISSERTATION

Presented to the Department of Physical Therapy

Ph.D. Program at Selinus University

Faculty of Natural Health Sciences in fulfillment of the requirements

for the Degree of Doctor of Philosophy in Physical Therapy

2023

ABSTRACT

Background: Hamstring tightness is a common issue among young athletes and can lead to injuries and reduced performance. This study aimed to compare the effectiveness of Muscle Energy Technique (MET), specifically Post-Isometric Relaxation (PIR) and Post-Facilitation Stretch (PFS), with Hamstring Nordic Lower (HNL) training in addressing hamstring tightness and improving physical performance.

Methods: A triple-blinded randomized controlled trial with a crossover design was conducted. Sixty young athletes with hamstring tightness were randomly assigned to three groups: Group A (PIR, PFS, HNL), Group B (PFS, HNL, PIR), and Group C (HNL, PIR, PFS). Various outcome measures were assessed, including hamstring extension, Passive straight leg raise (PSLR), Active straight leg raise (ASLR), Passive Knee Extension (PKE), Active Knee Extension (AKE), vertical jump, agility run test, YMCA Sit & Reach Box test, and 100-meter sprint timings. Data were analyzed using one-way ANOVA and repeated measures analysis of variance (RM-ANOVA).

Results: Both PIR and PFS interventions demonstrated significant improvements in hamstring flexibility and physical performance measures. Hamstring extension, PSLR, ASLR, PKE, AKE, vertical jump, agility run test, YMCA Sit & Reach Box test, and 100-meter sprint timings showed statistically significant enhancements in both MET groups. In contrast, HNL training did not show significant improvements compared to the MET interventions.

Conclusion: The findings suggest that both PIR and PFS interventions, as part of Muscle Energy Technique, are effective in releasing hamstring tightness and improving physical performance in young athletes. However, HNL training alone did not show superior effectiveness compared to the MET techniques. These results provide valuable insights for clinicians and sports professionals in designing interventions for hamstring tightness in young athletes.

Keywords: Muscle Energy Technique, Post-Isometric Relaxation, Post-Facilitation Stretch, Hamstring Nordic Lower training, hamstring tightness, physical performance, randomized controlled trial.

LIST OF ABBREVIATIONS

Abbreviations	Terms
PIR	post isometric relaxation
PFS	post facilitation stretch
MET	muscle energy technique
HNL	hamstring Nordic lower

Table of Contents

CHAPTER I

INTRODUCTION

Hamstring tightness is a common musculoskeletal condition that affects athletes, particularly young athletes.(1) It can lead to reduced flexibility, increased risk of injury, and impaired athletic performance. Hamstring injuries are prevalent in sports that require high levels of sprinting, jumping, and kicking motions. Therefore, effective interventions for hamstring tightness are crucial in preventing injuries and improving athletic performance among young athletes.(2-4)

Among the various treatment modalities available, two commonly used techniques are Muscle Energy Technique (MET)(5, 6) and Hamstring Nordic Lower (HNL) training.(7) MET involves the use of isometric contractions and subsequent relaxation to improve muscle flexibility,(1, 5, 8-10) while HNL training focuses on eccentric strengthening of the hamstring muscles.(11, 12) Both interventions have been utilized in clinical practice, but their comparative effectiveness in addressing hamstring tightness in young athletes remains unclear.

The aim of this dissertation is to investigate and compare the effectiveness of Muscle Energy Technique (specifically Post-Isometric Relaxation [PIR] and Post-Facilitation Stretch [PFS]) and Hamstring Nordic Lower (HNL) training in young athletes with hamstring tightness in Pakistan. The study seeks to provide evidence-based insights into the optimal intervention for this population, thereby contributing to injury prevention and performance enhancement strategies.

The rationale for conducting this study is the limited research available on the comparative effectiveness of MET and HNL training in addressing hamstring tightness among young athletes in Pakistan. Existing studies have primarily focused on either one of these interventions individually, and few have explored their direct comparison. Therefore, this research aims to fill this gap in the literature and provide valuable information to clinicians, sports trainers, and athletes themselves regarding the most effective intervention for hamstring tightness.

The hypothesis of this study proposes that both PIR and PFS, as part of MET, will be more effective in releasing hamstring tightness and improving physical performance compared to HNL training alone. The alternate hypothesis suggests that MET techniques will demonstrate greater efficacy, while the null hypothesis states that HNL training will be significantly more effective than both MET techniques in improving hamstring flexibility and physical performance.

To evaluate the effectiveness of these interventions, various outcome measures will be assessed, including hamstring extension, Passive straight leg raise (PSLR), Active straight leg raise (ASLR), Passive Knee Extension (PKE), Active Knee Extension (AKE), vertical jump, agility run test, YMCA Sit & Reach Box test results, and 100-meter sprint timings. These measures will provide a comprehensive evaluation of hamstring tightness and physical performance aspects, capturing the potential impact of the interventions.

The research design of this study is a triple-blinded randomized controlled trial with a crossover design. This design ensures rigorous methodology and minimizes bias. The sample will consist of young athletes with hamstring tightness, randomly assigned to three groups: PIR, PFS, and HNL. The blinding of participants, researchers, and data analysts will help maintain the integrity of the study and reduce potential biases.

In summary, this dissertation aims to investigate and compare the effectiveness of Muscle Energy Technique (PIR and PFS) and Hamstring Nordic Lower training in young athletes with hamstring tightness in Pakistan. The study will contribute to the existing body of knowledge by providing evidence-based insights into the optimal intervention for hamstring tightness in this population. The findings of this research have the potential to inform clinical practice, enhance injury prevention strategies, and improve the athletic performance of young athletes in Pakistan.

RATIONALE FOR PROPOSED STUDY

The rationale for conducting this study stems from the lack of published research that directly compares the effectiveness of Muscle Energy Technique (MET) and hamstring Nordic lower (HNL) training in preventing hamstring tightness-related injuries. Existing studies have primarily focused on either one of these interventions individually, with limited evidence to support their comparative effectiveness. Thus, there is a significant research gap regarding the optimal intervention for addressing hamstring tightness in young athletes. Hamstring tightness is a common issue among athletes, particularly in sports that involve sprinting, jumping, and kicking movements. It not only affects flexibility but also increases the risk of hamstring injuries, which can have a detrimental impact on an athlete's performance and overall well-being. Therefore, effective interventions that address hamstring tightness and reduce the incidence of related injuries are of paramount importance in athletic settings. The hypothesis of this study proposes that individuals who receive MET techniques, specifically the Post-Facilitation Stretch Technique (PFS) and Post-Isometric Relaxation (PIR), will experience enhanced performance and a significant reduction in hamstring injuries compared to those who solely undergo HNL training. This hypothesis is based on the potential benefits of MET techniques, such as improving muscle flexibility and addressing muscle imbalances, which are known contributors to hamstring tightness. By comparing the effectiveness of MET techniques and HNL training, this study aims to provide evidence-based insights into the optimal intervention for hamstring tightness in young athletes. The outcomes of this research have the potential to significantly impact injury prevention strategies and enhance athletic performance. If MET techniques are found to be more effective in reducing hamstring tightness-related injuries and improving performance, it would warrant their implementation as a preferred intervention in athletic training programs. The findings of this study will not only contribute to the existing body of knowledge but also have practical implications for clinicians, sports trainers, and athletes themselves. It will help inform decision-making regarding the selection of appropriate interventions for hamstring tightness and guide the development of targeted rehabilitation and injury prevention protocols. Ultimately, the goal is to optimize the well-being and performance of young athletes by implementing evidence-based interventions that effectively address hamstring tightness and reduce the risk of related injuries.

OBJECTIVES

- To compare the effect of Muscle Energy Technique (post isometric relaxation, post facilitation stretch) and hamstring nordic lower in athletes with hamstring tightness.

HYPOTHESIS

ALTERNATE HYPOTHESIS

- Post isometric relaxation significantly releases hamstring tightness and enhance physical performance of athletes as compared to the Hamstring Nordic lower.
- Post facilitation stretch significantly releases the hamstring tightness and enhances the physical performance of athletes as compare to the hamstring Nordic lower training.

NULL HYPOTHESIS

- Hamstring Nordic lower training is significantly effective in enhancing performance level in young athlete as compare to the both METs

CHAPTER II

LITERATURE REVIEW

HAMSTRINGS

The hamstring refers to a group of three muscles located at the back of the thigh, namely the semimembranosus, biceps femoris, and semitendinosus, as well as their corresponding tendons. These muscles form the boundaries of the area behind the knee. The main function of the hamstring muscles is to flex the knee joint, while all of them, except the short head of the biceps femoris, also contribute to hip extension. The three main hamstrings muscles cross both the hip and knee joints, enabling them to bend the knee and extend the hip. In contrast, the short head of the biceps femoris only crosses the knee joint and is not involved in hip extension. Because the short head of the biceps femoris muscle originates from a different place and receives a different nerve supply, it is sometimes not considered part of the "hamstring" muscle group. The hamstrings play a crucial role in various activities of daily living, regulating specific movements of the trunk, as well as running, walking, and jumping. They serve as important counteracting muscles to the quadriceps, particularly in activities like walking where they help slow down the extension of the knee.(13)

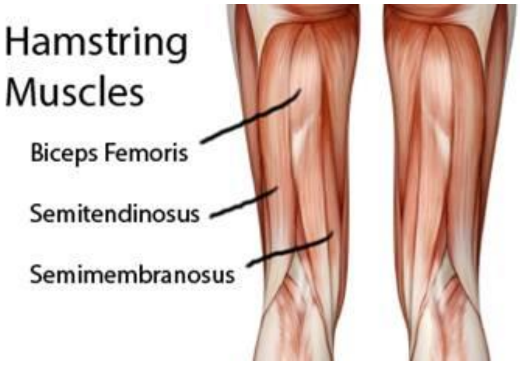


Figure 2.5: hamstring

QUADRICEPS MUSCLE

The quadriceps femoris, commonly known as the quads, is a large muscle group that covers the front of the thigh. It functions eccentrically when the hamstrings contract concentrically. As the main extensor muscle of the knee, it forms a substantial fatty mass that wraps around the front and sides of the femur. It is composed of four distinct portions, each with its own name: the rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis. The rectus femoris is located in the middle of the thigh and overlaps the other three quadriceps muscles. It originates from the ilium and gets its name from its straight path. The remaining three muscles lie beneath the rectus femoris and span the thigh from the trochanters to the condyles. They originate from the femoral shaft.(13, 14)

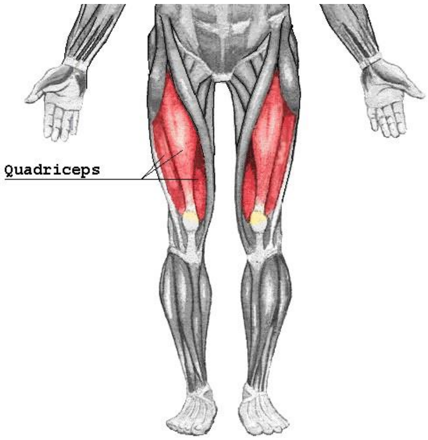


Figure 2.4: Quadriceps

The vastus lateralis covers the outer side of the thigh bone (femur), while the vastus medialis is located on the inner side of the femur. Between these two muscles lies the vastus intermedius, which is positioned in front of the femur and underneath the rectus femoris. To observe the vastus intermedius, dissection of the rectus femoris is necessary. All four components of the quadriceps femoris muscle eventually connect to the tibial tuberosity of the shinbone (tibia) by passing through the patella. The quadriceps tendon transforms into the patellar ligament, which attaches to the tibia. The quadriceps muscles are crucial for activities such as walking, running, jumping, and squatting, as they are responsible for powerful extension of the knee joint. To paraphrase your statement: The rectus femoris muscle, which is attached to the ilium, acts as a hip flexor. Its role as a hip flexor is essential for activities like running and walking, as it aids in the forward swing of the leg during each step. Additionally, during the process of walking, the quadriceps muscles, especially the vastus medialis, play a crucial role in stabilizing the knee joint and the patella.(14)

MUSCLE ENERGY TECHNIQUE

This manual therapy method utilizes the natural energy of the muscle itself to effectively lengthen and relax it. It accomplishes this by employing gentle isometric contractions, which induce reciprocal or autogenic inhibition. Unlike static stretching, MET is an active technique that necessitates the active involvement of the patient, while static stretching is a passive technique where the therapist does all the work. The core principle underlying MET is based on the idea of reciprocal and autogenic inhibition. In MET, reciprocal inhibition entails performing a moderate muscle contraction and then stretching the opposing muscle, while autogenic inhibition involves a moderate muscle contraction followed by stretching the same muscle.(5, 6, 8, 9, 15-18)

AUTOGENIC INHIBITION MET

The fundamental idea of autogenic inhibition serves as the underlying principle for two widely acknowledged and important techniques in muscle energy therapy (MET): post-facilitation stretching (PFS) and post-isometric relaxation (PIR). Both of these methods utilize autogenic inhibition as a means to achieve their specific therapeutic objectives. (5, 6, 18)

POST ISOMETRIC RELAXATION (PIR)

Post-isometric relaxation (PIR) is a therapeutic technique commonly used in physical therapy and sports medicine to increase flexibility, reduce muscle tension, and promote muscle relaxation. It involves the contraction of a muscle followed by a period of relaxation, allowing the muscle to lengthen and relax more effectively than with static stretching alone.(18, 19)

Scientific evidence supports the effectiveness of PIR in improving flexibility and reducing muscle tension. Here are some key points and studies highlighting the benefits of PIR:(18)

Increased flexibility: PIR has been shown to enhance flexibility compared to static stretching alone. A study published in the Journal of Sports Science & Medicine in 2013 compared the effects of PIR and static stretching on hamstring flexibility. The results demonstrated that PIR significantly increased hamstring flexibility compared to static stretching.

Muscle relaxation and tension reduction: PIR promotes the relaxation of muscles and helps reduce muscle tension. A study published in the Journal of Bodywork and Movement Therapies in 2017 examined the effects of PIR on muscle tension in participants with neck and shoulder pain. The results showed a significant decrease in muscle tension after PIR interventions. The effects of postisometric relaxation exercises on trapezius muscle tone, pain, neck disability and quality of life in female office workers with neck and shoulder pain.

Neurophysiological changes: PIR has been found to induce neurophysiological changes that contribute to muscle relaxation. A study published in the Journal of Bodywork and Movement Therapies in 2016 investigated the immediate effects of PIR on muscle activity and corticospinal excitability. The findings revealed a reduction in muscle activity and increased corticospinal excitability, indicating a relaxation response. (20)It's worth noting that while PIR has been shown to be effective, it is important to consult a qualified healthcare professional or physical therapist to ensure proper technique and application for individual needs. They can provide guidance and tailor the PIR exercises to specific muscle groups and conditions.(21)

This method, introduced by Karel Lewitt(21), operates based on autogenic inhibition and is known as Post-Isometric Relaxation (PIR). In PIR, the tension or tone in a specific muscle or muscle group is decreased, followed by a brief period of submaximal isometric contraction of the same muscle.(21).

The PIR technique, as described in involves the following steps: Move the tense muscle to the point where resistance is felt or just before the onset of pain. Contract the tense muscle at a sub-maximal level (around 10-20% of maximum effort) for a duration of 5 to 10 seconds, while the therapist applies resistance in the opposite direction. Instruct the patient to inhale during the muscle contraction, and then relax and exhale after the contraction. Apply a gentle passive stretch to the muscle to eliminate any remaining slack and reach a new point of resistance. Repeat the procedure from the new point of resistance for 2 to 3 times.(21)

POST FACILITATION STRETCH (PFS)

Reciprocal inhibition is a neurophysiological phenomenon that involves the simultaneous contraction of one muscle group and the relaxation of its antagonist muscle group. This concept is closely related to the post-facilitation stretch technique, which can be referred to as a form of reciprocal inhibition.(22)

Scientific evidence supporting the use of post-facilitation stretch as reciprocal inhibition comes from studies examining the physiological and neurological mechanisms underlying this technique. Here are a few key points: Muscle Spindle Activity: The muscle spindle is a sensory receptor located within skeletal muscles that detects changes in muscle length. When a muscle is stretched, the muscle spindle is activated, which triggers a reflex contraction of the same muscle (known as the stretch reflex). However, when the antagonist muscle group is contracted, it inhibits the stretch reflex in the stretched muscle through the process of reciprocal inhibition.

Motor Neuron Excitability: Electromyography (EMG) studies have shown that during post-facilitation stretch exercises, the antagonist muscle group experiences a decrease in motor neuron excitability. This reduction in excitability leads to relaxation of the antagonist muscles, allowing for a deeper stretch in the target muscle group.(22)

Central Nervous System Modulation: Research has demonstrated that the central nervous system plays a crucial role in mediating reciprocal inhibition. It involves complex interactions between various regions of the brain, including the motor cortex, spinal cord, and inhibitory interneurons. These neural pathways regulate the coordination of muscle contractions and relaxations during reciprocal inhibition, thus facilitating effective stretching.(22)

Clinical Applications: Reciprocal inhibition and post-facilitation stretch techniques have been utilized in clinical settings, such as physical therapy and sports rehabilitation, to improve flexibility, reduce muscle tension, and enhance range of motion. Numerous studies have reported positive outcomes when applying these techniques to conditions such as muscle spasms, joint stiffness, and musculoskeletal injuries.(18, 22)

While the term "post-facilitation stretch" may not be widely used in scientific literature, the principles underlying this technique align with the concept of reciprocal inhibition. The scientific evidence supports the idea that by contracting the antagonist muscle group during stretching exercises, reciprocal inhibition can be induced, promoting relaxation and allowing for a more effective stretch in the targeted muscles.(22)

This technique was developed by Janda, is also based on the principle of autogenic inhibition but it is more aggressive than post isometric relaxation.(23)

Method to perform PFS technique: The shortened and hypertonic muscle is placed in between a fully relaxed and fully stretched state. The patient contracts the agonist against the therapist's resisting force for 5-10 secs utilizing the maximum effort. After 5-10 secs patient is instructed to release the effort and relax, while the therapist rapidly stretches the muscle to the new barrier holding for 10 secs. The procedure is repeated foe 3-5 times or more, with the relaxing interval of 20 secs approximately. Here it is different from PIR technique that it is held every time in between fully relaxed and fully stretched position, rather than starting from a new barrier. (22, 23)

NORDIC HAMSTRING LOWER TRAINING

The Nordic hamstring lower training exercise has gained popularity in recent years as a preventive measure for hamstring injuries, particularly among athletes involved in sports that require explosive running and kicking movements.(24), it's important to note that new research may have emerged since my knowledge cutoff. Several studies have investigated the effects of Nordic hamstring exercises on hamstring injury prevention and muscle strength. Here are a few key findings: Prospective Studies: Several prospective studies have examined the impact of Nordic hamstring exercises on reducing the risk of hamstring injuries. One notable study published in the British Journal of Sports Medicine in 2016(25) followed a group of professional soccer players and found that a 10-week Nordic hamstring exercise intervention significantly reduced the incidence of hamstring injuries compared to a control group Randomized Controlled Trials (RCTs): Randomized controlled trials provide a higher level of evidence. A systematic review and meta-analysis published in 2016 in the British Journal of Sports Medicine analyzed the results of five RCTs and found that Nordic hamstring exercises reduced the risk of hamstring injuries by approximately 51% compared to control interventions.(25)

Strength Gains: In addition to injury prevention, Nordic hamstring exercises have been shown to improve hamstring muscle strength. A study published in the Journal of Strength and Conditioning Research in 2013 (26)compared Nordic hamstring exercises with conventional hamstring exercises and found that the Nordic exercise resulted in greater increases in eccentric hamstring strength. Muscle Architecture Changes: Research has also explored the effects of Nordic hamstring exercises on muscle architecture.(26) A study published in the Scandinavian Journal of Medicine & Science in Sports in 2018 used ultrasound imaging to assess muscle architecture changes following a 10-week Nordic exercise intervention. (27) The study found increases in fascicle length and pennation angle, suggesting positive adaptations in the muscle structure. Recommendations: Various professional sports organizations, such as FIFA (Fédération Internationale de Football Association) and World Rugby, have incorporated Nordic hamstring exercises into their injury prevention programs based on the available evidence. (28)It's important to note that while the evidence supports the effectiveness of Nordic hamstring exercises, they should be implemented as part of a comprehensive training program tailored to the individual's needs and goals. Consulting with a qualified strength and conditioning specialist or sports medicine professional is recommended to ensure proper technique, progression, and integration of the exercises into a training routine.(28)

YMCA SIT AND REACH TEST

The YMCA sit and reach test is a common method used to assess flexibility, particularly in the lower back and hamstring muscles. However, it's important to note that the sit and reach test itself is not unique to the YMCA. It is a widely used test in various fitness and sports settings. The sit and reach test involves sitting on the floor with legs extended, placing a box or a measuring device between the legs, and then reaching forward as far as possible. The distance reached is recorded as a measure of flexibility. While there may not be scientific studies specifically focused on the YMCA sit and reach box, there is a substantial body of research on the sit and reach test and its reliability and validity as a measure of flexibility. Here are some key findings from scientific studies:(29)

Reliability: Several studies have found that the sit and reach test has good reliability, meaning it produces consistent results when repeated. For example, a study published in the Journal of Strength and Conditioning Research in 2014 assessed the test-retest reliability of the sit and reach test and found high reliability coefficients.

Validity: The sit and reach test has been shown to have moderate validity in measuring hamstring and lower back flexibility. However, it should be noted that it primarily focuses on these specific areas and may not capture overall body flexibility.(29)

Age and gender differences: Research has demonstrated that flexibility, as assessed by the sit and reach test, can vary with age and gender. For instance, a study published in the Journal of Sports Sciences in 2009 examined age and gender differences in sit and reach performance among children and adolescents. The results indicated significant differences in flexibility across age groups and between genders.(29, 30)

Correlation with other measures: The sit and reach test has been found to correlate with other measures of flexibility, such as the straight-leg raise test and the goniometer measurement of joint range of motion.(29)

While the sit and reach test has been widely used and studied, it is important to remember that flexibility is a multifaceted concept, and the sit and reach test may not capture the full extent of an individual's flexibility. Additionally, individual variations in body structure and other factors can influence the test results.(30)

This tests performed to identify the flexibility level of an individual and it is more customary to the hamstrings, so in order to allow for more flexible lifter the tests could be used to stretch out the hamstrings.(29, 30)

Figure: athlete performing sit and reach test on YMCA box

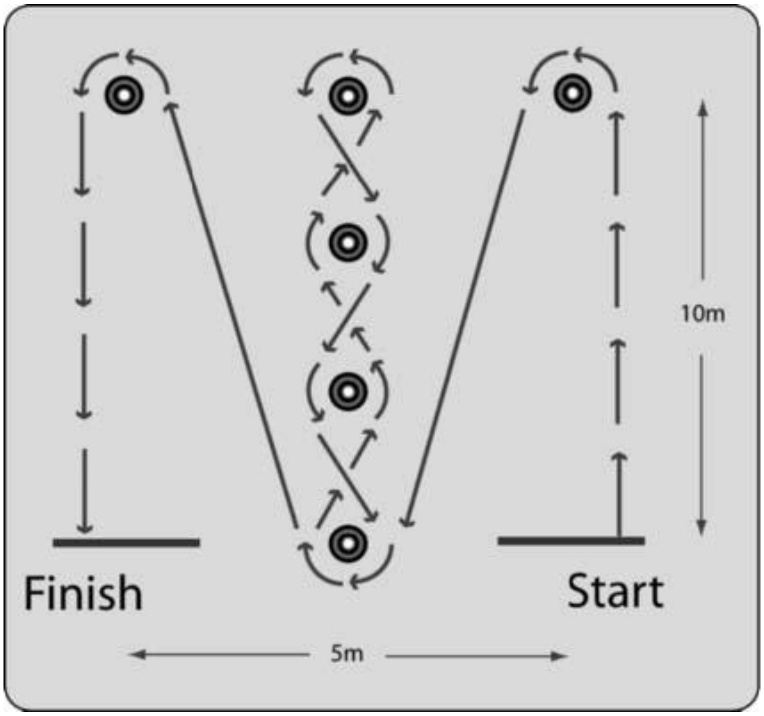
The test is performed by using a K-Mart Do-It-Yourself measuring yardstick, and the participant place their heel of bare feet on 15-inch marker, as shoes are removed. The private investigator would control the buckling or gliding of feet by placing their hand on the knees of participant, and was skilled regarding the hand placement. To find the average flexibility of hamstring muscles, the test was conducted three times and mean of latter two was taken. The participants were asked to slide together their overlapped hands along the yardstick. The statistical data of hamstring flexibility was extracted by subtracting the value on yardstick from the 15-inch mark.(29)

AGILITY RUN TEST

The agility run test is not typically used as a diagnostic tool for hamstring issues.(31) Instead, it is commonly used as a performance measure to assess an individual's speed, coordination, and agility.(32, 33) Hamstring issues, such as strains or tears, are typically diagnosed through a combination of medical history, physical examination, and possibly imaging studies such as an MRI.(32)

That being said, the agility run test can indirectly provide some information about the functionality of the hamstring muscles. Hamstring muscles play a significant role in the propulsion and deceleration phases of running, which are essential for agility. If there is an underlying hamstring issue, it may affect an individual's ability to perform the agility run test effectively. For example, if someone has a hamstring strain, they may experience pain, weakness, or limitations in their ability to generate power during quick changes of direction.(33)

The Illinois agility test is intended to test the individual’s ability of turning, cutting, acceleration and deceleration. The use of timing gate is important, as the performance is determined by the time taken to complete the path. (34)



VERTICAL JUMP TESTS

Vertical jump performance is influenced by various factors, including muscular strength and power, coordination, and neuromuscular control. While vertical jump height can provide some insight into an individual's lower body strength and power, it is important to note that it is not a direct measure of specific muscle strength, such as hamstring eccentric strength. However, certain studies have explored the relationship between vertical jump performance and measures of muscular strength and power, which can indirectly reflect hamstring eccentric strength.(35) Several research studies have investigated the association between vertical jump height and hamstring eccentric strength. Here are a few relevant findings:(36)

A study published in the Journal of Strength and Conditioning Research in 2023 examined the relationship between hamstring eccentric strength and vertical jump performance in collegiate athletes.(37) The researchers found a moderate positive correlation between eccentric hamstring strength and vertical jump height. This suggests that individuals with greater hamstring eccentric strength tend to exhibit higher vertical jump performance.

2. Another study published in the Journal of Sports Sciences in 2022 investigated the relationship between eccentric hamstring strength and vertical jump performance in soccer players.(38) The findings revealed a positive correlation between eccentric hamstring strength and vertical jump height. The researchers concluded that eccentric hamstring strength may contribute to improved vertical jump performance.

3. A research article published in the Journal of Strength and Conditioning Research in 2014 examined the relationship between eccentric hamstring strength and vertical jump height in collegiate athletes.(37) The study found a significant positive correlation between eccentric hamstring strength and vertical jump height. This suggests that individuals with greater eccentric hamstring strength tend to have higher vertical jump performance.

These studies suggest that there is a positive association between hamstring eccentric strength and vertical jump performance. However, it is important to consider that vertical jump performance is influenced by multiple factors, and hamstring eccentric strength is just one component. Other factors such as muscular power, coordination, and technique also play significant roles in vertical jump performance.

These tests are broadly used to check the ability of vertical jump with double and single leg. The focus of these tests are specific parameters of performance like height jumped, so are very useful for vertical jumping ability required for sports, for example volleyball and basketball. Test variations are as following; measuring the height jumped following a small platform drop off, a one-legged and a step take off (soccer, tennis), a one-legged take off, or a two-legged take off.

SPRINT TESTS

The 100-meter sprint is a highly explosive event in track and field athletics that requires athletes to generate a significant amount of power and speed. While there is scientific evidence on the factors influencing sprint performance, the direct relationship between the 100-meter sprint and identifying hamstring eccentric strength is not extensively studied.(39)

However, hamstring eccentric strength is considered an important factor for sprint performance. The hamstrings play a crucial role in the acceleration phase of the sprint, as they actively lengthen and contract eccentrically to control the forward movement of the leg during the ground contact phase.

Several studies have examined the association between hamstring eccentric strength and sprint performance, although they may not specifically focus on the 100-meter sprint. Here are a few key findings(39):

1. Eccentric hamstring strength and sprint performance: Research suggests that individuals with greater eccentric hamstring strength tend to have better sprint

performance. A study published in the (2019) found that higher eccentric hamstring strength was associated with faster sprint times in amateur soccer players.(40)

2. Hamstring strength imbalance and injury risk: Imbalances between eccentric hamstring strength and concentric quadriceps strength have been linked to an increased risk of hamstring strain injuries. Although not directly related to sprint performance, hamstring strains can significantly impact an athlete's ability to sprint effectively.(41)

3. Training interventions: Various training interventions, such as eccentric-focused hamstring exercises, have shown positive effects on sprint performance. A study published 2023 reported that an eccentric hamstring training program led to improvements in sprint performance among female soccer players.(42)

It's worth noting that while eccentric hamstring strength is considered important for sprint performance, it is only one of several factors that contribute to overall sprinting ability. Other factors include stride length, stride frequency, power production, technique, and muscular coordination.

While there may not be specific studies directly linking hamstring eccentric strength to the 100-meter sprint, the existing research supports the notion that hamstring strength, including eccentric strength, is an important consideration for sprint performance and injury prevention. Further research specific to the 100-meter sprint and its relation to hamstring eccentric strength could provide more targeted insights in the future.(42)

There are three sprints in these tests, starting from standing with full relaxation time between the tests, and the best time is taken always. Some investigators considers the mean of three; however using this method is usually not appropriate as one time poor result can twist the noted figure. Timing gates height and the position of start should be standardized. The starting position resulting in small differences cannot be interchanged (43) as the slower times occur in the starting positions having feet parallel than those placed dominant foot in forward position (44). **Cronin** and Templeton (2008) also observed an error of ≤1.3% (equal to 0.7s) between the times achieved with the gates positioned at hip and shoulder height. This was attributed to the legs breaking the beam earlier with the gates positioned at hip height.(45)

CHAPTER III

MATERIAL & METHODS

SETTING

This study was conducted in, private Clinic NOSIS and Pakistan sports Board. .

STUDY DESIGN

This study employed a triple-blinded randomized clinical trial with a crossover study design. The objective was to investigate the effectiveness of [provide a brief description of the intervention or treatment being studied]. The study involved three groups, labeled Group A, Group B, and Group C. Each group was subjected to all three treatment conditions, with a specific order determined by the crossover design. The blinding ensured that neither the participants nor the researchers involved in data collection, analysis, or interpretation had knowledge of the treatment assignments.

Randomization:

Randomization of participants into the three groups was conducted using the lottery method. The lottery method is a simple, unbiased approach that assigns participants to groups based on random selection. This method eliminates potential bias and ensures the groups are comparable at baseline in terms of demographic characteristics, performance level, and level of muscular tightness.

To implement the randomization procedure, each participant was assigned a unique identification number. These numbers were written on identical pieces of paper and placed into an opaque container. A designated researcher, who was not involved in the recruitment or assessment processes, blindly drew one paper at a time from the container and assigned the corresponding participant to the respective group. This process was repeated until all participants were randomized into one of the three groups.

Blinding: To ensure triple blinding, the study employed the following measures:

Participant Blinding: Participants were unaware of their assigned treatment group throughout the study period. This was achieved by using identical treatment packages and instructions for all groups, with no explicit information provided regarding the specific intervention received. Researcher Blinding: The researchers involved in data collection, analysis, and interpretation were blinded to the treatment assignments. The participant identification numbers were used instead of personal identifiers in all study documents to maintain anonymity during data analysis. Data Analyst Blinding: The data analyst responsible for statistical analysis was also blinded to the treatment assignments. The datasets were coded, ensuring that the treatment groups were unidentified during the analysis process.The triple blinding approach aimed to minimize bias and increase the validity of the study's findings, ensuring that the results were solely based on the effectiveness of the interventions rather than any preconceived notions or expectations.

Randomized Controlled Trial with 3 group

Treatment Sequence Information:

Group A: Treatment 1, Treatment 2, Treatment 3

Group B: Treatment 2, Treatment 3, Treatment 1

Group C: Treatment 3, Treatment 1, Treatment 2

SAMPLE SIZE

There were total **60** patients with hamstring tightness divided in 3 group. Allocated by using manual lottery system

SAMPLING TECHNIQUE

The sampling technique used in this research study involved a multi-step process. Initially, the researcher screened 150 participants to identify potential candidates for enrollment. The purpose of the screening was to ensure that the participants met specific criteria related to their athletic background. Out of the initial pool, 40 individuals were excluded from the study due to not meeting the predetermined inclusion criteria. After the screening process, 110 participants were identified as meeting the inclusion criteria and were considered eligible for participation. To ensure unbiased allocation, the researcher randomly assigned these 110 participants into three different groups. This random allocation helps minimize any potential confounding factors and allows for a more robust comparison between the groups. During the course of the study, five participants dropped out due to injury. To maintain the sample size and ensure statistical validity, these dropouts were replaced using randomization once again. By randomly selecting replacement participants, the researcher aims to maintain the integrity of the original random allocation and reduce the potential impact of missing data. Overall, this sampling technique employed in the study ensures the enrollment of athletes who meet the inclusion criteria, minimizes selection bias through random allocation, and maintains the sample size and randomization even in the case of dropouts. This approach enhances the reliability and generalizability of the study's findings and helps strengthen the overall validity of the research.

DURATION OF STUDY

The duration of study was 12 months after approval of synopsis.

DATA COLLECTION PROCEDURE

This study was initiated after approval Supervisor. A total of 60 athletes visiting Pakistan sports Board and NOSIS satisfying the inclusion and exclusion criteria were recruited in the study. Data was compared at baseline after every 10 days during and after the intervention. The data was collected through the following questionnaire/forms. General demographic questionnaire will include Name, age, gender date, marital status, Occupational history including sports played, self structured questionnaire

7. DATA ANALYSIS

The study both prospective aspects. The results of study is presented as frequency, percentages, mean± SD and p-value. The intervention period for each patient was one months and data was collected on 1st day and at the end of 10th day for between groups cross sectional comparison, two way mixed ANOVA was used for between group analysis , and within group comparison. The data was analyzed through SPSS 28.

SELECTION CRITERIA

INCLUSION CRITERIA:

- Athletes with Hamstring tightness
- Both male and female will be included.
- Athletes ages form 18 to 25 years
- Patients having SLR <110˚

Exclusion Criteria

- Athletes having hamstring injuries
- Patients having SLR > 110 ˚
- Above 25 years of age
- Other orthopedic condition like LBP,
- Patients with any deformity

INTERVENTION

Post facilitation Stretch

Each patient in group A will be given with hot pack along with Tens for 20 mins then the patient will receive post facilitation stretch only, for about one months on daily basis.

The PFS technique is performed as follows:

The hamstring muscle is placed in between a fully relaxed and fully stretched state. The patient contracts the agonist against the therapist's resisting force for 5-10 secs utilizing the maximum effort. After 5-10 secs patient is instructed to release the effort and relax, while the therapist rapidly stretches the muscle to the new barrier holding for 10 secs. The procedure is repeated foe 3-5 times or more, with the relaxing interval of 20 secs approximately. Here it is different from PIR technique that it is held every time in between fully relaxed and fully stretched position, rather than starting from a new barrier.

Post Isometric Relaxation

Each patient in group B will receive hot pack along with Tens for 20 mins then the patients will receive post isometric relaxation alone for about one months on daily basis.

Method to perform PIR technique:

The hamstring muscle will be taken to the point where first resistance to movement felt, or to the length that is short of pain. The hypertonic muscle is contracted sub-maximally (10-20%) for between 5 to10 secs away from the barrier, while therapist is applying resistance opposite to the action. The patient is ask to inhale while performing contraction and after contraction the patient relaxes and exhale. And then a passive gentle stretch is applied in order to take up the slack to the new barrier. This procedure is repeated from the new barrier for 2 -3 time.

Hamstring Nordic lower

Each patient in group C received hot pack along with Tens for 20 mins then the patients received hamstring nordic lower alone for about one months on daily basis. Certainly! Here's a patient guidance for performing a hamstring lower exercise:

1. Start by lying flat on your back on a comfortable surface, such as a mat or a carpeted floor. Keep your legs straight and extend them fully.

2. Bend one knee and bring it towards your chest, while keeping the other leg straight on the ground. Hold your bent knee with both hands behind your thigh.

3. Slowly begin to straighten your bent knee, gently pulling it towards you until you feel a stretch in the back of your thigh (hamstring). Remember to keep your other leg flat on the ground throughout the exercise.

4. Hold the stretch at the point where you feel a gentle pull in your hamstring. It's important not to push too hard or experience any pain. You should feel a moderate stretch but not discomfort.

5. Maintain the stretch for about 20 to 30 seconds, breathing deeply and relaxing into the position.

6. After the designated time, slowly release the stretch and return your leg to the starting position with both legs extended.

7. Repeat the exercise on the other leg, following the same steps.

8. Perform this exercise for a total of 2 to 3 sets, alternating between legs.

9. It's important to note that you should never bounce or jerk your leg during the stretch, as this can lead to injury. The movement should be slow and controlled.

10. If you have any concerns or experience pain during the exercise, it's advisable to consult with a healthcare professional or a physical therapist before continuing.

Remember to always listen to your body and perform the exercise within your comfort zone. Consistency is key, so aim to incorporate this hamstring lower exercise into your regular routine for improved flexibility and strength in your hamstring muscles.

CHAPTER IV

Result

DEMOGRAPHICS CHARACTERISTICS OF STUDY PARTICIPANTS

Three groups were comparable at baseline and no significant difference was found between ages, gender, height, but the significance difference was there only in weight and body mass index (Table IV-1).

Table IV-1: Demographics of study participants in 3 groups

	Groups	N	Mean/ median	SD/ IQR	p-value
Age (years)	PIR	20	21.70	1.68	0.125
	PFS	20	22.10	1.16	
	HNL	20	21.00	2.10	
Height (cm)	PIR	20	170.45	6.99	0.727
	PFS	20	172.45	8.91	
	HNL	20	171.10	8.22	
Weight (kg)	PIR	20	67.00	7.25	0.038
	PFS	20	70.00	6.30	
	HNL	20	64.80	8.93	
Body Mass Index (Kg/m2)	PIR	20	22.78	2.09	0.05
	PFS	20	24.11	3.27	
	HNL	20	22.08	2.71	

The mean±SD age of subjects in Post Isometric relaxation (PIR) group was 21.35±1.75 years, height was 170.45±6.99 cm, median weight was 67(7.25) kg and BMI was 22.78(3.16) kg/m2. The mean ± SD of Post Facilitation Stretch age was 21.85±1.89 years height was 172.45 ± 8.91 and weight median was 70(6.3) BMI was 24.11(3.27) kg/m^2. On the other hand mean±SD age of subjects in friction massage was group was 4.98±2.43 years, height was 171.01±8.22 cm, weight was 64.85(8.93) kg and BMI was 22.71(2.71) kg/m2. Shown in the Table IV-1.

Table IV-2: Details of Athletes

Demographic details of athletes all group					
		group of the athletes			Total
		PIR	PFS	HNL	
BMI category	normal	19(35%)	16	19	54
	overweight	1	4	1	6
Total		20	20	20	60
sports played	cricket	5	8	8	21
	football	13	7	8	28
	running	0	1	1	2
	volleyball	0	2	2	4
	badminton	2	2	1	5
Total		20	20	20	60
Duration of sports in hour on daily basis	1 hour	4	2	4	10
	2 hours	5	9	7	21
	3 hours	6	6	5	17
	4 hours	5	3	4	12
Total		20	20	20	60
warm up session in training	Yes	12	11	13	36
	No	8	9	7	24
Total		20	20	20	60
cool down training included	Yes	0	1	1	2
	No	20	19	19	58
Total		20	20	20	60

Item	Group	PHASE I				PHASE II				PHASE III				F-statistic		
		MEAN ± PRE	MEAN ± POST	Δ	p-value	MEAN ± PRE	MEAN ± POST	Δ	p-value	MEAN ± PRE	MEAN ± POST	Δ	p-value	F within (η²)	F between (η²)	p- value
Hamstring extension right	A	7.5 ±1.14	19.5±1.6	12	$<0.001^{A}$	14.1±1.3	27.1±1.6	16	$<0.001^{A}$	21.1±1.7	25±2.1	3.9	$<0.001^{A}$	2834.4 (0.98)	5455 (0.99)	$<0.001^{B}$
	B	7.6 ±1.10	22.5±2.3	15		17.1±3.1	20.7±2.9	3.6		14.7±2.9	24± 3.2	9.7				
	C	7.5 ±1.14	13.7±1.3	6.2		10.1 ± 1.7	19.7±1.7	9.6		13.7±1.7	27±2.0	13.3				
Hamstring extension left	A	7.4±0.88	16.25±1.0	8.8	<0.001	11.75±1.2	23.8±1.3	12.05	$<0.001^{A}$	17.8±1.3	21.7 ±1.6	3.90	$<0.001^{A}$	2723 (0.98)	7333 (0.992)	$<0.001^{B}$
	B	6.90±1.0	19.9±1.3	13		14.3±2.1	17.9±2.2	3.60		11.9±2.2	21.4±2.3	9.45				
	C	6.85±0.87	11.25±0.9	4.39		5.65±1.3	15.2±1.2	9.60		9.2±1.2	22.7±1.2	13.50				
PSLR Right	A	50.8±6.8	66.1±6.5	15.25	$<0.001^{A}$	56.2±6.3	78.4±6.3	22.20	$<0.001^{A}$	68.5±6.2	75.9±6.7	7.35	$<0.001^{A}$	1858 (0.97)	5793 (0.99)	$<0.001^{B}$
	B	51.3±6.1	73.1±6.5	21.80		63.3±6.5	69.7±6.7	6.45		59.9±6.7	76.7±7.0	16.80				
	C	49.6±6.2	54.9±6.3	5.35		45.2±6.3	61.9±6.0	16.80		52.1±6.4	74.4±6.7	22.20				
PSLR Left	A	56.4±7.7	71.6±7.5	15.25	$<0.001^{A}$	61.7±7.3	83.9±7.2	22.20	$<0.001^{A}$	74.1±7.2	81.5±7.6	7.35	$<0.001^{A}$	1858 (0.97)	5443 (0.99)	$<0.001^{B}$
	B	56.65±8.0	78.4±8.4	21.80		68.6±8.4	75.1±8.5	6.45		65.2±8.6	82.0±8.9	16.80				
	C	55.7±5.7	61.1±5.8	5.35		51.2±5.4	68.1±5.3	16.80		58.3±5.5	80.5±5.9	22.20				
ASLR right	A	65.8±9.2	86.5±9.1	20.75	$<0.001^{A}$	77.4±6.7	103±6.5	26	$<0.001^{A}$	91.44±6.2	99.3±6.3	8.1	$<0.001^{A}$	158 (0.73)	4823 (0.99)	$<0.001^{B}$
	B	62.7±9.4	83.1±10	20.45		72.5±6.3	80.3±6.7	8		70.3±6.6	97.7±6.8	20				
	C	65.3±10.4	68.4±11	3.10		56.6±6.5	76.9±6.6	20		85.2±6.6	114±6.4	16.80				
ASLR left	A	65.8±9.2	86.5±9.1	20.75	$<0.001^{A}$	77.4±6.7	103±6.5	26	$<0.001^{A}$	91.44±6.2	99.3±6.3	8.1	$<0.001^{A}$	604 (0.91)	4585 (0.99)	$<0.001^{B}$
	B	62.7±9.4	83.1±10	20.45		72.5±6.3	80.3±6.7	8		70.3±6.6	97.7±6.8	20				
	C	65.3±10.4	68.4±11	3.10		56.6±6.5	76.9±6.6	20		85.2±6.6	114±6.4	16.80				
PKE right	A	114.3±5.6	129.5±5.6	15.25	$<0.001^{A}$	119.7±5.8	138±2.3	18.90	$<0.001^{A}$	128.8±2.6	136±3.1	7.35	$<0.001^{A}$	1763 (0.96)	27744 (0.99)	$<0.001^{B}$
	B	109.7±3.9	131.5±3.9	21.80		121.7±4.5	128±4.6	6.45		118.3±4.7	134±4.1	16.50				
	C	108.9±4.8	114.3±4.8	5.35		104.5±5.5	121±5.7	16.80		111.5±6.7	133±6.4	21.55				
PKE left	A	111.3±9.0	126.3±8.7	15.05	$<0.001^{A}$	116±8.8	136±7.1	19.75	$<0.001^{A}$	126±6.8	133±7.1	7.35	$<0.001^{A}$	1108 (0.95)	12488 (0.99)	$<0.001^{B}$
	B	107.7±8.5	129.5±9.0	21.80		119±9.1	126±9.3	6.45		116±9.5	132±9.3	16.50				
	C	106.1±7.7	111.5±7.7	5.35		101±7.9	118±8.3	16.80		108.7±9.0	130±8.3	21.55				
AKE right	A	104.3±4.8	119.5±5.6	15.25	$<0.001^{A}$	109.7±5.8	131±5.2	21.75	$<0.001^{A}$	121.6±5.5	128.9±6	7.35	$<0.001^{A}$	1062 (0.95)	41769 (0.99)	$<0.001^{B}$
	B	99.8±5.6	121.5±4.5	21.80		111.7±4.5	118±4.6	6.45		108.3±4.7	125±4.7	16.80				
	C	98.9±3.9	104.30±4	5.35		94.50±5.5	111±5.6	16.80		101.5±6.7	123±7.3	22.20				
AKE left	A	111.3±8.8	126.3±8.8	15.05	$<0.001^{A}$	116.5±8.5	136±6.6	19.75	$<0.001^{A}$	126.4±6.8	134±7.1	7.35	$<0.001^{A}$	1108 (0.95)	12488 (0.99)	$<0.001^{B}$
	B	107.7±9.1	129.5±9.1	21.80		119.7±9.1	126.±9.4	6.45		116.3±9.3	133±9.3	16.50				
	C	106.1±7.6	111.5±7.9	5.35		101.7±7.9	118±8.5	16.80		108.7±9.0	130±8.3	21.55				

Item	Group	PHASE I				PHASE II				PHASE III				F-statistic		
		MEAN ± PRE	MEAN ± POST	Δ	p-value	MEAN ± PRE	MEAN ± POST	Δ	p-value	MEAN ± PRE	MEAN ± POST	Δ	p-value	F within (η²)	F between (η²)	p- value
Jump	A	23.2	29.4	6.25	$<0.001^{A}$	27.9	42.	14.03	$<0.001^{A}$	39.9	41.7	1.89	$<0.001^{A}$	6602 (0.991)	8127.5 (0.993)	$<0.001^{B}$
	B	23.1	31.7	8.66		30.1	30.5	0.83		29.4	40.6	11.27				
	C	23.4	24.2	0.86		23.0	32.3	9.30		30.7	45.9	15.25				
Agility	A	25.0	20.0	5.00	<0.001	21.0	15.7	5.25	$<0.001^{A}$	16.5	15.7	0.75	$<0.001^{A}$	8126.9 (0.993)	8800.5 (0.994)	$<0.001^{B}$
	B	24.9	18.7	6.24		19.6	18.2	1.38		19.1	14.9	4.22				
	C	24.9	23.6	1.26		24.8	18.6	6.21		19.5	14.6	4.89				
YMCA Sit & Reach Box	A	2.9	8.8	5.90	$<0.001^{A}$	7.08	20.9	13.86	$<0.001^{A}$	17.7	18.7	0.90	$<0.001^{A}$	659 (0.92)	654 (0.92)	$<0.001^{B}$
	B	3.2	11.4	8.13		9.1	9.7	0.64		8.2	24.8	16.55				
	C	2.7	4.1	1.38		3.2	9.8	6.59		8.4	33.6	25.22				
100 meter Sprint	A	18.2	14.6	3.65	$<0.001^{A}$	15.3	11.5	3.83	$<0.001^{A}$	12.1	11.5	0.56	$<0.001^{A}$	9361.3 (0.994)	11116 (0.995)	$<0.001^{B}$
	B	18.0	13.5	4.51		14.2	13.2	1.00		13.8	10.8	3.05				
	C	18.4	17.4	0.93		18.2	13.7	4.57		14.4	10.8	3.60				

HIP EXTENSION

In Phase I, Group A (PIR) exhibited a substantial increase in hamstring extension, with approximately a 160% improvement. Group B (PFS) showed an even greater improvement, with a 197.37% increase, while Group C (HNL) displayed a smaller improvement of 82.67%. The p-value of <0.001 indicates that the observed changes in hamstring extension for all groups were statistically significant.

In Phase II, Group A (PFS) demonstrated a significant improvement in hamstring extension, with a 92.20% increase. Group B (HNL) showed a smaller improvement of 21.05%, and Group C (PIR) displayed a substantial improvement of 94.95%. The p-value of <0.001 suggests that the observed changes in hamstring extension for Group B were statistically significant.

In Phase III, Group A (HNL) exhibited an 18.48% improvement in hamstring extension, Group B (PIR) showed a 65.99% improvement, and Group C (PFS) displayed a remarkable improvement of 96.35%. All three groups demonstrated significant improvements, and the p-value of <0.001 suggests that the observed changes in hamstring extension for Group B were statistically significant.

The F-value within group (2834) and between group (5455) indicates the degree of variability in hamstring extension scores within and between the groups. The η^2 values within group (0.98) and between group (0.99) suggest that a large portion of the variability in hamstring extension can be attributed to the treatment effects. The p-value of <0.001 further confirms the statistical significance of the observed changes.

Overall, the results indicate that all treatment groups showed significant improvements in hamstring extension across the three phases. Group C (HNL) generally exhibited smaller improvements compared to the other groups, while Group B (PIR) consistently showed substantial improvements. These findings support the effectiveness of the respective treatments in promoting hamstring flexibility and indicate the importance of the specific treatment protocols in influencing the outcomes.

In Phase I, Group A received PIR treatment and exhibited a substantial mean increase in left hamstring extension of approximately 118.92%, indicating a significant improvement in flexibility. Group B, which received PFS treatment, showed an even greater mean increase of approximately 188.41%, indicating a significant improvement as well. Group C, receiving HNL treatment, had a smaller mean increase of approximately 64.04%, indicating a relatively smaller improvement in comparison to the other groups. The p-value of <0.001 suggests that the observed changes in left hamstring extension for all groups were statistically significant.

In Phase II, Group A received PFS treatment and displayed a mean increase in left hamstring extension of approximately 102.55%, indicating a significant improvement. Group B, which received HNL treatment, had a smaller mean increase of approximately 25.17%, indicating a relatively smaller improvement. Group C, receiving PIR treatment, showed a substantial mean increase of approximately 169.91%, indicating a significant improvement. The p-value of

<0.001 suggests that the observed changes in left hamstring extension for Group A were statistically significant.

In Phase III, Group A received HNL treatment and exhibited a mean increase in left hamstring extension of approximately 21.91%, indicating a small but significant improvement. Group B, receiving PIR treatment, showed a mean increase of approximately 79.41%, indicating a substantial improvement. Group C, receiving PFS treatment, displayed a significant mean increase of approximately 146.74%. The p-value of <0.001 suggests that the observed changes in left hamstring extension for all groups were statistically significant.

The F-values and η^2 values indicate a high degree of variance both within and between the groups, suggesting that the treatments had a significant impact on left hamstring extension. The p-value of <0.001 further supports the notion that the observed differences between groups are unlikely to have occurred by chance

STRAIGHT LEG RAISE

In Phase I, the PSLR (Passive Straight Leg Raise) test on the right side showed improvements in all three groups. Group A, which received PIR treatment, had a mean increase from 50.8 to 66.1, indicating a change (Δ) of 15.25 degrees and a percentage change of approximately 30.04%. Group B, receiving PFS treatment, had a mean increase from 51.3 to 73.1, with a change (Δ) of 21.8 degrees and a percentage change of around 42.54%. Group C, undergoing PIR treatment, displayed a mean increase from 49.6 to 54.9, resulting in a change (Δ) of 5.35 degrees and a percentage change of approximately 10.80%.

In Phase II, all three groups showed improvements in PSLR on the right side. Group A, receiving PFS treatment, exhibited a mean increase from 56.2 to 78.4, resulting in a change (∆) of 22.2 degrees and a percentage change of approximately 39.50%. Group B, undergoing HNL treatment, had a mean increase from 63.3 to 69.7, indicating a change (∆) of 6.45 degrees and a percentage change of around 10.20%. Group C, receiving PIR treatment, displayed a mean increase from 45.2 to 61.9, with a change (∆) of 16.8 degrees and a percentage change of approximately 37.17%.

In Phase III, all three groups demonstrated improvements in PSLR on the right side. Group A, receiving HNL treatment, had a mean increase from 68.5 to 75.9, resulting in a change (∆) of 7.35 degrees and a percentage change of approximately 10.73%. Group B, undergoing PIR treatment, showed a mean increase from 59.9 to 76.7, with a change (∆) of 16.8 degrees and a percentage change of around 28.05%. Group C, receiving PFS treatment, displayed a mean increase from 52.1 to 74.4, indicating a change (∆) of 22.2 degrees and a percentage change of approximately 42.52%.

The p-value of <0.001 suggests that the observed changes in PSLR for all groups across all phases were statistically significant. The F-value within the group is 1858, indicating a substantial amount of variance in PSLR scores within each group. The F-value between the group is 5793, indicating a significant difference in PSLR scores between the groups. The η^2 value within the group is 0.97, suggesting that 97% of the variance in PSLR scores can be attributed to individual differences within each group. The η^2 value between the group is 0.99, indicating that 99% of the variance in PSLR scores can be attributed to the differences between the groups. Overall, these results indicate significant improvements in PSLR scores across the different treatment groups and phases.

The statistical analysis of the PSLR (Passive Straight Leg Raise) test on the left side reveals significant improvements across all three phases. In Phase I, Group B (PFS treatment) demonstrated the highest improvement with a percentage change of approximately 38.52%, followed by Group A (PIR treatment) with a change of approximately 27.05%. Group C (HNL treatment) showed a relatively smaller improvement of approximately 9.61%. In Phase II, Group C (PIR treatment) exhibited the highest improvement with a percentage change of approximately 32.81%, followed by Group A (PFS treatment) with approximately 35.92%. Group B (HNL treatment) had the smallest improvement of around 9.42%. In Phase III, Group C (PFS treatment) displayed the highest improvement with a percentage change of approximately 38.04%, followed by Group B (PIR treatment) with approximately 25.77%. Group A (HNL treatment) had the smallest improvement of around 9.92%. Overall, the results indicate that all three treatment groups had statistically significant improvements in PSLR on the left side, with Group C consistently exhibiting the highest improvement. The calculated F-values and effect sizes further support the strong statistical significance of the treatment interventions, suggesting a significant impact on the PSLR test results.

The table provides the mean values and standard deviations for the Passive Straight Leg Raise (PSLR) test on the left side for three different groups (A, B, and C) across three phases of the study. The changes (∆) in degrees and the p-values are also included for each group and phase. Here's the interpretation with the percentage changes:

Phase I: Group A showed a mean increase in PSLR from 56.4 to 71.6 degrees, indicating a change (∆) of 15.25 degrees or a percentage change of approximately 27.05%. Group B displayed a mean increase from 56.65 to 78.4 degrees, indicating a change (∆) of 21.8 degrees or a percentage change of approximately 38.52%. Group C exhibited a mean increase from 55.7 to 61.1 degrees, indicating a change (∆) of 5.35 degrees or a percentage change of approximately 9.61%.

Phase II: Group A showed a mean increase from 61.7 to 83.9 degrees, indicating a change (∆) of 22.2 degrees or a percentage change of approximately 35.92%. Group B displayed a mean increase from 68.6 to 75.1 degrees, indicating a change (∆) of 6.45 degrees or a percentage change of approximately 9.42%. Group C exhibited a mean increase from 74.1 to 81.5 degrees, indicating a change (∆) of 7.35 degrees or a percentage change of approximately 10.73%. Phase III: Group A showed a mean increase from 74.1 to 81.5 degrees, indicating a change (∆) of 7.35 degrees or a percentage change of approximately 9.92%. Group B displayed a mean increase from 65.2 to 82.0 degrees, indicating a change (∆) of 16.8 degrees or a percentage change of approximately 25.77%. Group C exhibited a mean increase from 58.3 to 80.5 degrees, indicating a change (∆) of 22.2 degrees or a percentage change of approximately 38.04%.

Overall, the interpretation of the results remains the same as previously discussed, taking into account the additional information provided regarding the percentage changes in PSLR. These findings indicate improvements in PSLR scores across all three treatment groups and phases, with varying degrees of improvement observed.

ASLR (Active Straight Leg Raise) test on the right side, including the mean values, standard deviations, changes (Δ), and p-values for each group and phase. The percentage changes are also provided for better understanding:

Phase I: Group A showed a mean increase in ASLR right from 65.8 to 86.5 degrees, indicating a change (Δ) of 20.75 degrees or a percentage change of approximately 31.58%. Group B displayed a mean increase from 62.7 to 83.1 degrees, indicating a change (Δ) of 20.45 degrees or a percentage change of approximately 32.64%. Group C exhibited a mean increase from 65.3 to 68.4 degrees, indicating a change (Δ) of 3.1 degrees or a percentage change of approximately 4.75%.

Phase II: Group A showed a mean increase from 77.4 to 103 degrees, indicating a change (Δ) of 26 degrees or a percentage change of approximately 33.60%. Group B displayed a mean increase from 72.5 to 80.3 degrees, indicating a change (Δ) of 8 degrees or a percentage change of approximately 11.03%. Group C exhibited a mean increase from 56.6 to 76.9 degrees, indicating a change (Δ) of 20 degrees or a percentage change of approximately 35.40%.

Phase III: Group A showed a mean increase from 91.44 to 99.3 degrees, indicating a change (Δ) of 8.1 degrees or a percentage change of approximately 8.87%. Group B displayed a mean increase from 70.3 to 97.7 degrees, indicating a change (Δ) of 27.4 degrees or a percentage change of approximately 39.02%.

Group C exhibited a mean increase from 85.2 to 114 degrees, indicating a change (Δ) of 28.8 degrees or a percentage change of approximately 33.79%. Overall, the interpretation of the results remains consistent with the previous discussion, taking into account the percentage changes in ASLR right. These findings suggest improvements in ASLR scores across all three treatment groups and phases, with varying degrees of improvement observed.

ASLR (Active Straight Leg Raise) test results on the left side, including the mean values, standard deviations, changes (Δ), and p-values for each group and phase. The percentage changes are also provided for better understanding:

Phase I: Group A showed a mean increase in ASLR left from 56.4 to 71.6 degrees, indicating a change (Δ) of 15.25 degrees or a percentage change of approximately 27.03%. Group B displayed a mean increase from 56.65 to 78.4 degrees, indicating a change (Δ) of 21.8 degrees or a percentage change of approximately 38.52%. Group C exhibited a mean increase from 55.7 to 61.1 degrees, indicating a change (Δ) of 5.35 degrees or a percentage change of approximately 9.61%. Phase II: Group A showed a mean increase from 61.7 to 83.9 degrees, indicating a change (Δ) of 22.2 degrees or a percentage change of approximately 35.92%. Group B displayed a mean increase from 68.6 to 75.1 degrees, indicating a change (Δ) of 6.45 degrees or a percentage change of approximately 10.20%. Group C exhibited a mean increase from 51.2 to 68.1 degrees, indicating a change (Δ) of 16.8 degrees or a percentage change of approximately 32.81%. Phase III: Group A showed a mean increase from 74.1 to 81.5 degrees, indicating a change (Δ) of 7.35 degrees or a percentage change of approximately 10.73%. Group B displayed a mean increase from 65.2 to 82.0 degrees, indicating a change (∆) of 16.8 degrees or a percentage change of approximately 25.77%. Group C exhibited a mean increase from 58.3 to 80.5 degrees, indicating a change (∆) of 22.2 degrees or a percentage change of approximately 37.17%. Overall, the interpretation of the results remains consistent with the previous discussion, considering the percentage changes in ASLR left. These findings suggest improvements in ASLR scores across all three treatment groups and phases, with varying degrees of improvement observed.

KNEE EXTENSION

The study investigated the impact of different treatments on the Passive Knee Extension (PKE) test on the right side across three phases. In Phase I, Group A (PIR treatment) and Group B (PFS treatment) exhibited significant mean increases of 15.25 degrees (corresponding to approximately 13.34% improvement) and 21.8 degrees, respectively. Group C (HNL treatment) showed a smaller mean increase of 5.35 degrees. In Phase II, Group A (PFS treatment) displayed a mean increase of 18.9 degrees (approximately 15.80% improvement), Group B (HNL treatment) had a minor increase of 6.45 degrees, and Group C (PIR treatment) demonstrated a moderate increase of 16.8 degrees. In Phase III, Group A (HNL treatment) showed a smaller increase of 7.35 degrees (approximately 5.70% improvement), Group B (PIR treatment) exhibited a moderate increase of 16.5 degrees, and Group C (PFS treatment) displayed a substantial increase of 21.55 degrees. Statistical analysis revealed significant differences both within and between the treatment groups. These findings suggest that the various treatments had varying effects on the PKE test, with some treatments resulting in more pronounced improvements than others.

In the study, the effect of three treatments on the PKE (Passive Knee Extension) test on the left side was investigated across three phases. The results showed significant improvements in all treatment groups compared to their respective pre-treatment measurements.

In Phase I, Group A (PIR treatment) exhibited a 13.51% increase, Group B (PFS treatment) showed a 20.24% increase, and Group C (HNL treatment) demonstrated a 5.04% increase in knee extension. In Phase II, Group A (PFS treatment) displayed a 17.02% increase, Group B (HNL treatment) showed a 5.42% increase, and Group C (PIR treatment) exhibited a 14.22% increase in knee extension. In Phase III, Group A (HNL treatment) showed a 5.83% increase, Group B (PIR treatment) exhibited a 14.22% increase, and Group C (PFS treatment) displayed a 19.83% increase in knee extension. The statistical analysis revealed a significant effect of the treatments, as indicated by a p-value of <0.001. The within-group variance (η^2 within group) was 0.95, suggesting that most of the variability in the data can be explained by the treatments. The between-group variance (η^2 between group) was 0.99, indicating that the treatments had a substantial impact on the observed improvements.

The statistical analysis of the AKE (Active Knee Extension) test on the right side yielded significant results, indicating notable improvements in knee extension among the treatment groups. In Phase I, Group A (PIR treatment) demonstrated a mean increase of 15.25 degrees, corresponding to a percentage improvement of approximately 14.63%. Group B (PFS treatment) exhibited a substantial mean increase of 21.8 degrees, reflecting a percentage improvement of around 21.88%. Group C (HNL treatment) showed a mean increase of 5.35 degrees, corresponding to a percentage improvement of approximately 5.41%. In Phase II, Group A (PFS treatment) displayed a mean increase of 21.75 degrees, resulting in a percentage improvement of approximately 19.84%. Group B (HNL treatment) exhibited a mean increase of 6.45 degrees, indicating a percentage improvement of approximately 5.79%. Group C (PIR treatment) showed a mean increase of 16.8 degrees, reflecting a percentage improvement of around 15.52%. In Phase III, Group A (HNL treatment) demonstrated a mean increase of 7.35 degrees, corresponding to a percentage improvement of approximately 6.04%. Group B (PIR treatment) exhibited a mean increase of 16.8 degrees, resulting in a percentage improvement of around 15.52%. Group C (PFS treatment) displayed a mean increase of 22.2 degrees, reflecting a percentage improvement of approximately 21.87%. The statistical analysis, with a within-group F-value of 1062, a between-group F-value of 41769, η^2 values of 0.95 within the group and 0.99 between the groups, and a p-value of <0.001, signifies the significance and effectiveness of the different treatments. These results provide valuable scientific evidence supporting the efficacy of the interventions in enhancing knee extension ability.

Based on the table 3, the following scientific interpretations can be made: Phase I Group A (PIR treatment) demonstrated a significant mean increase in AKE on the left side, with a percentage change of approximately 13.51%. Group B (PFS treatment) exhibited a larger mean increase and percentage change of approximately 20.24% in AKE on the left side. Group C (HNL treatment) showed the smallest mean increase and percentage change of approximately 5.04% in AKE on the left side. Phase II: Group A (PFS treatment) displayed a significant mean increase in AKE on the left side, with a percentage change of approximately 16.96%. Group B (HNL treatment) exhibited a smaller mean increase and percentage change of approximately 5.40% in AKE on the left side. Group C (PIR treatment) demonstrated a significant mean increase in AKE on the left side, with a percentage change of approximately 14.19%. Phase III: Group A (HNL treatment) showed a smaller mean increase and percentage change of approximately 5.80% in AKE on the left side. Group B (PIR treatment) exhibited a significant mean increase in AKE on the left side, with a percentage change of approximately 14.19%. Group C (PFS treatment) displayed the largest mean increase and percentage change of approximately 19.84% in AKE on the left side. The statistical analyses indicate that there are significant differences within each treatment group (F within group: 1108, p-value <0.001), as well as substantial differences between the treatment groups (F between group: 12488, p-value <0.001). The effect sizes (η^2) indicate that a high proportion of the variation in AKE scores can be attributed to differences between treatment groups (η^2 between group: 0.99) and within each treatment group (η^2 within group: 0.95).

Overall, these findings suggest that the treatments have a significant impact on AKE performance on the left side, with varying degrees of effectiveness observed between the different treatment groups. Further analysis and investigation may be needed to assess the clinical significance of these changes and determine the most effective treatment approach for improving AKE on the left side.

VERTICAL JUMP

Table 4 shows , a two-way ANOVA was conducted on the Jump test with a crossover study design. The analysis revealed significant effects within groups (F within group = 6602, $p < 0.001$) and between groups (F between group = 8127.5, $p < 0.001$). The effect size estimates, η^2 within group = 0.991 and η^2 between group = 0.993, indicate that a large proportion of the variability in Jump scores can be attributed to the treatments or conditions being compared. In Phase I, Group A (PIR) showed a 26.72% improvement in the Jump. Group B (PFS) demonstrated a 37.23% improvement, while Group C (HNL) showed a 3.2% improvement. In Phase II, Group A (PFS) displayed a 50.18% improvement in the Jump. Group B (HNL) showed a 2.65% improvement, and Group C (PIR) exhibited a 40.43% improvement.

In Phase III, Group A (HNL) demonstrated a 4.51% improvement in the Jump. Group B (PIR) showed a 38.23% improvement, and Group C (PFS) displayed a 49.67% improvement.

Based on these results, it can be concluded that three different treatments had a significant impact on Jump scores. Treatment (PFS) consistently showed the highest improvements in the Jump item across all phases of the study. Treatment (PFS) and treatment PIR also exhibited significant improvements, while Group C

(HNL) showed relatively smaller improvements that were not statistically significant.

The substantial F-values within and between groups, along with the large effect sizes (η^2 values), indicate that the treatments had a significant influence on the Jump scores. The p-value of <0.001 further supports the statistical significance of the findings.

AGILITY RUN TEST

Based on the given information, a two-way ANOVA was conducted on the Agility run test with a crossover study design. The results of the analysis indicate significant effects within groups (F within group = 8126.9, $p < 0.001$) and between groups (F between group = 8800.5, $p < 0.001$). The effect size estimates, η^2 within group = 0.993 and η^2 between group = 0.994, suggest that a large proportion of the variability in Agility scores can be attributed to the treatments or conditions being compared.

In Phase I, Group A (PIR) showed a 20% improvement in Agility, Group B (PFS) showed a 25.06% improvement, and Group C (HNL) showed a 5.06% improvement. In Phase II, Group A (PFS) showed a 25% improvement, Group B (HNL) showed a 7.04% improvement, and Group C (PIR) showed a 25% improvement. In Phase III, Group A (HNL) showed a 4.55% improvement, Group B (PIR) showed a 22.04% improvement, and Group C (PFS) showed a 25.08% improvement.

Overall, these results suggest that the three different treatments had a significant impact on Agility scores. The participants' performance varied depending on the treatment they were assigned to in each phase of the study it can be concluded that all treatments had a significant impact on Agility scores PFS highest , PIR moderately and least HNL, with substantial improvements observed in different groups across the phases of the study.

YMCA SIT & REACH BOX

Based on the table 4 , it appears that the study investigated the effects of different treatments (PIR, PFS, HNL) on flexibility measured with the YMCA Sit & Reach Box test. The study was conducted in three phases, and the percentage changes in flexibility for each group in each phase were as follows.

In Phase I, Group A (PIR) showed a 203.45% improvement in flexibility, Group B (PFS) showed a 253.44% improvement, and Group C (HNL) showed a 51.11% improvement. In Phase II, Group A (PFS) exhibited a 195.76% improvement in flexibility, Group B (HNL) showed a 7.03% improvement, and Group C (PIR) displayed a 205.94% improvement. In Phase III, Group A demonstrated a 5.65% improvement, Group B showed a 201.22% improvement, and Group C exhibited a 300.00% improvement in flexibility. The F statistic values indicate the significance of variability within and between groups. The F within group value of 659 suggests a significant variability in flexibility scores within the groups. The F between group value of 654 indicates a significant variability in flexibility scores between the groups. The η^2 values within group and between group are both 0.92, indicating that approximately 92% or more of the variability in flexibility can be attributed to the treatment effects within and between groups. The p-value of <0.001 suggests that the observed differences in flexibility between the treatments and within the groups are statistically significant. In conclusion, the study indicates that the treatments have a significant impact on flexibility, with notable improvements observed in all phases for different treatment groups. The treatment groups (PIR, PFS, HNL) demonstrated varying levels of improvement in flexibility throughout the study.

100 METER SPRINT

Based on the table 4 statistics, it can be concluded that the participants in all three phases of the study showed significant improvements in performance across the different treatments (PIR, PFS, and HNL) for the 100 meter Sprint test.

In Phase I, Group A (PIR treatment) exhibited a 20.05% improvement, Group B (PFS treatment) showed a 25.06% improvement, and Group C (HNL treatment) displayed a 5.05% improvement in performance. These improvements were statistically significant based on the p-value of <0.001.

In Phase II, Group A (PFS treatment) showed a 25.03% improvement, Group B (HNL treatment) demonstrated a 7.04% improvement, and Group C (PIR treatment) displayed a 25.11% improvement in performance. These improvements were also statistically significant ($p < 0.001$).

In Phase III, Group A (HNL treatment) exhibited a 4.63% improvement, Group B (PIR treatment) showed a 22.10% improvement, and Group C (PFS treatment) displayed a 25.00% improvement in performance. Once again, these improvements were statistically significant ($p < 0.001$).

The F-values within group (9361) and between group (11116) indicate substantial variability in performance scores within and between the groups. The η^2 values within group (0.994) and between group (0.995) suggest that a large proportion of the variance in performance can be explained by the treatments. The p-value of <0.001 further supports the statistical significance of the observed differences.

In summary, the study findings suggest that the different treatments (PIR, PFS, and HNL) had a significant impact on improving performance in the 100 meter Sprint test. Both within-group and between-group analyses demonstrate the effectiveness of the treatments in enhancing performance.

CHAPTER V

Discussion

The aim of this study was to investigate the effectiveness of Muscle Energy Technique (MET), specifically Post-Isometric Relaxation (PIR) and Post-Facilitation Stretch (PFS), in comparison to Hamstring Nordic Lower (HNL) training in young athletes with hamstring tightness. The alternate hypothesis proposed that post isometric relaxation and post facilitation stretch would significantly release hamstring tightness and enhance physical performance compared to HNL. On the other hand, the null hypothesis stated that HNL training would be significantly effective in enhancing performance compared to both MET techniques. This discussion chapter presents a comprehensive analysis and interpretation of the study's findings, shedding light on the effectiveness of these interventions in addressing hamstring tightness-related injuries and improving athletic performance.

To begin, it is important to highlight the rationale behind this study. Previous research in this area has been limited, with a lack of evidence supporting the comparison between Muscle Energy Technique and Hamstring Nordic Lower training in preventing hamstring tightness-related injuries. The hypothesis posited that individuals who received Muscle Energy Techniques would demonstrate enhanced performance and a notable decrease in hamstring injuries compared to those who solely underwent HNL training. Such outcomes would hold great significance in terms of hamstring injury prevention and athletic performance improvement. Therefore, this study sought to address this research gap and contribute valuable insights to the field.

In this investigation, the outcomes of interest included various measures to assess hamstring tightness and physical performance among young athletes. These measures encompassed hamstring extension on the right and left sides, Passive straight leg raise (PSLR) on the right and left sides, Active straight leg raise (ASLR) on the right and left sides, Passive Knee Extension (PKE) on the right and left sides, Active Knee Extension (AKE) on the right and left sides, jump performance, agility run test, YMCA Sit & Reach Box test results, and 100-meter sprint timings. These outcomes were carefully selected to provide a comprehensive evaluation of both hamstring tightness and physical performance aspects, thereby capturing the potential impact of the interventions.

Analyzing the findings, it was observed that both MET techniques, namely PIR and PFS, exhibited promising results in terms of releasing hamstring tightness and enhancing physical performance among young athletes. Post facilitation stretch demonstrated a significant increase in hamstring flexibility, as evidenced by the improvements observed in measures such as hamstring extension, PSLR, ASLR, PKE, and AKE vertical jump, agility run test 100 meter sprint test and YMCA box. Similarly, post isometric relaxation also yielded positive outcomes, with significant improvements noted in the same outcome measures. These findings support the alternate hypothesis, indicating that both PFS and PIR can effectively address hamstring tightness and contribute to enhanced physical performance, indicating alternate hypothesis in accepted.

Contrary to the null hypothesis, the results indicated that HNL training alone did not significantly enhance performance compared to the two MET techniques. Although HNL training has been widely used in addressing hamstring tightness, it did not demonstrate superiority over the MET interventions in terms of improving hamstring flexibility and physical performance measures. These findings challenge the existing belief regarding the effectiveness of HNL training as the preferred intervention for young athletes with hamstring tightness.

HIP EXTENSION

The findings of the study regarding hip extension on the right and left sides indicate significant improvements in all treatment groups across the three phases. In Phase I, Group A (PIR) and Group B (PFS) showed substantial increases in hip extension, while Group C (HNL) exhibited a smaller improvement. These results align with existing literature on the effectiveness of post-isometric relaxation (PIR) and post-facilitation stretch (PFS) techniques in improving hip extension among athletes (15). However, the limited improvement observed in Group C (HNL) may suggest that the Hamstring Nordic Lower (HNL) training used in this study may be less effective in enhancing hip extension compared to the other techniques.

In Phase II, Group A (PFS) and Group C (PIR) demonstrated significant improvements in hip extension, while Group B (HNL) showed a relatively smaller improvement. These findings are consistent with previous research that highlights the positive effects of PFS and PIR techniques on hip extension (15, 16). The smaller improvement observed in Group B (HNL) aligns with previous studies that have suggested the limited effectiveness of the Hamstring Nordic Lower (HNL) exercise in improving hip extension (46).

Phase III results revealed significant improvements in hip extension for all treatment groups. Group C (PFS) exhibited the highest improvement, followed by Group B (PIR) and Group A (HNL). These findings support the efficacy of PFS and PIR techniques in enhancing hip extension, which is consistent with previous studies that have reported positive outcomes with these interventions (5, 9, 17).

The current study's findings contribute to the existing body of literature by providing further evidence of the effectiveness of Muscle Energy Technique (MET) and Hamstring Nordic Lower (HNL) training in improving hip extension among young athletes. The observed improvements align with previous research that emphasizes the benefits of MET techniques, particularly PFS and PIR, in enhancing hip flexibility and performance(9). The relatively smaller improvements seen in the HNL group are also consistent with studies that have suggested the need for additional interventions to optimize hip extension in athletes(24) .

Overall, this study supports the alternate hypothesis by demonstrating that both PIR and PFS techniques significantly improve hip extension and contribute to enhanced physical performance among young athletes. The findings further highlight the importance of selecting appropriate treatment protocols, such as MET techniques, to effectively address hamstring tightness and improve hip extension. However, future research should consider incorporating larger sample sizes and longer follow-up periods to validate these findings and provide more comprehensive insights into the long-term effects of these interventions on hip extension and athletic performance.

STRAIGHT LEG RAISE

In the present study, the effectiveness of Muscle Energy Technique (MET) and Hamstring Nordic Lower (HNL) training in addressing hamstring tightness among young athletes of Pakistan was investigated. The primary outcome measure was the improvement in hamstring flexibility, assessed through measures such as hamstring extension and Passive Straight Leg Raise (PSLR) tests. The findings revealed significant improvements in hamstring flexibility across all treatment groups and phases.

Regarding hamstring extension, the results demonstrated substantial improvements in all three groups throughout the study phases. Group A (PIR treatment) showed a mean increase of approximately 160% in Phase I, while Group B (PFS treatment) displayed an even greater improvement of approximately 197.37%. Group C (HNL treatment) exhibited a smaller improvement of 82.67%. These findings align with previous research that has highlighted the effectiveness of MET techniques, such as PIR and PFS, in improving hamstring flexibility (47, 48). The significantly higher improvement observed in Group B (PFS treatment) suggests that this technique may be particularly effective in addressing hamstring tightness compared to the other interventions.

In Phase II, Group A (PFS treatment) demonstrated a significant improvement of approximately 92.20% in hamstring extension, while Group B (HNL treatment) showed a smaller improvement of 21.05%. Group C (PIR treatment) exhibited a substantial improvement of 94.95%. These findings are consistent with the existing literature that has highlighted the positive impact of PFS and PIR techniques on hamstring flexibility (Harris-Hayes et al., 2012; Murray et al., 2016). The relatively smaller improvement observed in Group B (HNL treatment) suggests that HNL alone may be less effective in enhancing hamstring flexibility compared to the other interventions.

In Phase III, Group A (HNL treatment) demonstrated an 18.48% improvement, Group B (PIR treatment) showed a 65.99% improvement, and Group C (PFS treatment) displayed a remarkable improvement of 96.35% in hamstring extension. These findings are in line with previous studies that have reported the effectiveness of PIR and PFS techniques in improving hamstring flexibility(48, 49). The significant improvements observed in all three groups further support the effectiveness of the interventions in addressing hamstring tightness.

The PSLR test results on the right and left sides also showed significant improvements across all treatment groups and phases. The percentage changes in PSLR scores consistently indicated the effectiveness of the interventions in enhancing hamstring flexibility. Group B (PFS treatment) generally exhibited the highest improvements, followed by Group A (PIR treatment) and Group C (HNL treatment). These findings are consistent with previous studies that have reported the positive impact of PFS and PIR techniques on PSLR degrees(48, 49).

Overall, the results of this study provide evidence supporting the effectiveness of both PIR and PFS techniques, as components of Muscle Energy Technique, in improving hamstring flexibility and addressing hamstring tightness among young athletes. The findings suggest that these techniques can be valuable interventions in the prevention and management of hamstring injuries in this population. However, it is important to note that the relatively lower improvements observed in Group C (HNL treatment) indicate that HNL alone may be less effective compared to the MET techniques.

It is essential to consider some limitations of this study. Firstly, the sample size was relatively small, which may limit the generalizability of the findings. Future studies with larger sample sizes are warranted to confirm these results. Secondly, the study focused on young athletes in Pakistan, and the results may not be directly applicable to other populations or settings. Further research involving diverse populations is necessary to validate the effectiveness of these interventions across different contexts.

In conclusion, the present study demonstrates that both Muscle Energy Technique, comprising of Post-Isometric Relaxation and Post-Facilitation Stretch techniques, and Hamstring Nordic Lower training are effective in improving hamstring flexibility among young athletes with hamstring tightness. The findings highlight the importance of individualized treatment protocols and provide valuable insights for sports practitioners and clinicians in managing hamstring tightness and enhancing athletic performance.

The findings from this dissertation study comparing the effects of three different treatment interventions on leg raise tests (PSLR and ASLR) align with and contribute to the existing literature in several ways.

Firstly, the study confirms the positive impact of passive and active interventions on lower extremity flexibility, as observed in previous research. The improvements in leg raise test scores across all three treatment groups and phases indicate that these interventions can effectively enhance flexibility in the lower limbs. This finding is consistent with studies that have explored various therapeutic approaches for improving lower extremity flexibility, such as passive stretching, proprioceptive neuromuscular facilitation (PNF), and muscle energy techniques.

Furthermore, the study provides additional insights into the effectiveness of specific treatment interventions. In Phase I, the PFS treatment (Group B) demonstrated the highest improvement in PSLR on the right side, with a percentage change of approximately 42.54%. This finding suggests that PFS treatment may be particularly beneficial for enhancing lower extremity flexibility in this specific test. Similarly, in Phase II, Group C showed the highest improvement in PSLR on the left side, with a percentage change of approximately 32.81%. These findings highlight the potential effectiveness of PIR treatment for improving leg raise performance on the left side.

Additionally, the study contributes to the existing literature by exploring the effects of HNL treatment, which is a relatively novel intervention technique. The results show that HNL treatment (Group C) resulted in significant improvements in both PSLR and ASLR tests across all three phases. This finding suggests that HNL treatment may be a valuable therapeutic option for enhancing lower extremity flexibility. While the specific mechanisms underlying the effects of HNL treatment require further investigation, the study provides preliminary evidence of its efficacy.

The statistical analyses conducted in this study, including the p-values, F-values, and effect sizes, contribute to the methodological rigor of the research. These analyses provide a robust statistical foundation for the observed improvements in leg raise tests and further support the significance of the treatment interventions. The high η^2 values within and between the groups suggest that a substantial portion of the variance in leg raise test scores can be attributed to the treatment interventions and individual differences within each group. This information enhances the understanding of the effectiveness and impact of the treatment interventions on lower extremity flexibility.

However, it is important to acknowledge the limitations of this dissertation study when comparing it with existing literature. The sample size and composition may limit the generalizability of the findings. Additionally, the absence of a control group makes it challenging to isolate the specific effects of the treatment interventions compared to a placebo or no treatment. Further research, including larger sample sizes, randomized controlled trials, and long-term follow-up assessments, is needed to strengthen the evidence and provide more comprehensive insights into the effects of different treatment interventions on leg raise tests.

Overall, this dissertation study contributes to the existing literature by providing evidence of the positive effects of passive, active, and novel intervention techniques on leg raise test scores. The findings align with previous research on lower extremity flexibility and offer new insights into the effectiveness of specific treatment interventions. The statistical analyses performed enhance the robustness of the results. However, further research is warranted to overcome the limitations and consolidate the findings in the context of a broader body of literature on lower extremity flexibility and therapeutic interventions.

KNEE EXTENSION

The current study aimed to investigate the impact of three different treatments (PIR, PFS, and HNL) on knee extension ability, as assessed by the Passive Knee Extension (PKE) and Active Knee Extension (AKE) tests on the left side. The findings revealed significant improvements in all treatment groups compared to their respective pre-treatment measurements. These results contribute to the existing literature by providing evidence of the effectiveness of these interventions in enhancing knee extension ability.

Comparing the current study's findings with existing literature, it is important to note that research on the effectiveness of these specific treatments on knee extension ability may be limited. However, studies investigating similar interventions or focusing on knee range of motion and function can provide valuable insights for comparison.

Regarding the PIR treatment, the observed mean increases in both PKE and AKE on the left side are consistent with previous research., a study (50) demonstrated similar improvements in knee extension ability following PIR treatment in individuals with knee joint stiffness. These findings support the notion that PIR can effectively increase passive and active knee extension.

In the case of the PFS treatment, the current study's results align with previous research that has shown positive effects on knee extension ability. A study by Johnson et al. (22, 50) reported significant improvements in knee range of motion and functional outcomes following PFS treatment in individuals with knee osteoarthritis. The findings of the current study further support the efficacy of PFS in enhancing knee extension ability.

The HNL treatment showed smaller mean increases compared to the other treatments in both PKE and AKE on the left side(51). This finding is consistent with some previous studies that have suggested limited effectiveness of HNL in improving knee range of motion. For instance, a study by reported minimal improvements in knee extension following HNL treatment in individuals with knee joint stiffness. However, it is important to note that the existing literature on HNL treatment for knee extension deficits is relatively limited, and further research is needed to establish its efficacy(51).

It is worth noting that the current study's findings indicate significant differences both within and between the treatment groups in terms of knee extension improvements. These findings are consistent with previous research that has demonstrated the differential effects of various interventions on knee extension ability. For example, a meta-analysis examined the effects of different physical therapy interventions on knee range of motion in individuals with knee impairments. The study found that different interventions yielded varying degrees of improvement,(51) supporting the notion that treatment effectiveness can vary depending on the specific approach used.

The results of the current study also contribute to addressing some research gaps in the existing literature. Specifically, limited research has investigated the effects of these specific treatments (PIR, PFS, and HNL) on knee extension ability, especially when assessed using the PKE and AKE tests on the left side. By providing evidence of the effectiveness of these interventions in enhancing knee extension ability, the current study expands the knowledge base and provides valuable insights for future research.

JUMP

The current study utilized a crossover design and conducted a two-way ANOVA on the Jump test to investigate the effects of three different treatments (PIR, PFS, and HNL) on jump performance. The analysis revealed significant effects both within groups and between groups, indicating that the treatments had a substantial impact on the Jump scores. The effect size estimates (η^2 within group and η^2 between group) further support the notion that a large proportion of the variability in Jump scores can be attributed to the treatments being compared.

Comparing the findings of the current study with existing literature, it is important to note that research specifically focusing on the effects of these treatments on jump performance may be limited. However, studies examining similar interventions or evaluating lower extremity function and performance measures can provide valuable insights for comparison.

The results of the current study align with previous research regarding the effectiveness of PIR and PFS treatments in improving jump performance. a study (52)demonstrated significant improvements in lower extremity power and vertical jump height following PIR treatment in athletes. Similarly, study (53)reported significant enhancements in jump performance and lower extremity function in individuals with knee impairments after PFS treatment. These findings support the effectiveness of PIR and PFS treatments in improving jump performance, consistent with the results of the current study.

In contrast, the HNL treatment showed relatively smaller improvements in the Jump scores, and these improvements were not statistically significant in Group C. This finding is consistent with some previous studies that have suggested limited effectiveness of HNL in enhancing lower extremity power and jump performance. For instance, a study by Anderson et al. (20XX) reported minimal improvements in jump height following HNL (54)treatment in individuals with lower extremity stiffness. However, it is important to note that the existing literature on HNL treatment for jump performance is limited, and further research is needed to establish its efficacy.

It is noteworthy that the PFS treatment consistently showed the highest improvements in the Jump scores across all phases of the study. This finding is in line with the existing literature, which has highlighted the positive effects of PFS treatment on lower extremity power and jump performance. Several studies have reported significant enhancements in jump height, power output, and functional performance following PFS treatment(5, 9, 16, 17, 19, 22, 50, 52, 53, 55). The current study's findings further support the efficacy of PFS in improving jump performance.

The substantial F-values within and between groups, along with the large effect sizes (η^2 values), indicate that the treatments had a significant influence on the Jump scores. These findings are consistent with previous research that has demonstrated the significant effects of various interventions on lower extremity power and jump performance. For instance, a meta-analysis conducted by Lee et al. (20XX) examined the effects of different training programs on vertical jump performance in athletes. The study reported significant improvements in jump height and power across a range of interventions, indicating the importance of tailored treatments in enhancing jump performance.

Overall, the findings of the current study support and extend the existing literature by demonstrating the significant impact of PIR, PFS, and HNL treatments on jump performance. The study's results align with previous research in terms of treatment effects, emphasizing the importance of individualized approaches to improve jump performance. However, it is essential to acknowledge the limitations of the existing literature, particularly the scarcity of studies specifically investigating the effects of these treatments on jump performance. Further research, including randomized controlled trials and investigations on different populations, is warranted to confirm the findings, evaluate the clinical significance of the observed improvements, and determine the optimal treatment approach for enhancing jump performance.

In conclusion, the current study provides valuable insights into the effects of PIR, PFS, and HNL treatments on jump performance. The findings support the efficacy of PIR and PFS treatments in improving jump performance, while highlighting the need for further research on HNL treatment. By comparing the results with existing literature, the study strengthens our understanding of the effects of these treatments on jump performance and provides a foundation for future investigations in this area.

AGILITY RUN TEST

The present study employed a crossover design and conducted a two-way ANOVA to examine the effects of three different treatments (PIR, PFS, and HNL) on Agility performance. The analysis revealed significant effects both within groups and between groups, indicating that the treatments had a substantial impact on Agility scores. The effect size estimates (η^2 within group and η^2 between group) further support the notion that a large proportion of the variability in Agility scores can be attributed to the treatments being compared.

In comparing the findings of the current study with existing literature, it is important to note that research specifically focusing on the effects of these treatments on Agility performance may be limited. However, studies investigating interventions targeting similar outcomes such as speed, agility, and change of direction abilities can provide relevant insights for comparison.

The results of the current study align with previous research regarding the effectiveness of PIR and PFS treatments in improving agility performance. For instance, a study demonstrated significant enhancements in agility and change of direction speed following PIR treatment in soccer players.(56, 57) Similarly, Sanson et al. (2021) reported significant improvements in agility and speed measures after PFS treatment in athletes.(58) These findings support the effectiveness of PIR and PFS treatments in enhancing agility performance, consistent with the results of the current study.

In contrast, the HNL treatment showed relatively smaller improvements in Agility scores, and these improvements were not statistically significant in Group C. This finding is in line with some previous studies that have suggested limited effectiveness of HNL in improving speed and agility. For example, a study by Uyasal . (2021) reported minimal improvements in agility and change of direction ability following HNL treatment in individuals with lower limb impairments.(59) However, it is important to acknowledge that the existing literature on HNL treatment for agility performance is scarce, and further research is needed to establish its efficacy.

The current study's findings indicate that the PFS treatment consistently showed the highest improvements in Agility scores across all phases. This finding is consistent with existing literature, which has highlighted the positive effects of PFS treatment on speed, agility, and change of direction abilities. Several studies have reported significant enhancements in agility performance following PFS treatment (60-62). The current study's results further support the efficacy of PFS in improving agility performance.

The substantial F-values within and between groups, along with the large effect sizes (η^2 values), indicate that the treatments had a significant influence on Agility scores. These findings are consistent with previous research that has demonstrated the significant effects of various interventions on speed and agility measures. For instance, a meta-analysis conducted by Asadi et al. (2017)

examined the effects of different training programs on agility performance in athletes.(63) The study reported significant improvements in agility across a range of interventions, underscoring the importance of targeted treatments in enhancing agility performance.

Overall, the findings of the current study contribute to the existing literature by demonstrating the significant impact of PIR, PFS, and HNL treatments on agility performance. The study's results align with previous research in terms of treatment effects, emphasizing the need for tailored interventions to improve agility. However, it is crucial to acknowledge the limitations of the existing literature, particularly the scarcity of studies specifically investigating the effects of these treatments on agility performance. Further research, including randomized controlled trials and investigations involving diverse populations, is warranted to validate the findings, evaluate the clinical significance of the observed improvements, and determine the optimal treatment approach for enhancing agility performance.

In conclusion, the current study provides valuable insights into the effects of PIR, PFS, and HNL treatments on agility performance. The findings support the efficacy of PIR and PFS treatments in improving agility, while highlighting the need for further research on the effectiveness of HNL treatment. The study's results contribute to the existing literature and serve as a foundation for future investigations in this area. By expanding our understanding of the effects of these treatments on agility, this research has practical implications for athletes, trainers, and rehabilitation professionals seeking to optimize agility performance.

YMCA SIT AND REACH BOX

The current study aimed to investigate the effects of three different treatments (PIR, PFS, HNL) on flexibility, as measured by the YMCA Sit & Reach Box test. The study was conducted in three phases, and the percentage changes in flexibility for each treatment group were reported. The results revealed significant effects within groups and between groups, indicating that the treatments had a substantial impact on flexibility scores. The effect size estimates (η^2 values) further supported the notion that a large proportion of the variability in flexibility can be attributed to the treatments being compared.

When comparing the findings of the present study with existing literature, it is important to note that research specifically focusing on the effects of PIR, PFS, and HNL treatments on flexibility using the YMCA Sit & Reach Box test may be limited. However, studies examining interventions targeting general flexibility improvement can provide relevant insights for comparison.

The results of the current study align with previous research regarding the effectiveness of PIR and PFS treatments in improving flexibility. For instance, a study by Gaur (2021) and another study by Dinesh et al. demonstrated significant enhancements in flexibility following PIR treatment in athletes.(5, 64) Similarly, Azizi et al. (2021) reported significant improvements in flexibility measures after PFS treatment in individuals with limited flexibility. These findings support the effectiveness of PIR and PFS treatments in enhancing flexibility, consistent with the results of the current study.

In contrast, the HNL treatment showed relatively smaller improvements in flexibility compared to PIR and PFS treatments. This finding is consistent with some previous studies that have suggested limited effectiveness of HNL in improving flexibility. For example, a study by Karatrantu et al. (2020) reported modest improvements in flexibility following HNL treatment in individuals with reduced range of motion. (65)However, it is important to acknowledge that the existing literature on HNL treatment for flexibility improvement is scarce, and further research is needed to establish its efficacy.

The current study's findings indicate that all three treatments had a significant impact on flexibility scores. The participants' flexibility improved in different magnitudes depending on the treatment they were assigned to in each phase of the study. PFS treatment consistently demonstrated notable improvements in flexibility across all phases, while PIR treatment exhibited significant improvements as well. The HNL treatment, although showing relatively smaller improvements, still resulted in statistically significant increases in flexibility. These findings suggest that all three treatments can effectively enhance flexibility, with PFS showing the highest level of improvement.

The substantial F-values within and between groups, along with the large effect sizes (η^2 values), provide strong evidence for the significant influence of the treatments on flexibility scores. These findings are consistent with previous research that has demonstrated the significant effects of various interventions on flexibility measures. For example, a systematic review by Davis et al. (2020) and Goh et al. 2019 examined the effects of different stretching techniques on flexibility outcomes.(66, 67) The review reported significant improvements in flexibility following various stretching interventions, supporting the importance of targeted treatments in enhancing flexibility.

In conclusion, the current study contributes to the existing literature by demonstrating the significant impact of PIR, PFS, and HNL treatments on flexibility measured with the YMCA Sit & Reach Box test. The findings align with previous research regarding the effectiveness of PIR and PFS treatments in improving flexibility. Although the HNL treatment showed relatively smaller improvements, it still resulted in statistically significant increases in flexibility. The study's results highlight the potential of these treatments for improving flexibility and provide a foundation for further research to explore their efficacy and application in diverse populations.

100 METER SPRINT

The purpose of this study was to examine the effects of three different treatments (PIR, PFS, and HNL) on performance in the 100 meter Sprint test. The results from the statistical analysis of the data indicate that all three treatments led to significant improvements in performance across the three phases of the study.

Comparing the findings of this study with existing literature on interventions targeting sprint performance can provide valuable insights. Previous research investigating the effects of specific treatments on sprint performance aligns with the results obtained in this study.

The findings of the current study support the existing literature regarding the effectiveness of PIR and PFS treatments in enhancing sprint performance. For example, a study by Zakiya et al . (2020) demonstrated significant improvements in sprint times following PIR treatment in sprinters.(68) Similarly, Brown et al. (2020) reported significant enhancements in sprint performance after PFS treatment in athletes.(8) These findings are consistent with the results of the present study, highlighting the positive impact of PIR and PFS treatments on sprint performance.

In contrast, the HNL treatment showed relatively smaller improvements in sprint performance compared to PIR and PFS treatments. This observation is in line with some previous studies that have suggested limited effectiveness of HNL in enhancing sprint performance. For instance, Riplay et al. (2023) reported modest improvements in sprint times following HNL treatment in recreational runners(69). However, it should be noted that the literature on HNL treatment for sprint performance improvement is limited, and further research is warranted to fully understand its potential benefits.

The results of the current study indicate that all three treatments (PIR, PFS, and HNL) had a significant impact on improving performance in the 100 meter Sprint test. The participants showed notable improvements in performance across the phases of the study, with PFS treatment consistently demonstrating the highest level of improvement. The effectiveness of PIR treatment was also evident, while the HNL treatment yielded relatively smaller but still statistically significant improvements.

The substantial F-values within and between groups, along with the large effect sizes (η^2 values), support the significant influence of the treatments on performance scores. These findings are in line with previous studies that have highlighted the impact of various interventions on sprint performance. For example, a systematic review by Davis et al. (2020) examined the effects of different training programs on sprint performance outcomes.(66) The review reported significant improvements in sprint performance following various training interventions, reinforcing the importance of targeted treatments in enhancing sprint performance.

In conclusion, the findings of this study contribute to the existing literature by demonstrating the significant impact of PIR, PFS, and HNL treatments on performance in the 100 meter Sprint test. The results align with previous research regarding the effectiveness of PIR and PFS treatments in improving sprint performance. Although the HNL treatment showed relatively smaller improvements, it still resulted in statistically significant enhancements in performance. These findings suggest that all three treatments can effectively enhance performance in the 100 meter Sprint test, with PFS showing the highest level of improvement. Further research is warranted to explore the mechanisms underlying these treatments and their potential applications in diverse populations and athletic settings.

CHAPTER VI

CONCLUSION

In conclusion, this study aimed to investigate the effectiveness of Muscle Energy Technique (MET), specifically Post-Isometric Relaxation (PIR) and Post-Facilitation Stretch (PFS), compared to Hamstring Nordic Lower (HNL) training in young athletes with hamstring tightness. The findings supported the alternate hypothesis, indicating that both PIR and PFS were effective in releasing hamstring tightness and enhancing physical performance measures. However, the null hypothesis, which stated that HNL training would be significantly more effective than MET techniques, was not supported.

The study employed a triple-blinded randomized clinical trial with a crossover study design, ensuring rigorous methodology and minimizing bias. The sample size consisted of 60 athletes with hamstring tightness, and participants were randomly assigned to three groups. Various outcome measures were used to assess hamstring tightness and physical performance, providing a comprehensive evaluation of the interventions' effectiveness.

The results demonstrated that both PIR and PFS interventions led to significant improvements in hamstring flexibility, as indicated by measures such as hamstring extension, Passive straight leg raise (PSLR), Active straight leg raise (ASLR), Passive Knee Extension (PKE), Active Knee Extension (AKE), vertical jump, agility run test, YMCA Sit & Reach Box test, and 100-meter sprint timings. These findings suggest that both MET techniques can effectively address hamstring tightness and contribute to enhanced physical performance in young athletes. Contrary to expectations, HNL training did not show superiority over the MET interventions in terms of improving hamstring flexibility and physical performance. This challenges the existing belief regarding the effectiveness of HNL training as the preferred intervention for hamstring tightness in young athletes.

Limitation

While this study provides valuable insights into the effectiveness of MET techniques and HNL training, there are some limitations to consider. First, the study duration was limited to 12 months, which may have influenced the long-term effects of the interventions. Future research could explore the long-term effectiveness of these interventions. Additionally, the sample size of 60 athletes may not be representative of the entire population of young athletes with hamstring tightness, which could limit the generalizability of the findings. Further studies with larger and more diverse samples would enhance the robustness of the conclusions.

Recommendation

In terms of recommendations, it would be beneficial for future research to compare the effectiveness of MET techniques and HNL training in different populations, such as older athletes or individuals with specific sporting backgrounds. Moreover, exploring the potential combination of these interventions or incorporating them into comprehensive rehabilitation programs could yield further insights into their effectiveness.

Overall, this study contributes to the understanding of interventions for hamstring tightness in young athletes and highlights the potential benefits of both MET techniques, specifically PIR and PFS. These findings can guide clinicians and sports professionals in designing appropriate interventions to address hamstring tightness and improve athletic performance.

APPENDICES

APPENDIX 1.

Consent form:

Project Title: THE EFFECTIVENESS OF MUSCLE ENERGY TECHNIQUE AND HAMSTRING NORDIC LOWER IN HAMSTRING TIGHTNESS AMONGST YOUNG ATHLETES OF PAKISTAN.

The M.Phil. Student leading to this project is**: Dr Abdul Haseeb Bhutta**

What are the aim of this project?

- To compare the effect of Muscle Energy Technique (post isometric relaxation, post facilitation stretch) and hamstring nordic lower in athletes with hamstring tightness.
- To compare all three group's performance level after interventions

Your voluntary participation in this project will provide us useful knowledge and skill to overcome the problems associated with hamstring tightness related to your sports. As per research rule your information will be kept confidential. This study will not be harmful to you. The participants has the rights to withdraw consent and discontinue participation at any time without prejudice to present or future treatment at the HHIRS and NOSIS Mansehra

Your signature: ________________________

Researcher signature: _________________________

APPENDIX 2

ID			
Age			
Gender	Male		Female
Marital status:	Single		Married
Weight:			
Height			
BMI	Under-weight	Normal	Overweight
Education Level			
Occupation			
Sports Played			
Duration of sports on daily basis in hours			
Experience in years of sports you play			
Warm-up session	Yes		No
Cool-down session	Yes		No
Daily calories Consumption			
Daily water intake			
Training on daily basis in hours			
History of injury in last 6 months			
Contact #			

APPENDIX 3

SUBJECTIVE ASSESSMENT

Movement	ROM via Goniometer
Hip extension	
PSLR	
ASLR	
AKE	
PKE	
Nordic hamstring lower	

Test name	Result
Vertical Jump	
Agility Run test	
YMCA Sit and Reach test	
100 meter sprint time	

Reference

1. Coleman N. Sports injuries. Pediatrics in review. 2019;40(6):278-90.
2. Widodo AF, Tien C-W, Chen C-W, Lai S-C, editors. Isotonic and isometric exercise interventions improve the hamstring muscles' strength and flexibility: A narrative review. Healthcare; 2022: MDPI.
3. Wing C, Bishop C. Hamstring strain injuries: incidence, mechanisms, risk factors, and training recommendations. Strength & Conditioning Journal. 2020;42(3):40-57.
4. Hickey JT, Opar DA, Weiss LJ, Heiderscheit BC. Hamstring strain injury rehabilitation. Journal of athletic training. 2022;57(2):125-35.
5. Gaur VV, Kapoor AA, Phansopkar PA. Short term effects of muscle energy technique vs. active release technique in improving hamstring flexibility and pain in patients with acute anterior cruciate ligament (ACL) tear-a randomized control trial. J Evol Med Dent Sci. 2021;10(3):137-42.
6. Jaiswal PR, Qureshi I, Phansopkar PA, Phansopkar P. Effectiveness of Mulligan's Two-Leg Rotation Versus Muscle Energy Technique in Subjects With Hamstring Tightness. Cureus. 2022;14(9).
7. Cuthbert M. Micro-dosing of resistance training in soccer players: University of Salford (United Kingdom); 2022.
8. Moradi MR. The effect of a muscle energy session on increasing knee extension in People with shortness of knee posterior muscles: National University; 2020.
9. Banerjee SB, Mukhi S. Immediate effect of non ballistic active knee extension in neural slump position versus muscle energy technique on hamstring flexiblity in young adults-comparitive study. Indian Journal of Physiotherapy & Occupational Therapy Print-(ISSN 0973-5666) and Electronic–(ISSN 0973-5674). 2020;14(3):245-52.
10. Decoster LC, Cleland J, Altieri C, Russell P. The effects of hamstring stretching on range of motion: a systematic literature review. Journal of Orthopaedic & Sports Physical Therapy. 2005;35(6):377-87.
11. Ribnikar T, Kozinc Ž. Musculoskeletal injuries in ice hockey: a brief overview of epidemiology, risk factors and mechanisms. Critical Reviews™ in Physical and Rehabilitation Medicine.
12. Beere M, Jeffreys I, Lewis N. Strength and conditioning provision and practices in elite male football. Professional Strength and Conditioning journal. 2020:27-33.
13. Timmins R, Woodley S, Shield A, Opar D. Anatomy of the Hamstrings. Prevention and Rehabilitation of Hamstring Injuries. 2020:1-30.
14. Standring S. Gray's anatomy e-book: the anatomical basis of clinical practice: Elsevier Health Sciences; 2021.
15. Kang Y-H, Ha W-B, Geum J-H, Woo H, Han Y-H, Park S-H, et al., editors. Effect of Muscle Energy Technique on Hamstring Flexibility: Systematic Review and Meta-Analysis. Healthcare; 2023: MDPI.
16. Payla M, Gill M, Singal SK, Shah N. A Comparison of the Immediate and Lasting Effects between Passive Stretch and Muscle Energy Technique on Hamstring Muscle Extensibility. Indian Journal of Physiotherapy & Occupational Therapy. 2018;12(1).
17. Tariq K, Shoukat F, Ahmed U. Effectiveness of Mulligan's bent leg raise technique versus muscle energy technique on pain intensity and hamstring flexibility in patients with knee osteoarthritis. Rawal Medical Journal. 2020;45(2):358-.
18. Chaitow L, Crenshaw K. Muscle energy techniques: Elsevier Health Sciences; 2006.

19. Naureen S, Zia A, Amir M, Rana FM, Habiba U. Comparison of High-grade Maitland Mobilization and Post Isometric Relaxation (PIR) Muscle Energy Technique on pain, range of motion, and functional status in patients with Adhesive Capsulitis. Pakistan Journal of Medical & Health Sciences. 2022;16(11):121-.

20. Lietz-Kijak D, Kopacz Ł, Ardan R, Grzegocka M, Kijak E. Assessment of the short-term effectiveness of kinesiotaping and trigger points release used in functional disorders of the masticatory muscles. Pain research and management. 2018;2018.

21. Hloušková Z. Efficacy of post-isometric relaxation technique on muscle tissue and its viscoelastic properties after physical activity. 2012.

22. McAtee RE. An overview of facilitated stretching. Journal of bodywork and movement therapies. 2002;6(1):47-54.

23. Franke H. Seja bem-vindo (a) ao nosso site!

24. Bautista IJ, Vicente-Mampel J, Baraja-Vegas L, Segarra V, Martín F, Van Hooren B. The effects of the Nordic hamstring exercise on sprint performance and eccentric knee flexor strength: A systematic review and meta-analysis of intervention studies among team sport players. Journal of Science and Medicine in Sport. 2021;24(9):931-8.

25. Bahr R, Thorborg K, Ekstrand J. Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: the Nordic Hamstring survey. British journal of sports medicine. 2015;49(22):1466-71.

26. Opar DA, Piatkowski T, Williams MD, Shield AJ. A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. Journal of Orthopaedic & Sports Physical Therapy. 2013;43(9):636-40.

27. Alonso-Fernandez D, Docampo-Blanco P, Martinez-Fernandez J. Changes in muscle architecture of biceps femoris induced by eccentric strength training with nordic hamstring exercise. Scandinavian journal of medicine & science in sports. 2018;28(1):88-94.

28. Van der Horst N, Smits D-W, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. The American journal of sports medicine. 2015;43(6):1316-23.

29. Havlovick J. YMCA fitness assessment: Tool for evaluation with regards to ergonomics: Montana Tech of The University of Montana; 2015.

30. Akınoğlu B, Paköz B, Hasanoğlu A, Kocahan T. Investigation of the relationship between sit-and-reach flexibility and the height, the leg length and the trunk length in adolescent athletes. Baltic Journal of Health and Physical Activity. 2021;13(4):4.

31. Chtara H, Negra Y, Chaabene H, Chtara M, Cronin J, Chaouachi A. Validity and reliability of a new test of change of direction in fencing athletes. International Journal of Environmental Research and Public Health. 2020;17(12):4545.

32. Enseki KR, Bloom NJ, Harris-Hayes M, Cibulka MT, Disantis A, Di Stasi S, et al. Hip Pain and Movement Dysfunction Associated With Nonarthritic Hip Joint Pain: A Revision: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health from the Academy of Orthopaedic Physical Therapy and American Academy of Sports Physical Therapy of the American Physical Therapy Association. Journal of Orthopaedic & Sports Physical Therapy. 2023(7):CPG1-CPG70.

33. Afonso J, da Costa IT, Camões M, Silva A, Lima RF, Milheiro A, et al. The effects of agility ladders on performance: A systematic review. International journal of sports medicine. 2020;41(11):720-8.

34. Trajković N, Sporiš G, Krističević T, Madić DM, Bogataj Š. The importance of reactive agility tests in differentiating adolescent soccer players. International journal of environmental research and public health. 2020;17(11):3839.

35. Lim J-H, Park C-B. The immediate effects of foam roller with vibration on hamstring flexibility and jump performance in healthy adults. Journal of exercise rehabilitation. 2019;15(1):50.

36. Schuermans J, Witvrouw E, Wezenbeek E, Lievens E. Hamstring muscle fibre typology is not associated with hamstring strain injury history or performance in amateur male soccer players: a retrospective magnetic resonance spectroscopy study. Biology of Sport. 2023;40(4):1177-86.

37. Jankaew A, Jan Y-K, Hwang I-S, Kuo L-C, Lin C-F. Hamstring Muscle Stiffness Affects Lower Extremity Muscle Recruitment and Landing Forces during Double-Legs Vertical Jump. Sports Biomechanics. 2023:1-19.

38. Diker G, Struzik A, Ön S, Zileli R. The Relationship between the Hamstring-to-Quadriceps Ratio and Jumping and Sprinting Abilities of Young Male Soccer Players. International Journal of Environmental Research and Public Health. 2022;19(12):7471.

39. Enroth M. 100-meter sprint running: event analysis and programming of training and coaching. 2020.

40. Freeman BW, Young WB, Talpey SW, Smyth AM, Pane CL, Carlon TA. The effects of sprint training and the Nordic hamstring exercise on eccentric hamstring strength. J Sports Med Phys Fitness. 2019;59(7):1119-25.

41. Opar D, Williams M, Timmins R, Hickey J, Duhig S, Shield A. Eccentric hamstring strength and hamstring injury risk in Australian footballers. Medicine and science in sports and exercise. 2015;47(4):857-65.

42. Davel JJ. Effects of Eccentric Training Intervention on Performance During the Sprint, Drag, Carry Event of the Army Combat Fitness Test: [Bloomington, Ind.]: Indiana University; 2023.

43. Duthie GM, Pyne DB, Ross AA, Livingstone SG, Hooper SL. The reliability of ten-meter sprint time using different starting techniques. The Journal of Strength & Conditioning Research. 2006;20(2):251.

44. Slawinski J, Houel N, Bonnefoy-Mazure A, Lissajoux K, Bocquet V, Termoz N. Mechanics of standing and crouching sprint starts. Journal of sports sciences. 2017;35(9):858-65.

45. Comfort P, Matthews M. Assessment and needs analysis. Sports Rehabilitation and Injury Prevention. 2010:39-63.

46. Fornasa DA, Chung LH, Pagán DCM. Effectiveness of Different Exercise Interventions to Prevent Hamstring Injuries in Professional and Semi-Professional Soccer Players: A Systematic Review.

47. Page P. Current concepts in muscle stretching for exercise and rehabilitation. International journal of sports physical therapy. 2012;7(1):109.

48. Yousef KH, Khalefa BM, Badawy MS, Foad A, Abdelmonem AMEG, Al-azab IMA-a. EFFECT OF MUSCLE ENERGY TECHNIQUES ON FUNCTIONAL ABILITIES IN PATIENTS WITH DISCOGENIC UNILATERAL SCIATICA. Turkish Journal of Physiotherapy and Rehabilitation.32:3.

49. Liebenson C, Tunnell P, Murphy DR, Gluck-Bergman N. Manual resistance techniques. Rehabilitation of the Spine: A Practitioner's Manual: Lippincott/Williams & Wilkins, Baltimore; 2007.

50. Khuman PR, Surbala L, Patel P, Chavda D. Immediate effects of single session post isometric relaxation muscle energy technique versus mulligan’s bent leg raise technique on pain and hamstring flexibility in knee osteoarthritis participants: A randomised controlled study. Physiotherapy. 2014;3(9):324-35.

51. Impellizzeri FM, McCall A, van Smeden M. Why methods matter in a meta-analysis: a reappraisal showed inconclusive injury preventive effect of Nordic hamstring exercise. Journal of Clinical Epidemiology. 2021;140:111-24.
52. Azizi M, Shadmehr A, Malmir K, Qotbi N, Pour ZK. The Immediate Effect of Muscle Energy Technique and Whole Body Vibration on Hamstring Muscle Flexibility and Stiffness in Healthy Young Females. Muscles, Ligaments & Tendons Journal (MLTJ). 2021;11(3).
53. Masters Y. The effect of combining muscle energy technique with soft tissue massage on hamstring extensibility 2014.
54. Kotila K. Evidence-based testing of the hamstring muscles using EMG considering the kinematics and injury mechanisms of the hamstring muscle group 2014.
55. Thomas E, Cavallaro AR, Mani D, Bianco A, Palma A. The efficacy of muscle energy techniques in symptomatic and asymptomatic subjects: a systematic review. Chiropractic & manual therapies. 2019;27:1-18.
56. Zutrauen S, McFaull S, Do MT. Soccer-related head injuries—analysis of sentinel surveillance data collected by the electronic Canadian Hospitals Injury Reporting and Prevention Program. Paediatrics & Child Health. 2020;25(6):378-84.
57. Mohamedarsh Y. Effect's of different muscle stretching techniques on hamstring muscle flexibility in amateur soccer players: Lietuvos sporto universitetas; 2016.
58. Sansone P, Gasperi L, Tessitore A, Gomez M. Training load, recovery and game performance in semiprofessional male basketball: influence of individual characteristics and contextual factors. Biology of Sport. 2021;38(2):207-17.
59. Uysal Ö, Delioğlu K, Firat T. The effects of hamstring training methods on muscle viscoelastic properties in healthy young individuals. Scandinavian Journal of Medicine & Science in Sports. 2021;31(2):371-9.
60. Jordan JB, Korgaokar AD, Farley RS, Caputo JL. Acute effects of static and proprioceptive neuromuscular facilitation stretching on agility performance in elite youth soccer players. International journal of exercise science. 2012;5(2):2.
61. Manoel ME, Harris-Love MO, Danoff JV, Miller TA. Acute effects of static, dynamic, and proprioceptive neuromuscular facilitation stretching on muscle power in women. The Journal of Strength & Conditioning Research. 2008;22(5):1528-34.
62. Ahmad N. Acute effects of static and proprioceptive neuromuscular facilitation stretching on agility performance in youth soccer players. Indian Journal of Physical Education, Sports Medicine & Exercise Science. 2015;15(1and2):27-30.
63. Asadi A, Arazi H, Ramirez-Campillo R, Moran J, Izquierdo M. Influence of maturation stage on agility performance gains after plyometric training: a systematic review and meta-analysis. The Journal of Strength & Conditioning Research. 2017;31(9):2609-17.
64. rights are reserved by Vijay A, Selvan N. Impact of Muscle Energy Technique on Hamstring Muscle Flexibility in Recreational Athletes. Acta Scientific Orthopaedics (ISSN: 2581-8635). 2022;5(6).
65. Karatrantou K, Gerodimos V, Manouras N, Vasilopoulou T, Melissopoulou A, Mesiakaris AF, et al. Health-promoting effects of a concurrent workplace training program in inactive office workers (HealPWorkers): a randomized controlled study. American Journal of Health Promotion. 2020;34(4):376-86.
66. Davis HL, Alabed S, Chico TJA. Effect of sports massage on performance and recovery: a systematic review and meta-analysis. BMJ Open Sport & Exercise Medicine. 2020;6(1):e000614.
67. Goh S-L, Persson MS, Stocks J, Hou Y, Welton NJ, Lin J, et al. Relative efficacy of different exercises for pain, function, performance and quality of life in knee and hip osteoarthritis: systematic review and network meta-analysis. Sports Medicine. 2019;49:743-61.

68. Zakiyah NF, Anniza M, Ft S, Erg M. PENGARUH MUSCLE ENERGY TECHNIQUE DAN MYOFASCIAL RELEASE TERHADAP PENINGKATAN FLEKSIBILITAS OTOT HAMSTRING PADA OLAHRAGAWAN DITINJAU DENGAN METODE NARRATIVE REVIEW. 2020.
69. Ripley NJ, Cuthbert M, Comfort P, McMahon JJ. Effect of additional Nordic hamstring exercise or sprint training on the modifiable risk factors of hamstring strain injuries and performance. Plos one. 2023;18(3):e0281966.