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EFFECT OF HOLD-RELAX AND CONTRACT-RELAX STRETCHING ON HAMSTRING FLEXIBILITY: AN EXPERIMENTAL STUDY

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ABSTRACT

BACKGROUND AND OBJECTIVES: Proprioceptive Neuromuscular Facilitation (PNF) stretching techniques, such as hold-relax and contract-relax, have been widely used to improve muscle flexibility and joint range of motion. These techniques are particularly effective for the hamstrings, which are prone to tightness and injuries. However, there is paucity of literature regarding the comparison of "Hold Relax" And "Contract Relax" stretching approaches in enhancing hamstring flexibility. The objectives of the study were

To find out the effect of the Hold-Relax technique on Hamstring Flexibility.

To find out the effect of the Contract-Relax technique on Hamstring Flexibility.

To compare the effect of Hold-Relax and Contract-Relax technique on Hamstring Flexibility.

METHODOLOGY: A total of 40 subjects with Hamstring Tightness were included. The participants were recruited via convenience sampling. 20 subjects in each Group A and B were given with Hold Relax and Contract-Relax respectively. Flexibility of muscle following pre and post intervention was analyzed by goniometer, Fingertip to Floor testing and Active Knee Extension test. Dependent and independent t-test was used to analyze the results statistically. Data were numerically coded and analyzed through SPSS software program version 26.

RESULTS: Group A (HR) and Group B (CR) were given suitable intervention for hamstring tightness. Pre- and post-intervention measures of all outcomes for both groups were significantly different from each other. Between the group comparison showed that the changes in all outcomes (Range of Motion, Fingertip to Floor testing and Active Knee Extension test) were significantly greater in the Hold-Relax group as compared to the Contract-Relax, indicating difference between the groups.

CONCLUSION: This experimental study increased ROM at the hip and knee joints, improved knee extension angle, and reduced fingertip-to-floor distance in both the groups. However, intergroup analysis concluded that Hold-Relax technique is better than the Contract-Relax technique for increasing muscle flexibility.

KEYWORDS: Hamstring Flexibility, Hold-relax, Contract-Relax

ACRONYMS

HR	Hold -Relax
CR	Contract-Relax
SD	Standard deviation
ROM	Range of Motion
PNF	Proprioceptive Neuromuscular Facilitation
SPSS	Statistical Package for Social Sciences

INTRODUCTION

1.1 Flexibility

Flexibility is a key component of the physical fitness and held as an important attribute that enable the person to move smoothly and safely (Sandeep et al., 2015). Flexibility is vital to one's overall fitness for maintenance of functional range of motion (ROM) and to provide significant musculoskeletal health benefits (Bea et al., 2017). Flexibility is a vital component of a physical conditioning programme that allow the tissue to accommodate easily to stress, to dissipate shock impact, and to improve efficiency of movement, thus minimizing or preventing injury (Ahmed et al., 2015). Flexibility is the ability to rotate a single joint or series of joints smoothly and easily through an unrestricted, pain-free ROM (Kisner et al., 2019). Flexibility was described by Dantas as "physical feature responsible for the voluntary execution of maximum joint range of motion, by a single or multiple joints, within morphological limits, without the risk of injury (Dantas et al., 2011). Limited muscular flexibility has been shown to predispose a person to several musculoskeletal injuries and significantly affect a person's level of function (Davis et al., 2005). Loss of flexibility can be a predisposing factor for pain syndrome or balance disorders. There are many factors that affect flexibility: Internal factors-training oversight, muscle strength, endurance and range of motion and genetics. External factors-weather, age, walking surface, shoes (Bea et al., 2017). There are various methods used to improve flexibility but stretching is most commonly used. Within stretching are several subgroups such as ballistic stretching, dynamic stretching, and static stretching (Bea et al., 2017).

Static flexibility occurs when the individual maintains a position, moving the segment slowly and gradually until the maximum articular arc has been reached. This type of flexibility is most frequently used to evaluate flexibility (Cayco et al.,2019).

Dynamic flexibility (also called kinetic flexibility) is the ability to perform dynamic movement of the muscle to bring a limb through its full range of motion in the joints (Kisner et al, 2017).

Ballistic flexibility forces the limb into an extended range of motion when the muscle is not relaxed enough to enter it. It involves fast bouncing movements and is widely used by ballerinas and gymnasts (Cayco et al., 2019).

However, hamstring muscle is the most common muscle that goes into shortens or tightness motion either the individual is living active lifestyle or sedentary lifestyle (Rajendran et al., 2016). Risk for hamstring injury to occur is exacerbated by the presence of poor hamstring length.10 Among lower extremity injuries, hamstring injuries are described as the third most common orthopaedic problem and often a have long 2 recovery time

(Bea et al., 2017). The numerous factors influencing the hamstring flexibility includes the age, gender, race, tissue temperature, strength training, stiffness, awkward posture and reduced warm up period during exercise (Sandeep et al., 2015). Hamstring is a muscle that generally experiences adaptive shortening compared to other muscle groups. Hamstring muscle plays an important role in both sporting activities and daily routine activities likewise in controlled movement of trunk, walking, running, kicking and jumping (Adkitte et al., 2016). Deficiency in hamstring flexibility can generate several postural changes and movement limitations. Tight hamstring affects posture, gait, and the way the body moves during exercise. Hamstring tightness occurs due to immobilization of a tissue in a shortened position which can result in decreased elasticity of normal tissue, a change in length tension relationship of the muscle and loss of flexibility (Ramesh and Sivasankar., 2014).

Obesity, absence of regular exercise and sedentary daily routine are being observed as risk factors of hamstring tightness (Jabbar et al., 2021). Understanding risk factors for hamstring injury is critical for developing prevention and rehabilitation strategies, these risk factors can be categorized as modifiable and non-modifiable risk factors (Lui et al., 2012).

Modifiable risk factors include shortened optimum muscle length, lack of muscular flexibility, strength imbalance, insufficient warm-up, fatigue, low back injury, and increased muscle neural tension (Lui et al., 2012).

Non-modifiable risk factors include muscle composition, age, race, and previous injuries (Lui et al., 2012).

1.2 Anatomy of the Hamstring

A group of large muscles in the body, occupying posterior compartment of thigh, that enables a person to walk, run or jump by providing the ability to extend the hip joint and flex the knee joint is referred to as hamstrings muscle group (Khalil et al., 2022). The semitendinosus, semimembranosus, and biceps femoris muscles comprise the hamstring muscle group.

1.2.1 Biceps Femoris: Short Head

- Origin: Lateral lip of the Linea aspera
- Insertion: The fibular head and lateral condyle of the tibia
- Function: Knee flexion and lateral rotation of the tibia
- Innervation: Fibular (common peroneal) nerve
- Vascular supply: Perforating branches of the deep femoral artery

(Rodgers and Raja., 2023)

1.2.2 Biceps Femoris: Long Head

- Origin: Ischial tuberosity
- Insertion: The fibular head and lateral condyle of the tibia
- Function: Knee flexion, lateral rotation of the tibia, and hip extension
- Innervation: Tibial nerve
- Vascular supply: Perforating branches of the deep femoral artery

(Rodgers and Raja., 2023)

1.2.3 Semitendinosus

- Origin: Lower, medial surface of the ischial tuberosity
- Insertion: Medial tibia (pes anserinus)

- Function: Knee flexion, hip extension, and medial rotation of the tibia (with knee flexion)
- Innervation: Tibial nerve
- Vascular supply: Perforating branches of the deep femoral artery

(Rodgers and Raja., 2023)

1.2.4 Semimembranosus

- Origin: Ischial tuberosity
- Insertion: Medial tibial condyle
- Function: Knee flexion, hip extension, and medial rotation of the tibia (with knee flexion)
- Innervation: Tibial nerve
- Vascular supply: Perforating branches of the deep femoral artery

(Rodgers and Raja., 2023)

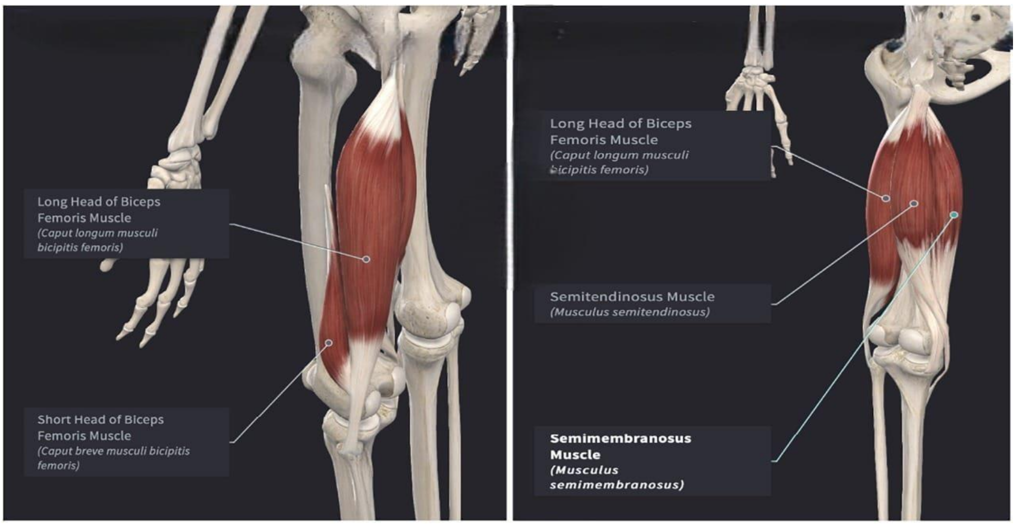

Fig.1.1- Diagram of the Hamstring muscle complex (Afonso et al., 2021)

1.3 Individual function of Hamstring Muscle:

The biomechanical analysis of hamstrings indicates some differences between each of the individual muscles. Based on their anatomy, each muscle generates contractions in a slightly different plane and direction (Stepien et al., 2018).

The BF with its distal insertion on the lateral side of the proximal fibula and tibia influences stability of the posterolateral corner of the knee. The contraction of the BF rotates the tibia and fibula externally. Consequently, it prevents internal rotation of the tibia in relation to the femur. The BF is the most effective hamstring muscle in reducing the ACL-loading component produced by the QF through decreasing anterior tibial translation (Stepien et al., 2018).

Due to their distal insertion on the medial part of the proximal tibia, the ST and SM contraction induce an internal rotation of the tibia. These muscles are antagonists of the external rotation generated by the BF. The application of a proximally oriented traction force on the ST and lhBF nicely demonstrate their respective functions as internal and external rotators of the tibia (Stepien et al., 2018).

1.4 Biomechanical features of Hamstring

The muscles of the HMC are important hip extensors and flexors of the knee in the gait cycle. They become active in the last 25% of the swing phase just as hip extension begins and continue for 50% of the swing phase to actively produce extension at the hip and actively resist extension of the knee (Stepien et al., 2018).

With heel strike, the HMC also functions to decelerate the forward translation of the tibia during knee extension when foot strike occurs and the weight of the body is shifted forward. The HMC is thus a dynamic stabilizer of anterior tibial translation, working alongside the corresponding static stabilizer, the anterior cruciate ligament (ACL) (Stepien et al., 2018).

1.5 Importance of Hamstring Muscle Flexibility

The capacity of a muscle to extend, enabling one joint (or several joints in succession) to move across its range of motion is how the dictionary defines muscular flexibility. Variations in flexibility can lead to abnormal stress on musculoskeletal system, which can put strain on the body and even cause damage. Flexibility is essential for all motions, and any alteration in flexibility can cause injury. Researchers found that people with lower back pain had tight hamstrings. This makes sense, since less flexibility in the hamstrings is thought to be one of the risk factors for pain in lower back region. For walking, the hamstring is one of the most essential muscles in the body. The hamstring muscles do a wide range of things, such as running, jumping, bending forward when sitting or standing, and controlling your posture in different ways. Flexibility of the hamstring muscles is particularly essential in the area of rehabilitation, where it helps to maintain postural balance, maintain full range of motion (ROM) in the knee and hip joints, avoid injuries, and optimise musculoskeletal function and performance (Nikun et al., 2022). Reduced hamstring flexibility influences back flexibility. This can be explained as hamstring muscle which is located posteriorly to the thigh bone, is also a part of SBL. The erector spinae as a part of SBL spans the spine from sacrum to occiput covering the posterior side of the spinal curves. Also, the hamstring muscle and back muscles are part of the posterior anatomical chain in the body, thus an improvement in hamstring flexibility might also increase back flexibility (Grieve et al., 2014).

There are several methods to improve hamstring flexibility which are given to attain a visible change in hamstring tightness. Both electrotherapy and manual therapy is used to improve hamstring flexibility. The techniques commonly used are cryotherapy, soft tissue massage, myofascial therapy, short wave diathermy, ultrasound, Kinesio-taping, and eccentric training. The stretching techniques are widely used by most of the clinicians; some of them are such as active stretching, passive stretching, ballistic stretching, muscle energy technique (MET) and proprioceptive neuromuscular facilitation (PNF).

1.6 Proprioceptive Neuromuscular Facilitation

Proprioceptive neuromuscular facilitation (PNF) has been shown to be useful in many aspects of sports training, three of which include injury prevention and reduction, performance enhancement, and therapeutic use (Sassone., 2021). PNF is a positive, integrated approach, developed by Knot and Voss in 1968 (Yadav et al.,2019). Proprioceptive neuromuscular facilitation (PNF) is a more advanced form of flexibility training that involves both the stretching and contraction of the muscle group being targeted. PNF stretching was originally developed as a form of rehabilitation. While there are several variations of PNF stretching they all have one thing in common; they facilitate muscular inhibition. The techniques of proprioceptive neuromuscular facilitation rely mainly on stimulation of the proprioceptors for increasing the demand made on the neuromuscular mechanism to obtain and facilitate its response. PNF improves flexibility by triggering the inverse myotatic reflex, which then allows the muscle fibres to relax and stretch further (Hindle et. al, 2012). PNF applies neurophysiological principles of the sensory/motor system to manual evaluation and treatment of neuromuscular skeletal dysfunctions. The purpose of this technique is to increase flexibility and range of motion (ROM) through the stimulation of the neuromuscular system and the proprioceptors (kaya). PNF provides the therapist with an efficient means for evaluating and treating neuromuscular and structural dysfunctions (Salabia et al., 2021). Proprioceptive Neuromuscular Facilitation (PNF) is a stretching technique utilized to improve muscle elasticity and has been shown to have a positive effect on active and passive range of motions (Hindle et al., 2012). This type of stretching is known to be the fastest and most effective method of improving static and passive flexibility (Sajedi et al., 2020).

Various PNF stretching technique based on Kabat's concept are: hold relax, contract relax, and contract relax – antagonist contract (CRAC) etc. There are four theoretical physiological mechanisms contributing to PNF increasing ROM. These are autogenic inhibition, reciprocal inhibition, stress relaxation and the gate control theory.

NEED OF THE STUDY

The Prevalence of hamstring tightness is very high. Prevalence of hamstring tightness in youngsters is 82% (Koli and Anap., 2018). There is 55.5% prevalence of HMS tightness due to prolonged sitting among administration staff (Jabbar et al., 2021); prevalence of hamstring tightness is very high among Dimond assorters (95.3% in right side and 94% in left side) (Chaphekar et al., 2021). Poor flexibility of the hamstring is also linked to lower back and lower extremity injuries. It is a contributing factor for reduced range of motion and can also lead to other musculoskeletal diseases in the common population (Ehsan et at., 2022). The hamstring mobility of those with tight hamstrings has reportedly been greatly improved by muscle energy techniques, active static stretching, and passive static stretching. However, there is paucity of literature regarding the comparison of "hold relax" and "contract relax" stretching approaches in enhancing hamstring flexibility. Thus, is the need of the study.

1.1 STATEMENT OF PROBLEM

What are the effects of HR and CR on Hamstring Flexibility?
Which technique HR or CR is better for treating subjects with Hamstring Tightness?

1.2 AIMS AND OBJECTIVES OF THE STUDY

AIMS

Many studies have explored the effects of various interventions on hamstring tightness. Among these, Proprioceptive Neuromuscular Facilitation (PNF) techniques have been frequently studied. However, there is a lack of comparative research on the efficacy of different PNF techniques in addressing hamstring tightness. Therefore, the aim of the study was to determine the effect of Hold-Relax Technique and Contract-Relax Technique on Hamstring Flexibility.

OBJECTIVES

The objectives of the study were
To find out the effect of the Hold-Relax technique on Hamstring Flexibility.
To find out the effect of the Contract-Relax technique on Hamstring Flexibility.
To compare the effect of Hold-Relax and Contract-Relax technique on Hamstring Flexibility.

1.3 OPERATIONAL DEFINITIONS

1. Hold Relax technique (HR)

Resisted isometric contraction of the agonist muscles (shortened muscles) followed by relaxation and movement into the new increased range either actively or passively (Adler et al., 2013).

Purpose- HR is used to facilitate relaxation and increased range, utilizing an isometric rather than an isotonic contraction.

Indication- In the presence of pain or to increase range of motion an isometric contraction provides greater control of the procedure (Salabia et al., 2021).

2. Contract Relax technique (CR)

Resisted isotonic contraction of the restricting muscles (agonist) followed by relaxation and movement into the new increased range either actively or passively (Adler et al., 2013).

Purpose- Contract relax utilizes the development of muscle tension through a concentric or maintained contraction to facilitate relaxation and stretching of the intrinsic connective tissue elements of that muscle

(Salabia et al., 2021).

Indication- To increase range of motion of the myofascial unit, by facilitating relaxation and improving extensibility of the myofascial tissues. Relaxation of unnecessary muscle tension may also serve to improve local circulation (Salabia et al., 2021).

REVIEW OF LITERATURE

Ahmed et al (2020) did a **comparative study on effect of modified hold-relax stretching and static stretching on hamstring muscle flexibility**. Forty-five male subjects with hamstring tightness were included in this study. The subjects were randomly placed into three groups: the modified hold-relax stretching, static stretching and control groups. The results of this study indicate that both the modified hold-relax stretching technique and static stretching are equally effective, as there was no significant difference in improving the hamstring muscle flexibility between the two groups.

Yadav and Lehri (2019) studied **the Effect of Proprioceptive Neuromuscular Facilitation on Flexibility in Males with Hamstring Tightness.** A total of 134 male subjects (age 20-24 years) with bilateral hamstring tightness were recruited. The subjects were randomly divided into Group A (PNF-HR) and Group B (Control group). The outcome measures - straight leg raise-dominant leg side (SLR-D), straight leg raise-non-dominant leg side (SLR-nD), knee extension angle –dominant leg side (KEAD), straight leg raise- non-dominant leg side (KEA-nD), sit and reach test (SRT) were measured at first day before treatment and fifth day after treatment. The findings conclude that PNF-HR is effective in improving flexibility in males with hamstring tightness.

Vamsidhar et al (2014) did a **study to compare the effectiveness of static stretching and hold-relax technique on hamstring flexibility.** The 30 selected subjects randomly and divided into two groups (Experimental group and control group). By comparing the means of Group – I, given Static Stretch and Group – II, given Hold relax Technique for six weeks implied that there is improvement of flexibility in Group – II and the 'P' value < 0.01 shows the difference is highly significant.

Tanigawa (1972) did a conducted **a study comparing the effects of passive mobilization and Hold-Relax technique on muscle lengthening.** Thirty subjects were studied to compare the effects of PNF hold-relax and passive mobilization on tight hamstring muscles. All subjects were mobilized for three weeks followed by one week without mobilization. Statistical analysis of the data showed the PNF hold-relax procedure to be more effective in increasing the range of motion of shortened tissue than passive mobilization. Also, the increase in range occurred at a faster rate with the PNF hold-relax procedure than with passive mobilization.

Shaha et al (2015) conducted a **study to compare the effect of static, ballistic and contract relax stretching on hamstring muscles flexibility in young individuals**. 90 young, healthy individuals were assessed for the inclusion and exclusion criteria and randomly divided into 3 groups. Group A (static stretching), Group B (dynamic stretching) and Group (contract-relax stretching) for hamstring muscles. Sit and reach test (SRT) and popliteal angle (PA) test were used as a standard outcome. All three static, ballistic and contract-relax stretching methods are beneficial in improving flexibility of hamstring muscles but contract relax stretching is more effective than the static stretching and ballistic stretching ($p<0.05$).

Naima et al (2015) conducted a study to find Combination effect of core stability exercise and contract relax exercise on hamstring flexibility. 22 subjects were analysed (CS,n=7;CR,n=8;CS+CR,n=7). The paired t test analysis of each group showed significant CS ($p=0.03$), CR ($p=0.00$), CS+CR ($p=0.01$) in increasing of result sit and reach test was observed. There was a difference between the three groups by the ANOVA test ($p=0.00$). This study shows that combination of core stability and contract relax exercises can increase hamstring flexibility.

Feland et al (2001) conducted a **study to compare the acute effects of PNF with static stretch on hamstring flexibility in senior athletes**. While there was not a statistically significant difference between the CRPNF and static stretch treatments in those age 65 and older, both were effective at improving acute Flexibility in the senior athletes tested. Overall CRPNF stretching appears to be more effective than static stretching at producing acute Flexibility gains in the hamstrings muscle group in senior athletes age 55 to 64 years. These results remained unchanged after adjusting for age and gender, with corresponding P values 0.0001, 0.0001, and 0.0831, respectively.

Morcelli et al (2013) This study aimed **to compare the effect of three stretching techniques (ballistic, static and contract relax) on instant gain muscle flexibility on the hamstring muscle**. A total of 23 subjects of both gender [means (SD) age 21.17 (1.4) years] were included in the study. Significant difference for the ballistic (6.26%) (p=0.01; f=5.84) and contract-relax stretching (6.5%) (p=0.009; f = 7.41) was observed. The results of this preliminary study suggests that ballistic and contract-relax techniques may improve the immediate flexibility gain of the hamstring muscles.

Cayco et al (2018) Current best evidence from **multiple RCT** with generally low to moderate-quality trials in adults **demonstrates that HR and CR** are safe and effective in increasing hamstrings flexibility immediately within-session and after repeated administration (i. e. it is better than control/nothing). Conflicting or limited evidence from generally low-to moderate-quality trials demonstrates that HR and CR have long-term effects and are superior to other stretching techniques. Long-term effects of HR and CR and superiority to other stretching techniques require further examination. Further research to test effects of HR and CR should use rigorous trial designs, and apply optimal exercise prescription parameters. Although clinicians can expect large gains following administration of HR and CR, a regular stretching routine is needed to maintain gains and for such gains to be clinically useful.

MATERIALS AND METHODOLOGY

STUDY DESIGN

: An Experimental (pre-post) Study design

3.1 STUDY SETTING

The study was conducted at the Out-Patient Department (OPD) Of Physiotherapy at Sri Guru Granth Sahib World University, Fatehgarh Sahib (Punjab)

3.2 POPULATION

A total of 40 subjects with hamstring tightness were recruited in the study with 20 participants equally divided into two groups- Group A (Hold-Relax + hot pack), Group B (Contract-Relax + hot pack) assuming the 10% dropout in the study. The participants were recruited via convenience sampling.

The sample size was calculated with the following formula based on the pervious study (Charan and Biswas.,2013).

$n= 2\times SD^2 (Z\alpha+Z\beta)^2 \div d^2$

Where, $Z\alpha/2$ is the critical value of this normal distribution at $Z\alpha/2$ (e.g. For a confidence level of 95%, $\alpha= 0.05$ and critical value is 1.96),

$Z\beta$ is the critical value of the normal distribution at β (e.g. for a power of 80%, $\beta = 0.20$, and this critical value is 0.84., d is the effect size (which is the difference in mean1 and mean2).

The value of d is 3.67(Vamsidhar et al., 2014)

Power and Sample Size

Comparing mean1 and mean2

Calculating power for mean1= mean2 + difference
Alpha = 0.05, assumed standard deviation= 5.56
$n= 2\times SD^2 (Z\alpha+Z\beta)^2 \div d^2$
$n= 2\times 5.56^2 (1.96 + 0.84)^2 \div 3.67^2$
$n= 2\times 30.91 (7.84) \div 13.46$
$n= 484.66 \div 13.46$
n= 36.00 (approximately 40 subjects)

3.3 SAMPLE AND SAMPLING TECHNIQUE:

Sample was taken by using convenience sampling method due to time limitation and assist is the one of the easiest, cheapest and quicker method of sample selection.

3.4 SEARCH DATA BASE:

- Google Scholar
- PubMed
- Research Gate

3.5 STUDY DURATION:

6 Months

3.6 INCLUSION CRITERIA

Subjects of age group of 20-40 years were included.

Subjects with hamstring tightness (inability to achieve greater than 160 degrees of knee extension with hip joint at 90 degrees flexion), and

Both male and female subjects were included in the study.

3.7 EXCLUSION CRITERIA

Subjects with any history of musculoskeletal and neurological pathology of low back, pelvis, hip knee, and

Subjects with any injury or surgery of low back, hip, knee or hamstring muscle in last six months were excluded from this study.

3.8 MATERIAL AND TOOLS

The materials and tools for this study were consent form, SPSS (Statistical Package for the Social Sciences) software-26 version to analyze data.

3.9 DATA COLLECTION TECHNIQUE AND TOOLS

The hamstring muscle tightness leads to the decreased or reduced motion of the knee joint. The reduced range of motion was measured with universal goniometer and supple tape. Before performing the intervention procedure, a consent form was explained to the subjects and signed by the subjects.
Universal Goniometer and Supple Tape: The outcome measures included was the universal goniometer and measurement tape for measuring the hamstring muscle tightness (knee extension angle) and (Fingertip to Floor). Measurements were performed before the treatment session, and immediate after the intervention.
Validity and Reliability of universal goniometer

Validity, r = 0.97-0.98; ICC = 0.98-0.99 (Gogia et al., 2018)
Reliability, r = 0.98; ICC = 0.99 (Gogia et al., 2018)
Validity and Reliability of Fingertip-to-Floor Test
Validity, r = -.96; ICC = .99 (Perret et al., 2001)
Reliability, r = -.25; ICC = .99 (Perret et al., 2001)

Fingertip-to-floor test

The subjects were asked to keep the knees completely extended, and, from then on, to flex the trunk towards the floor, with head and arms relaxed. Final flexion position was indicated by a sensation of muscular tension that caused great HM discomfort and, in this moment, pictures were taken (Carregaro et al., 2006).

Figure 3.1 Fingertip to Floor Test

Active Knee Extension test

Goniometric hamstring length via the knee angle was measured in the supine position. The distal tip of the lateral malleolus was marked. The hip was placed into flexion until the femur was perpendicular to the exam table and tibia was parallel to the treatment table. The subjects were then instructed to actively lift the lifted leg as straight as possible. The ankle was relaxed during the final knee angle measurements (Dafda., 2019).

Figure 3.2 Active Knee Extension Test

PROCEDURE

Measurement Methods

Goniometry of the hip and knee joint was done using a universal goniometer, and two measurements were made for each movement. The results were obtained from the calculation of the mean values.

Hip Extension

Motion occurs in a sagittal plane around a medial– lateral axis. Normal hip extension ROM values for adults vary from about 18 to 30 degrees (Norkin,2016).

Testing Position- the individual in the prone position, with both knees extended and the hip to be tested in 0 degrees of abduction, adduction, and rotation (Norkin,2016).

Goniometer Alignment-

Centre fulcrum of the goniometer over the lateral aspect of the hip joint, using the greater trochanter of the femur for reference.

Align proximal arm with the lateral midline of the pelvis.

Align distal arm with the lateral midline of the femur, using the lateral epicondyle as a reference (Norkin., 2016).

Testing motion- the individual was instructed to extend the hip by raising the lower extremity from the table. Maintain the knee in extension throughout the movement (Norkin., 2016)

Figure 1.3 Hip Extension Range of Motion

Knee Flexion

Motion occurs in the sagittal plane around a medial– lateral axis. The normal range of flexion for adults varies from 130 to 140 degrees

Testing Position- the individual is in prone position, with both the knees extended and position the hips is in 0 degrees of flexion, extension, abduction, adduction, and rotation.

Goniometer Alignment-

Centre fulcrum of the goniometer over the lateral epicondyle of the femur.

Proximal arm with the lateral midline of the femur, using the greater trochanter for reference.

Distal arm with the lateral midline of the fibula, using the lateral malleolus and fibular head for reference (Norkin.,16).

Testing motion- The individual was instructed to gently bends the knee by flexing it towards the buttocks. The knee was flexed until either the individual feels discomfort or a firm endpoint is reached where further flexion is not possible.

Figure 1.4 Knee Flexion Range of Motion

3.17 Procedure

Based on the inclusion and exclusion criteria, a total of 40 subjects with hamstring tightness were divided into two groups. The hamstring muscle flexibility were assessed before and after the treatment. Brief instructions about the procedure were given to the subjects before the assessment. Group A (hold-relax stretching+ hot pack), Group B (Contract-Relax stretching+ hold relax) consisting of 20 subjects each.

Group A- 20 subjects were given Hold-Relax stretching + hot pack to hamstring muscle bilaterally.

Position- in Hold-Relax procedure, the range limiting muscle is first lengthened to the point of limitation or to extent that is comfortable for the subject. The subject then performs isometric contraction for 7 seconds followed by voluntary relaxation of the tight muscle. The limb is then passively moved into the new range as range limiting muscle is elongated and held for 20 seconds. This was repeated for 4 times (Dafda., 2019).

Figure 1.4 Hold Relax for Hamstring

Group B – 20 subjects were given Contract-Relax stretching + hot pack to the hamstring muscle bilaterally.

Position- in this technique, the leg was raised to a point of mild stretch was raised to a point of mild discomfort in a straight leg raising technique. Once the point of discomfort was reached, the subject was asked to perform a maximum voluntary contraction of the hip extensors for 6 seconds, the leg was then further raised to maintain mild discomfort and the subject relaxed at that point for 10 seconds followed by another 6 second contraction. The stretch was repeated 4 times (Feland et al., 2001).

Figure 1.5 Contract Relax for Hamstrings

3.10 TIME TO ADMINISTER

Group A received a Hold-Relax (HR) technique combined with a hot pack (isometric contraction for 7 seconds followed by voluntary relaxation of the tight muscle, repeated 4 times), while Group B received a Contract-Relax (CR) technique combined with a hot pack (maximum voluntary isotonic contraction of the hip extensors for 7 seconds, repeated 4 times).

3.11 DATA ANALYSIS

The data was analyzed and interpreted statistically using version 26 of SPSS (Statistical Package for Social Sciences) descriptive statics were means, standard deviation and standard error mean. Repeated measurement test was used to compare the clinical test measurements in each group 3 times. In case of significant differences, a paired T- test was used in each group to compare the pre-post and independent T-test was used to compare the changes after the intervention in Fingertip to Floor test, Active Knee Extension test and ROM between the two groups.

3.12 RESULTS

Table 4.1: Pre-test characteristics and demographic detail of subjects

This section presents the demographic details of the subjects (n=40) under study.

S.no.	**Demographic details**	**Group A (HR) (n=20)**	**Group B (CR) (n=20)**
1	Age (Years)	29.75±6.42	29.10±6.24
2	Height (Centimeters)	168.30±7.79	194.50±5.92
3	Weight (Kilograms)	65.75±11.70	63.20±13.73
4	BMI	23.09±3.28	22.06±3.71

Table 4.1 depicts the Mean and Standard Deviation of Group A and Group B with 95% confidence interval for Age (29.75±6.42) and (29.10±6.24), Height (168.30±7.79) and (194.50±5.92), Weight (65.75±11.70) and (63.20±13.73), and Body Mass Index (BMI) (23.09±3.28) and (22.06±3.71) respectively.

Table 4.2: Baseline (pre-test) measures and Post intervention measures of Group A (Hold-Relax stretching)- Fingertip to Floor test, Active Knee Extension test

Outcome measures	Pre-test Mean ± SD	Post-test Mean ± SD	p- value
Fingertip to floor test	20.00±6.32	12.25±7.13	0.000
Active Knee Extension Test			
Right	133.47±9.76	145.67±11.64	.000
Left	132.77±9.74	144.30±11.30	.000

Table 4.2 depicts the outcome measures for the fingertip to floor test for both the right and left leg. The mean value of the baseline measures for the right leg is20.00 with a standard deviation (SD) of 6.32, while the mean value after intervention is 12.25 with an SD of 7.13. The p-value is .000, which is less than 0.05. This shows that the findings were statistically significant and implies that the test values following intervention from baseline were significantly different.

Table 4.2 also depicts the outcome measures for the Active Knee Extension test for both the right and left leg. The mean value of the baseline measures for the right leg is133.47 with a standard deviation (SD) of 9.76, while the mean value after intervention is 145.67 with an SD of 11.64. The p-value is .000, which is less than 0.05. This shows that the findings were statistically significant and implies that the test values following intervention from baseline were significantly different. The same pattern is observed for the left leg, with a baseline mean of 132.77 and with an SD of 9.74 and after intervention mean of 144.30 with an SD of 11.30 and a p-value of .000 (<0.05).

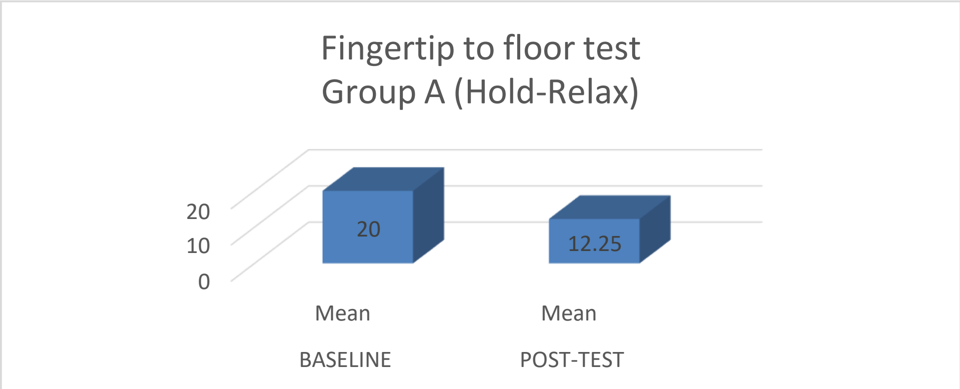

Figure 4.1: Bar graph representation of pre-intervention and post-intervention mean of Fingertip to Floor test of Group A

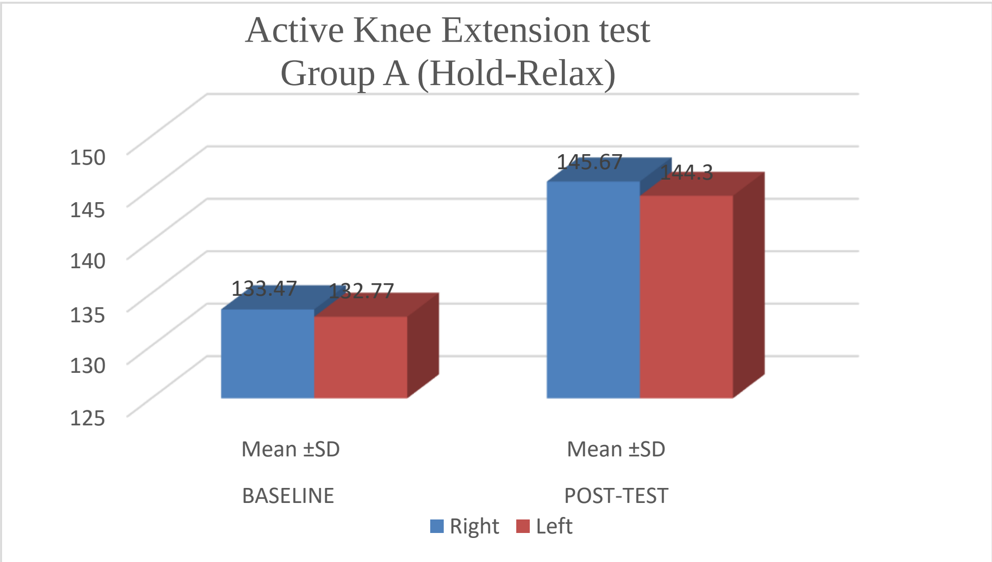

Figure 4.2: Bar graph representation of pre-intervention and post-intervention mean of Active Knee Extension Test of Group A

Table 4.3 Baseline (pre-test) ROM and Post intervention ROM of Group A (Hold-Relax stretching)

Outcome Measure		PRE- TEST Mean ±SD	POST-TEST Mean ±SD	p- value
Hip Extension	Right AROM	15.82±5.42	73.05±53.42	.008
	Right PROM	20.57±6.25	78.72±54.43	.002
	Left AROM	15.62±5.64	22.35±7.74	.000
	Left PROM	21.25±6.98	27.57±8.15	.000
Knee Flexion	Right AROM	69.60±53.09	107.15±203.95	.010
	Right PROM	77.62±56.16	85.45±57.22	.000
	Left AROM	124.20±12.49	134.00±14.12	.000
	Left PROM	132.00±11.72	139.80±21.42	.000

Table 4.3 Baseline (pre-test) ROM and Post intervention ROM of Group A (Hold-Relax stretching)

Table 4.3 depicts the outcome measures for hip extension and knee flexion (ROM) for both the right and left leg. The mean value of the baseline measures for the hip extension right AROM is 15.82 with a standard deviation (SD) of 5.42, while the mean value after intervention is 73.05 with an SD of 53.42. The p-value is .008, which is more than 0.05. This shows that the findings were statistically significant and implies that the ROM values following intervention from baseline were significantly different. The same pattern is observed for the right hip extension PROM, with a baseline mean of 20.57 and an after intervention mean of 6.25 and a p-value of .002 (<0.05). The same pattern is observed for the left hip extension AROM and PROM, with a baseline mean of 15.62 and 21.25 and an after intervention mean of 22.35 and 27.57 respectively and p-value of .000 (<0.05).

The mean value of the baseline measures for the knee flexion right AROM is 69.60 with a standard deviation (SD) of 53.09, while the mean value after intervention is 107.15 with an SD of 203.95. The p-value is .010, which is less than 0.05. This shows that the findings were statistically significant and implies that the ROM values following intervention from baseline were significantly different. The same pattern is observed for the right knee flexion PROM, with a baseline mean of 77.62 and an after intervention mean of 8.5.45 and a p-value of .000 (<0.05). The same pattern is observed for the left knee flexion AROM and PROM, with a baseline mean of 124.20 and 132.00 and an after intervention mean of 134.00 and 139.80 respectively and p-value of .000 (<0.05).

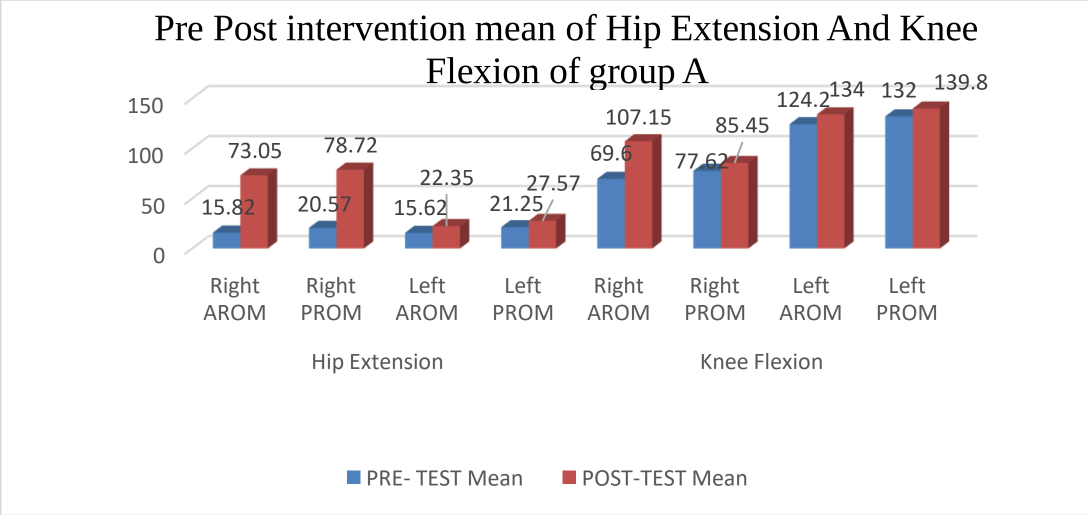

Figure 4.3: Bar graph representation of pre-intervention and post-intervention mean of Hip Extension and Knee Flexion of Group A

Table 4.4: Baseline (pre-test) measures and Post intervention measures of Group B (Contract-Relax stretching)- Fingertip to Floor test, Active Knee Extension test

Test	Pre- test Mean ± SD	Post-test Mean ± SD	p- value
Fingertip to floor test	18.85±7.56	11.05±9.11	.000
Active Knee Extension Test			
Right	132.15±12.25	144.50±13.96	.000
Left	134.75±11.58	145.00±13.09	.000

Table 4.2 depicts the outcome measures for the fingertip to floor test for both the right and left leg. The mean value of the baseline measures is 18.85 with a standard deviation (SD) of 7.56, while the mean value after intervention is 11.05 with an SD of 9.11. The p-value is .000, which is less than 0.05. This shows that the findings were statistically significant and implies that the test values following intervention from baseline were significantly different.

Table 4.5 depicts the outcome measures for the Active Knee Extension test for both the right and left leg. The mean value of the baseline measures for the right leg is 132.15 with a standard deviation (SD) of 12.25, while the mean value after intervention is 144.50 with an SD of 13.96. The p-value is .000, which is less than 0.05. This shows that the findings were statistically significant and implies that the test values following intervention from baseline were significantly different. The same pattern is observed for the left leg, with a baseline mean of 134.75 with an SD of 11.58 and after intervention mean of 145.00 with an SD of 13.09 and a p-value of 0.00 (<0.05).

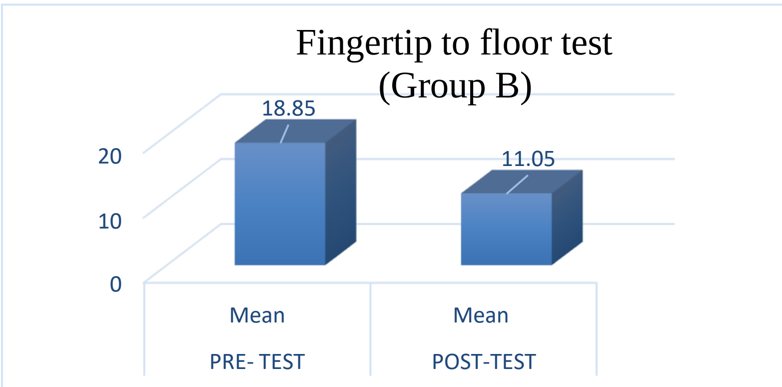

Figure 4.4: Bar graph representation of pre-intervention and post-intervention mean of Fingertip to Floor test of Group B

Figure 4.5: Bar graph representation of pre-intervention and post-intervention mean of Active Knee Extension Test of Group B

Outcome Measure		PRE- TEST Mean ±SD	POST-TEST Mean ±SD	p- value
Hip Extension	Right AROM	17.65±5.34	24.20±8.46	.000
	Right PROM	22.95±6.42	29.200±8.36	.000
	Left AROM	17.85±7.13	24.45±8.46	.000
	Left PROM	23.00±8.30	29.75±8.92	.000
Knee Flexion	Right AROM	129.50±12.69	140.05±15.71	.000
	Right PROM	136.30±11.40	148.10±12.80	.000
	Left AROM	124.80±13.11	134.65±14.18	.000
	Left PROM	131.45±13.36	124.10±13.68	.000

Table 4.5 Baseline (pre-test) ROM and Post intervention ROM of Group B (Contract-Relax stretching)

Table 4.7 depicts the outcome measures for hip extension and knee flexion (ROM) for both the right and left leg. The mean value of the baseline measures for the hip extension right AROM is 17.65with a standard deviation (SD) of 5.34, while the mean value after intervention is 24.20 with an SD of 8.46. The p-value is .000, which is less than 0.05. This shows that the findings were statistically significant and implies that the ROM values following intervention from baseline were significantly different. The same pattern is observed for the right hip extension PROM, with a baseline mean of 22.95 and an after intervention mean of 29.20 and a p-value of .000 (<0.05). The same pattern is observed for the left hip extension AROM and PROM, with a baseline mean of 17.85 and23.00 and an after intervention mean of 24.45 and 29.75 respectively and p-value of .000 (<0.05).

The mean value of the baseline measures for the knee flexion right AROM is 129.50 with a standard deviation (SD) of 12.69, while the mean value after intervention is 140.05 with an SD of 15.71. The p-value is .000, which is less than 0.05. This shows that the findings were statistically significant and implies that the ROM values following intervention from baseline were significantly different. The same pattern is observed for the right knee flexion PROM, with a baseline mean of 136.30 and an after intervention mean of 148.10 and a p-value of .000 (<0.05). The same pattern is observed for the left knee flexion AROM and PROM, with a baseline mean of 124.80 and 131.45 and an after intervention mean of 134.65 and 142.10 respectively and p-value of .000 (<0.05).

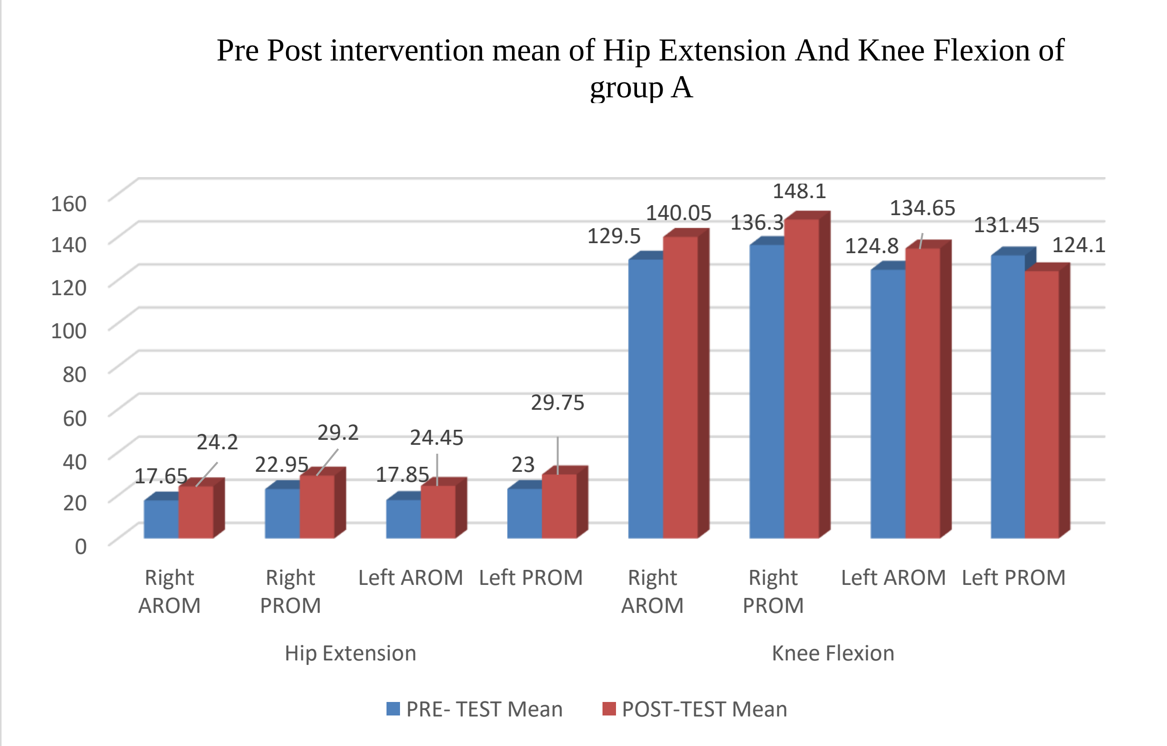

Figure 4.6: Bar graph representation of pre-intervention and post-intervention mean of Hip Extension and Knee Flexion of Group B

Table 4.6: Between the group comparison of before-intervention and after- intervention measures and their p-value

Outcome Measures		Group A (Hold Relax Technique)		Group-B (Contract-Relax technique)		P-value	Effect Size
		Before intervention Mean ±SD	After intervention Mean ±SD	Before intervention Mean ±SD	After intervention Mean ±SD		
Fingertip to Floor test		18.85±7.56	11.05±9.11	21.15±4.71	20.15±7.56	0.25	1.20
Active Knee Extension test	right	132.15±12.25	144.50±13.9	134.80±6.48	146.85±8.98	0.53	0.26
	left	134.75±11.59	145.00±13.09	130.80±7.22	143.60±9.48	0.07	0.14

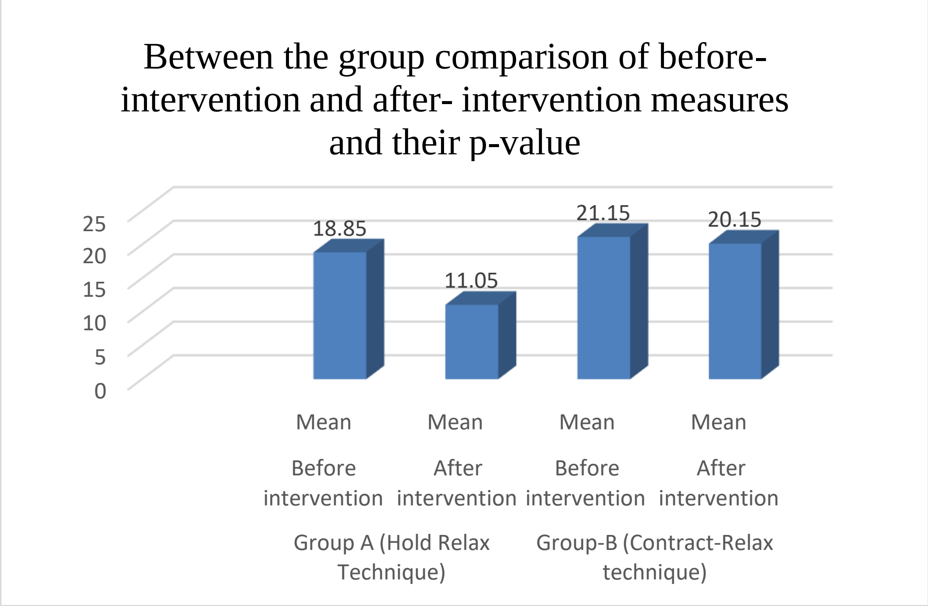

Figure 4.7: Bar graph representation of pre-intervention and post-intervention mean of Fingertip to Floor Test of Group A and Group B

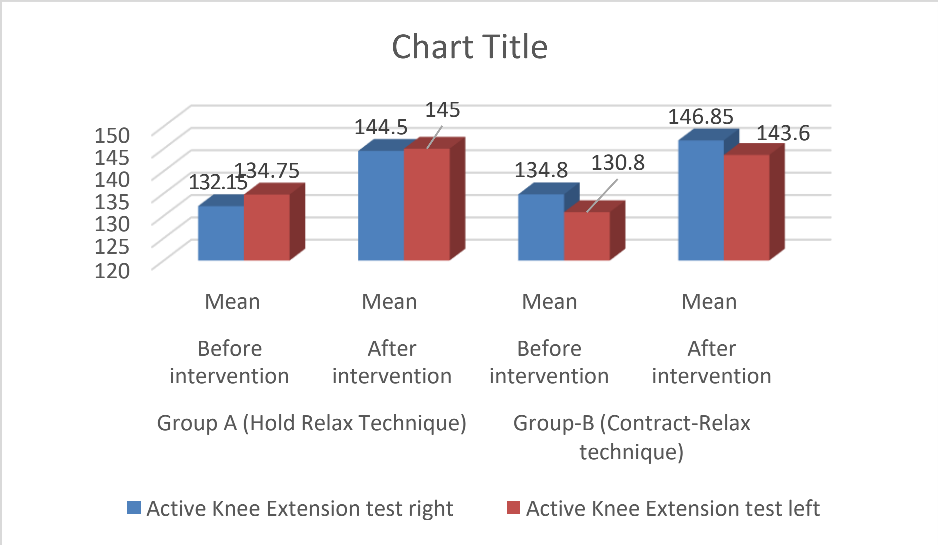

Figure 4.8: Bar graph representation of pre-intervention and post-intervention mean of Active Knee Extension test of Group A and Group B

Table 4.7: Between the group comparison of before-intervention and after- intervention measures and their p-value

Outcome Measures		Group A (Hold Relax Technique)		Group-B (Contract-Relax technique)		P-value	Effect Size
		Before intervention Mean ±SD	After intervention Mean ±SD	Before intervention Mean ±SD	After intervention Mean ±SD		
Hip Extension	AROM	17.65±5.34	124.80±13.11	14.00±4.98	21.30±6.90	0.00	15
	PROM	22.95±6.41	131.45±13.36	18.20±5.21	26.00±7.03	0.00	15
Hip Extension	AROM	17.65±5.34	24.20±8.45	13.60±5.30	20.50±6.64	0.13	0.55
	PROM	22.95±6.41	24.20±8.45	19.55±7.25	20.50±6.64	0.21	0.55

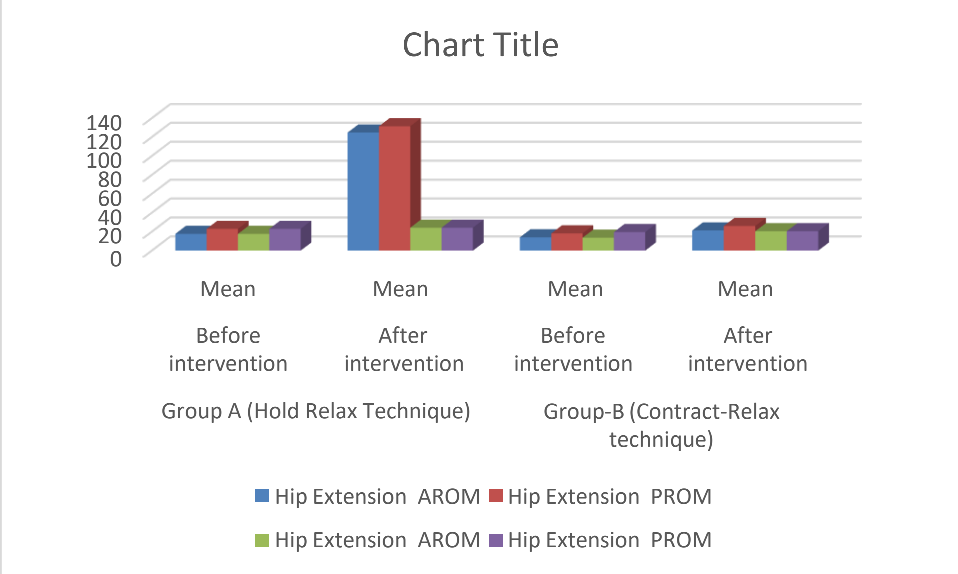

Figure 4.9: Bar graph representation of pre-intervention and post-intervention mean of Hip Extension ROM of Group A and Group B

Outcome Measures		Group A (Hold Relax Technique)		Group-B (Contract-Relax technique)		P-value	Effect Size
		Before intervention Mean ±SD	After intervention Mean ±SD	Before intervention Mean ±SD	After intervention Mean ±SD		
Knee Flexion (Right)	AROM	17.85±7.12	24.45±8.46	121.35±9.83	29.75±8.91	0.00	0.59
	PROM	23.00±8.30	189.85±266.29	132.25±11.18	141.15±10.42	0.00	4.66
Knee Flexion (Left)	AROM	129.50±12.69	140.05±15.70	118.90±10.01	127.95±9.25	0.00	1.30
	PROM	136.30±11.39	148.10±12.80	127.70±10.64	131.50±12.80	0.00	

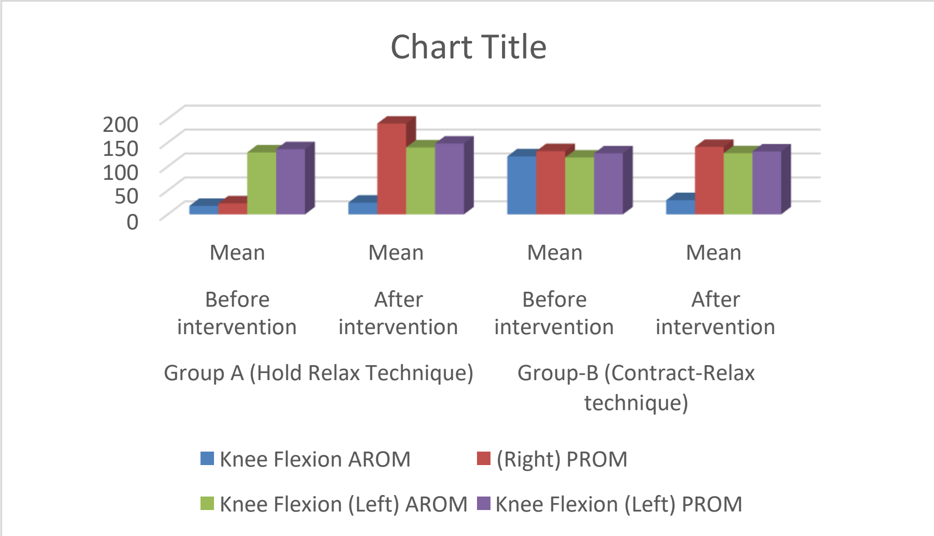

Figure 1: Bar graph representation of pre-intervention and post-intervention mean of Knee Flexion ROM of Group A and Group B

Table 4.7 shows the result of a study comparing the effects of Hold-Relax Stretching (Group-A) and Contract-Relax stretching (Group-B) on hamstring flexibility. The statistical analysis includes paired t- test to compare the before and after intervention measures within each group and independent t -test to compare the between group differences.

The before and after intervention measures of all outcomes for both the groups were significantly different from each other, as evidenced by the low p-values (less than 0.05), which indicates a significant improvement in hamstring flexibility after intervention for both groups.

The between group comparison showed that the changes in all outcome measures were significantly greater in the Hold-Relax group compared to the Contract-Relax group. These findings were supported by the greater mean values, indicating a significant difference between the groups.

Based on the results in Table 4.7, both Group A (HR+ hot pack) and Group B (CR+ hot pack) showed significant improvements in all outcome measures after intervention ($p<0.05$). However, the p-values indicate that the improvements were significantly greater in Group A that in Group B. Therefore, it can be concluded that Hold-Relax (HR) was more effective in improving the hamstring muscle flexibility, compared to Contract-Relax group.

DISUSSION

The hamstrings play a crucial role in the biomechanics of the lower limb, contributing to fundamental activities such as walking, running, and squatting. Reduced hamstring muscle flexibility is a prevalent clinical finding among young adults and is often considered a common musculoskeletal complaint or disorder, which can lead to functional impairments (Rizvi et al., 2020). A shortened hamstring muscle can cause joint imbalances and poor postural alignment, potentially resulting in injury and joint dysfunction. Inadequate flexibility in the hamstrings is believed to increase the risk of hamstring injuries. Furthermore, stiff and short hamstring muscles may contribute to low back pain and the development of patellar tendinopathy (Renuka, 2019). Given the essential role of the hamstrings in facilitating movement and providing stability, optimizing their flexibility is paramount for individuals across all age groups and activity levels (Feland et al., 2001).

This study included 40 subjects, divided into two groups. Group A received a Hold-Relax (HR) technique combined with a hot pack (isometric contraction for 7 seconds followed by voluntary relaxation of the tight muscle, repeated 4 times), while Group B received a Contract-Relax (CR) technique combined with a hot pack (maximum voluntary isotonic contraction of the hip extensors for 7 seconds, repeated 4 times). Pre- and post-intervention range of motion (ROM) values were assessed. The results demonstrated increased ROM at the hip and knee joints, improved knee extension angle, and reduced fingertip-to-floor distance, indicating

enhanced hamstring flexibility.
A paired t-test comparing the pre- and post-intervention results within the individual groups revealed significant improvements in both intervention groups. Specifically, the paired t-test yielded p<0.001 for both Group A (Hold-Relax) and Group B (Contract-Relax), indicating statistically significant improvements in flexibility following the interventions.
Supporting these findings, Singh et al. (2017) concluded that PNF (Hold-Relax) stretching was more effective in increasing hamstring muscle flexibility in collegiate students than neurodynamic sliding. Another study by Renuka (2019) found the Hold-Relax technique to be more effective in increasing hamstring muscle flexibility compared to the agonist contract technique. Lehman et al. (2018) compared the effects of Hold-Relax and static stretching on muscle flexibility, concluding that both methods significantly increased flexibility, with Hold-Relax showing a slightly greater effect.
The proposed mechanism behind the improvement in hamstring flexibility for Group A may involve the viscoelastic nature of the muscle. According to Knott and Voss (1968), the Golgi tendon organ, a nerve receptor present in tendons, activates during muscle stretching or contracting, leading to autogenic inhibition and subsequent muscle relaxation (Singh et al., 2017).
Subjects in Group B also showed significant results after the intervention, indicating that the Contract-Relax technique combined with a hot pack significantly enhances muscle flexibility. This effect is likely due to the ability of contract-relax stretching to overcome the muscle's protective stretch response, allowing for a deeper release of tension compared to other stretching techniques (Morcelli et al., 2013). Studies by Mitchell et al. (2007), Lustig et al., and Morcelli et al. (2013) supported that contract-relax stretching can result in greater increases in flexibility compared to other stretching techniques.
A study by Borges et al. (2018) found an immediate effect favoring Hold-Relax and Contract-Relax techniques over static stretching using the Active Knee Extension test. A systematic review by Cayco et al. (2016) indicated that Hold-Relax and Contract-Relax are safe and effective in increasing hamstring flexibility with long-term benefits, outperforming other stretching techniques.
On the other hand, an independent t-test was conducted to compare the mean scores of Group A and Group B on the variables of interest. The results revealed a significant difference between the two groups, indicating that the means were statistically different. In particular, Group A mean difference score for the Fingertip to Floor test was 7.8±1.55, while Group B was 1.00±2.85. The mean difference score of Group A for the Active Knee Extension test was 12.35±1.65, (left) 10.25±1.5, and for Group B mean difference score was 12.05±2.5, (left) 12.8±2.26. Similarly, for Group A range of motion for the Active knee Extension test was 110.15±7.71 (Active Hip Extension; left) 6.55±3.11 and for Group B was 7.3±1.92 (Active Hip Extension; left) 6.9±1.34 for Group B it was 91.6±0.92 and (Active Knee Flexion; left) 3.8± 2.16.
These findings suggest that the Hold-Relax technique outperforms the Contract-Relax technique on several parameters, including fingertip-to-floor distance, active knee extension, and range of motion. This may be due to the targeted and effective stretching achieved when the same muscle that is contracted subsequently relaxes and is stretched. Sharman et al. (2006) suggest that the Hold-Relax method promotes greater flexibility and ROM due to the sustained isometric contraction leading to more significant muscle relaxation. Hindle et al. (2012) also noted that the Hold-Relax technique allows for prolonged muscle relaxation, contributing to greater increases in ROM. The result of the study is corroborated by similar studies done by Singh et al. (2017), Renuka (2019), Hindle et al. (2012) Lehman et al. (2018), Sharman et al., (2006) who have reported Hold-Relax technique to give better results than contract relax.
The possible mechanism for the improvement with Hold- relax technique may be due to the effects of autogenic inhibition. The hold- relax technique works on the principle of autogenic inhibition, which relies on the body’s self-regulatory mechanisms of the GTOs in order to protect the structures. Autogenic Inhibition is what occurs in a contracted or stretched muscle in the form of a decrease in the excitability because of inhibitory signals sent from the GTOs of the same muscle (Sharman et al., 2006). This tension causes activation of Ib afferent fibers within the GTOs. Afferent fibers send signals to the spinal cord where the stimulus causes the activation of inhibitory interneurons within the spinal cord. These interneurons place an inhibitory stimulus upon the alpha motoneuron, decreasing the nerves’ excitability and decreasing the

muscles' efferent motor drive (Sharman et al., 2006). It is theorized that this reflex occurs as the body attempts to spread the workload evenly across the motor unit within the muscle, assisting the asynchronous recruitment of the body in preventing specific motor units from fatiguing. This chain reaction causes the targeted muscle to relax, which is one of the driving theories behind the increased elongation of the muscle fibers.

Moreover, this study was conducted on healthy individuals, which likely contributed to the superior outcomes observed with the hold-relax technique. In healthy participants, muscle tissue responds well to static stretching, enhancing flexibility and range of motion, as demonstrated by Feland et al., (2004), which found significant improvements in range of motion with hold-relax techniques in non-injured subjects. However, in cases of acute injury, the contract-relax method could potentially yield better results. This is supported by research from Sharman et al., (2006), which indicates that the contract-relax technique, involving an isometric contraction phase before the stretch, can enhance blood flow and neuromuscular facilitation, which are crucial for recovery in injured tissues. Therefore, while hold-relax proves effective for uninjured muscles, contract-relax might be more beneficial for addressing the specific needs of acutely injured muscles.

Despite the scarcity of direct comparative research, the results indicate that both Contract-Relax and Hold-Relax stretching are effective methods for increasing range of motion and reducing muscle tightness (Cayco et al., 2019). Further studies are needed to be done in this direction for more reliable results.

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