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Comparative Study of Mulligan Bent Leg Raise *vs.* Hold Relax Proprioceptive Neuromuscular Facilitation on Hamstring Tightness in High School Student

Phadnis TR[1*] and Bhave SM[2]

[1]*Department of Physiotherapy, Nanded Physiotherapy College & Research Center, Nanded, Maharashtra, India*
[2]*Department of Physiotherapy, PT School and Centre GMC, Nagpur, Maharashtra, India*

Abstract

Background: Hamstring group of muscle are postural muscle and as they are biarticular, they has tendency to shorten even under normal circumstances. Since they are superficial two joint muscle, they tend to become very tight leading to muscle imbalance, which can give rise to number of postural problems and leave us with open muscle injury.

Prevalence & incidence of Hamstrings tightness in normal individuals in day today life is high due to limited activity and lack of regular exercise. It has been observed that 75% of boys and 35% of girls aged 10 revealed reduced flexibility of hamstrings.

Aim & Objectives: To study and compare the effectiveness of Mulligan Bent Leg Raise technique and Hold Relax PNF technique in High school going students with hamstring muscle tightness.

Methodology: Sixty students were selected from high schools and study group were formed by alternate method of sampling. Group A underwent mulligan bent leg raise (BLR) and Group B underwent Proprioceptive neuromuscular facilitation (PNF) hold relax technique. The two groups were evaluated on the basis of Active knee extension test (AKE) test. Intervention used to improve AKE range of motion consisted of 15 session conducted over duration of 3 weeks. Each session lasted for 15 minutes consisting of 3 repetitions respectively done on 5 consecutive days per week. The two groups were compared and results obtained using unpaired t test and repetitive measure ANOVA test.

Results: In Group A 43.3% were male and 56.7% were females, in Group B 53.3% were male 46.7% were female. Comparison of baseline values of mean AKE ROM of Right side in Group A was 135.2 and in Group B was 138.8. For left side the mean AKE ROM value in Group A was 136.3 and in Group B were 140.3. There is no significant statistical difference between baseline values. Comparison of mean of difference in AKE ROM from post intervention value of right side the mean of difference on 5 day for group A was 19.1 and for group B it was 6.93. On day 10 for Group A, it was 33.16 and for Group B it was 19.9, on day 15 for Group A it was 42.5 and for Group B it was 33.76. Comparison was done with unpaired t-test. On comparison there was statistically significant difference between group A and B p-value <0.0001. Mean of difference in AKE ROM from pre intervention value of left side the mean of difference on 5 day for Group A was 18.8 and for Group B it was 7.13. On day 10 for Group A it was 33.13 and for Group B it was 20.5. On day 15 for Group A it was 42.36 and for Group B it was 34.67. Comparison was done with unpaired t-test. On comparison there was statistically significant difference between Group A and B, p-value <0.0001.

Conclusion: Effect of Mulligan Bent Leg Raise Technique shown more reduction in hamstring tightness, and improves Active knee extension range of motion compare to PNF hold relax technique.

Keywords: Hamstring tightness; High school students; Mulligan BLR; PNF hold relax

Introduction

Flexibility is ability to move a single joint or series of joints through an unrestricted pain free range of motion (ROM). It is dependent upon the extensibility of muscle which allows muscle that crosses a joint to relax, lengthen and yield to a stretch force [1].

In the literature, the terms "flexibility" and "muscle length" are often used synonymously when referring to the ability of muscles to be lengthened to their end range [2].

Posterior femoral muscles includes Biceps femoris, Semitendinosus, Semimembranosus collectively termed as Hamstrings, which crosses hip and knee joints integrating co-axial extension with genu flexion. Functioning as a unit, the hamstrings are responsible for flexion and extension of knee joint, as well as extension of hip through the movement of the thigh in a reverse direction [3].

Being a two joint muscle its important characteristic is hamstrings plays a crucial role in many daily activities such as walking, running, jumping, and controlling some movement of the trunk. In gait cycle, hamstrings plays an important role in stance phase. They work

***Corresponding author:** Tejaswini Rajendra Phadnis, Department of Physiotherapy, Nanded Physiotherapy College & Research Center, Nanded-431606, Maharashtra, India, Tel: +919561349184; E-mail: dr.tejaswiniphadnis@gmail.com

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effectively as knee flexors when hip is flexed by increasing the length and tension in muscle group [4].

Hamstrings muscle is a postural muscle and as it is biarticular, it has tendency to shorten even under normal circumstances [5]. Since it is a superficial two joint muscle, they tend to become very tight leading to muscle imbalance, which can give rise to number of postural problems and leave us with open muscle injury [6].

Under ordinary condition two joint muscles are seldom used to move both joints simultaneously and more often the action of two joint muscles is prevented at one joint by resistance from gravity or continuation of other muscle, so a two joint muscle have tendency to shorten quickly [1].

Running long distance causes the active muscle to become strong and less flexible whereas opposing muscles which are relatively underused become weaker [1]. Immobilization for prolonged period also causes muscle tightness as the muscle is not used for longer time [1]. Slow muscle fibers maintain posture; they activate more easily and are capable of more sustained contraction and tend to become shortened and tight. In females, wearing high heels for long period of time causes hamstrings tightness [1].

Muscle tightness is caused by a decrease in the ability of the muscle to deform, resulting in a decrease in the range of motion at the joint on which it acts. The term has also been used to denote a slight to moderate decrease in muscle length; usually the movement in the direction of the elongating muscle is limited [7].

It could make the musculotendinous unit more susceptible to injury, increase resistance to various anatomical structures, which may lead to overuse syndrome. It could also lead to some pathological conditions at the joint on which the muscle acts, especially on muscles like the hamstrings which passes over two joints [7].

Anatomical causes of reduced muscle extensibility have been categorized as “muscle shortness” and “muscle stiffness” [8]. A short muscle is a musculotendinous unit that has a reduced capacity to lengthen due to reduction in the number of sarcomeres in series [9,10], or a reduction in the length or elasticity of the connective tissues (such as occurring with scar tissue formation following injury) [8].

Physiological cause of reduced muscle extensibility is related to the contractility of the muscle cells. Activity in alpha motor neurons that results in muscle contraction can increase the force necessary to elongate the homologous muscle, and thus the muscle will have increased stiffness and decreased flexibility [11].

Prevalence & incidence of Hamstrings tightness in normal individuals in day today life is high due to limited activity and lack of regular exercise. Tight Hamstrings usually start at the age of 5 or 6 years, when children start their seated school careers [3].

Inability to achieve greater than 160 degree of knee extension with hip at 90 degree of flexion is considered as hamstring tightness [12]. Some researchers have defined it as at least 15 degree loss of active knee extension while others have defined it as equal to or greater than 30 degree loss of active knee extension with the femur held at 90 degree of hip flexion [7].

It has been observed that 75% of boys and 35% of girls aged 10 revealed reduced flexibility of hamstrings and confirmed that this observation has to be done in 15 to 17 year old boys [13]. Akinpelu et al. [7] performed study on influence of age on hamstring tightness in apparently healthy Nigerians. In which they concluded hamstring tightness increases in apparently healthy Nigerians from childhood up to age 40-49 years and it is higher in males than females.

Journal of Dental and Medical Sciences (volume 9, issue 3) presented a study on student population in age group of 17-23 years as they have the posture of sitting with hip and knee flexion at 90 degree which predisposes them to hamstring tightness [1].

Stretching is a general term used to describe any therapeutic man oeuvre designed to increase the extensibility of soft tissues, thereby improving flexibility and ROM by elongating structures that have adaptively shortened and have become hypo mobile over time [14]. The goal of all stretching programs is to optimize joint mobility while maintaining joint stability. Concern should always be focused on systematic, safe and effective application of range of motion techniques utilized [2].

In general the following effects are attributed to stretching: precaution against developing short muscles, lowering of muscular resting tension, prevention of muscle tightness, increase of joint's range of motion, prophylaxis against injuries and due to these stretching effects a general increase of muscular performance [15].

According to Nelson, stretching was the way or method to gain flexibility in our body. It has been found out that stretching, helped the biochemical accuracy of competitive movements by improving the muscle function which increasingly raised the body temperature, decreased the muscle stiffness and increased the range of motion (ROM) at the joint, especially at the lower extremity (hip flexion, hip abduction, knee flexion and knee dorsiflexion, and also trunk flexion) [16].

Proprioceptive neuromuscular facilitation stretching technique developed by Herman Kabat, is a group of stretching techniques developed in 1965. The purpose of this technique is to increase flexibility and range of motion through the stimulation of the neuromuscular system and the proprioceptors. PNF is an approach that attempts to increase efficiency in movement and provide the necessary range of motion to complete activities of daily living. It was also designed to improve reflexes and postural impairments in order to restore balance and coordination. It is a widely used practice in rehabilitation settings by physical therapists and other health professionals. As with other forms of stretching it is important to employ proper technique during the movements to avoid injuries to the tendons, muscles or ligaments [17].

Funk concluded in his study that those who exercised and received PNF stretching experienced more of an increase in flexibility when compared to the baseline group and the group without exercise and PNF. However, there were no differences observed in the static stretching groups (baseline, with exercise, and without exercise) [18].

It has been compared that three stretching techniques which included static, dynamic, and the CR method of PNF. Each of these treatments was found to produce significant improvements when comparing the beginning test to the end test. It turned out that the longer the treatment time, the less significant the results differed among the three treatments (Figures 1 and 2) [18].

Mulligan BLR technique consist of gentle isometrics stretching of hamstring in specific directions in progressively greater positions of hip flexion, the expecting results are increased flexibility of hamstring muscle with increased ROM of active knee extension (Figure 3).

Mulligan bent leg raise (BLR) technique has been described as a means of improving range of straight leg raise (SLR) in subjects with

Figure 1: Materials used.

Figure 2: Treatment table.

Figure 3: Active knee extension.

LBP and or referred thigh pain. It stretches the lower extremity muscles in combination of hamstring, adductors, and rotators [19].

Improvement of SLR range because of the BLR technique might be due to mobilization of painful sensitized nerve tissues, similar to the slider effects describe by Butler [20].

Another beneficial effect of BLR technique might be a change in stretch tolerance of the hamstrings. Jonhagen et al. [5] demonstrated that the increase range of SLR, following stretching is mediated via an increase in hip flexion and pelvic rotation as well as hamstring length and not related to increased hamstring viscoelastic properties [4].

Material and Methods

Permission and approval to carry out the research work was obtained from head of institution and institutional ethical committee.

1. Research design: Comparative study.
2. Place of study: The study was conducted at outpatient Physiotherapy setup.
3. Data was collected at outpatient physiotherapy setup.
4. Duration of study: From September 2014 to October 2015.

Population

Students in the age group of 15-18 years with hamstring tightness of more than 30° constituted the population of the study.

Sample size

Patients were screened using proforma [Annexure D]. 72 students were screened. Total 60 who met the inclusion criteria and accepted to participate, were included in the study.

Selection criteria

Inclusion criteria

1. Both male and female in age group of 15- 18 years.
2. Students with hamstring tightness more than 30 degree.

Exclusion criteria

1. Any traumatic and infectious condition involving lower limb.
2. Pathologies and deformities related to knee and hip joint.

Material use

1. Universal full-circle Goniometer.
2. Treatment table.
3. Stabilizing belts.
4. Velcro straps.
5. Soft pad.
6. Pen.
7. Paper

Procedure for Data Collection

The study was approved by institution ethics committee. Written informed consent was taken from students, explaining the study procedures, possible benefits of study, right to withdraw from the study in a language they understood. The patients were then evaluated according to the proforma (Annexure I) [21-24].

Examination

The demographic data like age, gender, occupation, contact number and address was collected. Then hamstring tightness was measured.

Measurment of hamstring tightness

Student was in supine position. Opposite leg was stabilised by stabilising belt. The side to be measured was taken in hip and knee 90°of flexion.

Fulcrum of goniometer was placed on condyle of femur, stationary arm was parallel to shaft of femur and movable arm was moved with reference to lateral malleolus. Student did the active knee extension with hip 90° of flexion and reading was taken [25].

All the students who were assessed were assigned into two groups by alternate method. Even numbers were allotted in the group A and odd numbers were allotted in group B.

Group A: Mulligan's Bent Leg Raise Technique.

Group B: Hold Relax PNF technique.

Intervention

Therapy programme for Group A

Total 30 patients were included in this group. Guidelines for Mulligan bent leg raise: These guidelines have been followed during the MWM technique application.

1. Treatment was given in supine position.
2. Subjects were told to inform if the movement was painful.
3. Subjects were asked not to perform movements actively.
4. The communication with the patients was maintained during treatment.

The technique was explained to the Patients prior to application, continuous instruction and encouragement was given during the treatment.

Patients were instructed to report any discomfort and pain during technique.

Mulligan bent leg raise for hamstring tightness.

Patient's position: Subject was positioned in supine lying. Knee was on the therapist shoulder so as hip and knee of the side to be stretched were bent at 90-90 degree.

Therapist's position: Therapist was standing to the side which is to be treated facing the patient.

Hand placement for technique: Hand was placed on lower end of femur.

Technique: Subject's flexed knee was placed over therapist's shoulder, the popliteal fossa of the knee resting on the therapist shoulder. A distraction (longitudinal traction force along the long axis of femur) was applied at the lower end of femur and subject was asked to push the therapist shoulder with his or her leg followed by voluntary relaxation.

At this point of relaxation, the therapist pushed the bent knee up as far as possible in the direction of the shoulder on the same side in pain free range. This stretch was sustained for 5-10 sec and then relaxed (Figures 4 and 5).

Figure 4: Mulligan bent leg raise technique (starting position).

Figure 5: Mulligan bent leg raise technique (end position).

If the pain or restriction eased, the hip was taken into further flexion. It was ensured that there was no pain during the procedure. If it was painful the direction of the leg raise was altered by medial rotating or abducting the hip.

The contra lateral leg was kept relaxed and allowed to move as it goes. At the end of the range, the position was held for 10 seconds and limb brought back to neutral position. The traction was maintained throughout the technique [26].

Group B

Total 30 patients were included in this group. Following points were considered while Hold Relax PNF technique was used.

1. The patient should be comfortable in supine lying position.
2. Stabilization was given to opposite extremity.
3. The communication with the patients was maintained during treatment. The technique was explained to the patients prior to application, continuous instruction and encouragement was given during the treatment.
4. The resistant force was exactly matched with the patient's effort (20% of available strength initially which was increased subsequently if no pain was produced by the effort.)

Hold relax PNF technique for hamstring tightness

Patient position: Patient was positioned in a supine lying at the edge of the treatment table.

Therapist position: Therapist was standing at the side to be treated, facing the head end of the bed, at the waist level.

Stabilization: Stabilization was given to the opposite extremity with stabilizing belt at the thigh anteriorly.

Technique: Subject was positioned in supine lying with low back as flat as possible. Hip was flexed to 90˚with slight flexed knee supported by the therapist at the ankle by placing it on his shoulder (Figure 6). The opposite extremity was stabilized along the anterior aspect of thigh with the support of stabilizing belt. With the knee in maximum extension passively, the hip was flexed at 90˚ until the participant felt the stretch and sustained for 15 sec. Then subject was asked to give resistance with the knee flexion with ankle on shoulder. Again hold was given for 15 sec then relaxed and patient was asked for active extension of knee. According to the Rule of three 3 repetitions were given [14].

Statistical Analysis and Results

Data analysis

Following dependent variables were analyzed for statistics.

1. Active knee extension Range of motion (AKE ROM).
2. Data of 60 subjects were analysed.

Continuous variables (Age, AKE ROM) were presented as Mean ± SD. Categorical variables (Gender) were expressed in actual numbers and percentages. AKE ROM was compared at different follow up period in each group by performing one way repeated measure ANOVA.

Figure 6: Hold relax PNF technique.

Changes in AKE ROM at Day 5, Day 10 and day 15 compared from baseline (pre intervention test) between Group A and Group B by performing unpaired t-test. $p<0.05$ was considered as statistical significance. Statistical software STATA version 13.0 was used for statistical analysis.

Table 1 showing age distribution and mean age of students. In Group A maximum number of subjects of age group of 15 year and in Group B also maximum no of subject of age group of 15. Mean age of Group A is 15.86 and Group B 16.16, there is no significant difference between both the groups p-value 0.3643 (Figure 7a).

Pie diag- Showing of mean age of subjects in Group A is 15.86 and Group B is 16.16 which was no significant difference hence baseline is comparable (Figure 7b).

Age in years	Group-A		Group-B	
	Number	Percent	Number	Percent
15 year	18	60	15	50
16 year	4	13.3	3	10
17 year	2	6.7	4	13.3
18 year	6	20	8	26.7
Total	30	100	30	100
Mean Age	15.86 ± 2.99 (15-18)		16.16 ± 1.31 (15-18)	
P Value-0.3643,NS				

Table 1: Age distribution of subjects of the study in 2 groups.

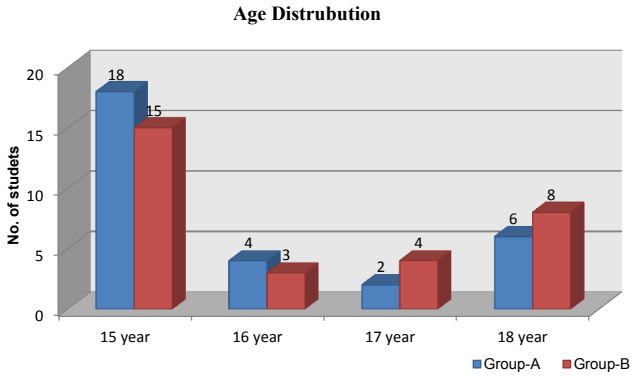

Figure 7a: Showing no of students with age distribution in Group A and in Group B.

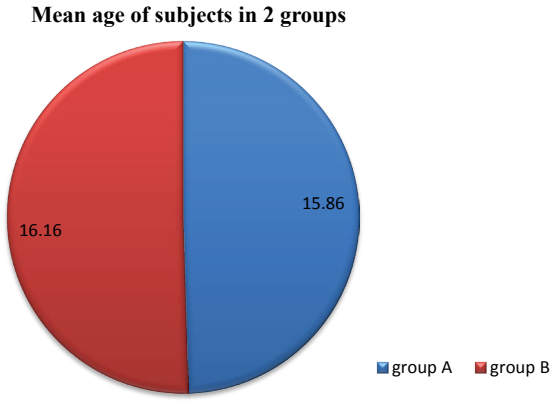

Figure 7b: Mean age of subjects in 2 groups

Table 2 showing comparison baseline values of mean AKE ROM of Right side Group A 135.2 and Group B 138.8. For left side Group A 136.3 and Group B 140.3. There is no statistical significant difference between baseline values. P value of Right side of Group A and B is 0.0618 and left side of Group A and B are 0.0661.

Figure 8 showing No any significant difference between mean of AKE ROM, hence at the baselines the mean of AKE ROM were comparable.

Table 3 shows mean of AKE ROM of right side of subjects of Group A, pretest was 135.25, on day 5 it was 154.33, on day 10 it was 168.4, on day 15 it was 177.73. On comparison with one way repeated measure ANOVA it was statistically highly significant difference p-value is <0.001.

Table 4 Showing mean of AKE ROM of right side of subjects of Group B pretest it was 138.8, on day 5 it was 145.73, on day 10 it was 158.7, on day 15 it was 172.56. On comparison with one way repeated measure ANOVA it was statistically highly significant different p-value is <0.001.

Figure 9 Showing comparison of mean of AKE ROM of Group A of Right side on pretest, on day 5, on day 10 and on day 15. Table 5 Showing mean AKE ROM of left side of Group A of pretest it was 136.3, on day 5 it was 155.1, on day 10 it was 169.4, on day 15 it was 178.66. On comparison with one way repeated measure ANOVA it was statistically highly significant different p-value is <0.001.

Table 6 showing mean AKE ROM of left side of Group B of pretest it was 140.33, on day 5 it was 147.46, on day 10 it was 160.83, on day 15 it was 175. On comparison with one way repeated measure ANOVA it was statistically highly significant different p-value is <0.001. Figure 10 showing comparison of mean of AKE ROM of Group A and Group B of left side on pretest, on day 5, on day 10, and on day 15.

Table 7 Showing comparison of mean of difference in AKE ROM from post intervention value of right side the mean of difference on 5 day for group A was 19.1 and for group B it was 6.93. On day 10 for group A, it was 33.16 and for group B it was 19.9, on day 15 for group A it was 42.5 and for group B it was 33.76. Comparison was done with unpaired t-test.

On comparison there was statistically highly significant difference between group A and B p-value <0.001. Figure 11 showing extremely significant change in AKE ROM of group A and group B of right side from base line. Table 8 Showing comparison of mean of difference in

	Group-A	Group-B	t-value	p-value
Right	135.2	138.8	1.9048	0.0618
Left	136.3	140.3	1.8729	0.0661

Table 2: Baseline values of mean of AKE ROM between Group-A and Group-B.

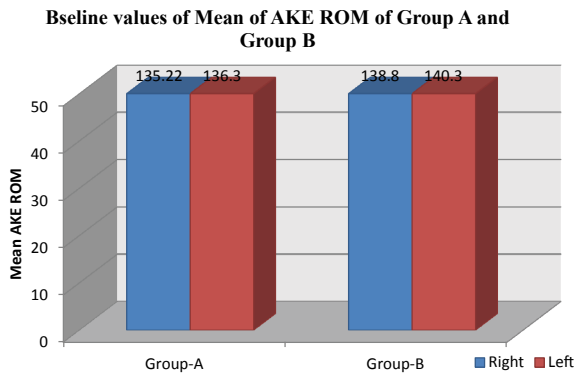

Figure 8: Bseline values of mean of AKE ROM of Group A and Group B.

	Pre test	Day 5	Day 10	Day 15	f-value	p-value
Mean	135.25	154.33	168.4	177.73	775.09	<0.001
SD	8.14	5.978	6.641	2.97		
Median	135	156	169	178		

Table 3: Descriptive statistics of AKE ROM in Group-A (right side).

	Pre test	Day 5	Day 10	Day 15	f-value	p-value
Mean	138.8	145.73	158.7	172.56	227.2	<0.001
SD	6.23	6.34	5.82	4.5		
Median	139	145.5	158.5	173.5		

Table 4: Descriptive statistics of AKE ROM in Group-B (right side).

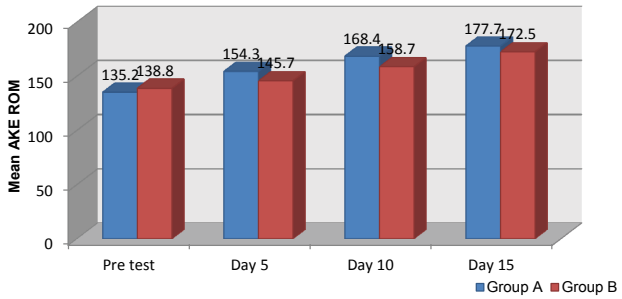

Figure 9: Mean AKE ROM in group A and B at different follow-up periods (right side)

	Pre test	Day 5	Day 10	Day 15	F-value	p-value
Mean	136.3	155.1	169.4	178.66	434.7	<0.001
SD	9.89	6.55	6.04	2.27		
Median	136.5	158	170	180		

Table 5: Descriptive statistics of AKE ROM in Group-A (left side).

	Pre test	Day 5	Day 10	Day 15	f-value	p-value
Mean	140.33	147.46	160.83	175	232.8	<0.001
SD	6.42	6.57	6.34	5.212		
Median	140	147	161.5	176		

Table 6: Descriptive statistics of AKE ROM in Group-B (left side).

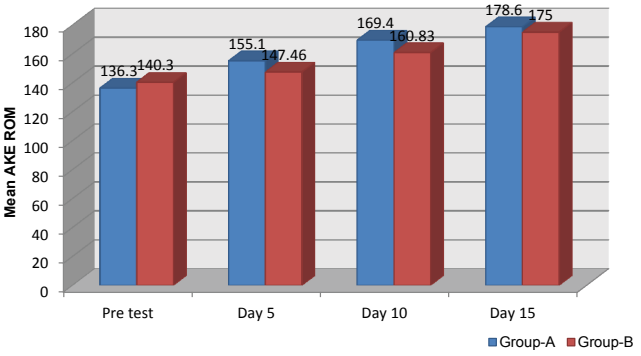

Figure 10: Mean AKE ROM in group A and group B at different follow-up periods (left side).

Time	Group-A	Group-B	t-value	p-value
Day 5	19.1 ± 5.05	6.93 ± 0.98	12.9447	<0.001
Day 10	33.16 ± 6.35	19.9 ± 2.45	10.6704	<0.001
Day 15	42.5 ± 6.47	33.76 ± 3.29	6.5794	<0.001

Table 7: Comparison of mean of difference in AKE ROM between Group-A and Group-B on day 5, day10 and day 15 from baseline. (right side).

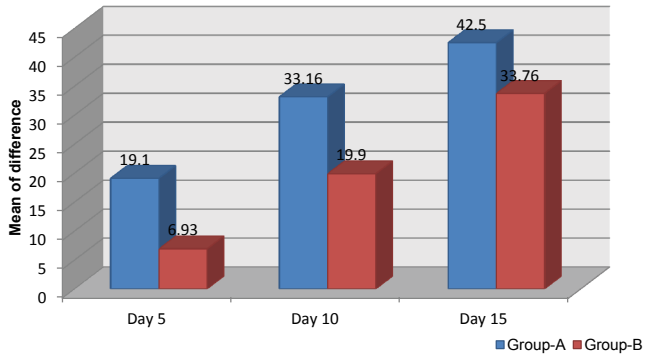

Figure 11: Mean of difference in AKE ROM group A and group B on Day 5, 10 and 15 from baseline (right side).

Time	Group-A	Group-B	t-value	p-value
Day 5	18.8 ± 7.46	7.13 ± 1.65	8.3552	<0.001
Day 10	33.13 ± 8.74	20.5 ± 2.85	7.5268	<0.001
Day 15	42.36 ± 8.94	34.67 ± 2.64	4.521	<0.001

Table 8: Comparison of mean of difference in AKE ROM between Group-A and Group-B on day5, day10 and day 15 from baseline. (left side).

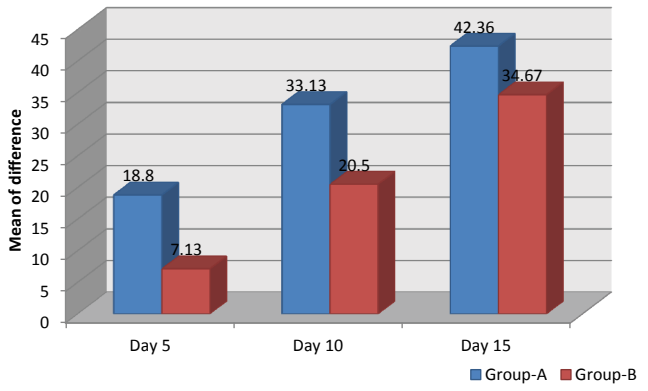

Figure 12: Mean of difference in AKE ROM between Group A and Group B on day 5, 10 and 15 from baseline (left side)

AKE ROM from post intervention value of left side the mean of difference on 5 day for Group A, it was 18.8 and for Group B it was 7.13.

On day 10 for Group A, it was 33.13 and for Group B it was 20.5. On day 15 for Group A it was 42.36 and for Group B it was 34.67. Comparison was done with unpaired t-test. On comparison there was statistically highly significant difference between Group A and B p-value <0.001. Figure 12 showing extremely significant change in AKE ROM of Group A and Group B of left side from base line.

Discussion

The study was designed to compare the effectiveness of Mulligan Bent Leg Raise and Hold Relax Proprioceptive Neuromuscular Facilitation (PNF) in high school students with hamstring tightness. 60 students with age group of 15-18 were taken. The subjects were selected as per inclusion criteria as mentioned in the material and method. The subjects were allotted into two groups by alternate method. Group A received Mulligan's Bent leg raise exercises, Group B received Hold Relax PNF exercises. The subjects received interventions for 15 days, for 3 weeks, 5 consecutive days per week.

The subjects were initially assessed on day 1st (pre intervention) and reassessed on day 5th, 10th, 15th after intervention for the outcome parameters. The outcome measure analyzed in the present study was Active Knee Range of Motion (ROM) to see the comparative effectiveness of Mulligan Bent Leg Raise and Hold Relax PNF in high school student with hamstring tightness more than 30 degree.

60 students were included in the study; it was conducted on high school students in the age group of 15-18 years, with the mean age of (15.86 ± 2.99 years) in Group A, (16.16 ± 1.31) years in Group B. There was no significant difference observed after analysis in mean age of the two groups with p>0.05. Thus the both the groups at baseline were comparable. The gender wise distribution of the subjects were 13 males and 17 females in group A and 14 males and 16 females in group B, 30 subjects in each group.

The outcome measures of the study were Active Knee Extension Range of Motion (AKE ROM) which was measured with Active knee extension test. Gajdosik and Lusin [25] concluded in their study that the active knee extension test is an objective and reliable tool for measuring hamstring muscle tightness when conducted under controlled conditions. High reliability depends on strict body stabilization, a well-defined and easily observed end point of motion, and precise instrument placement. The test, if conducted properly, should provide therapist in the clinic or research setting with a reliable method for measuring hamstring tightness.

Norris CM and Matthews **[27]** had done a study to find out the inter-tester reliability of self-monitored active knee extension test and concluded that the Active Knee Extension when used in conjunction with goniometry is an accurate and a reliable measure of hamstring muscle length.

Phansopkar and Kage [3] said in his study vol.20/issue 34/2014 Romanian Journal of physical therapy that Active Knee Extension test is a reliable and valid tool in measuring the Hamstring muscle tightness, with reliability coefficients for test measurements were 0.99 and reliability co efficient for re test measurements were 0.99.

The pre intervention Active Knee Extension Range of Motion (AKE ROM) was measured for sides, right and left of Group A and B. For Group A right side mean of Active Knee Extension Range of Motion was (135.2 ± 8.14) and Group B right side (138.8 ± 6.23) with p value 0.0618 which is not a significant difference. Group A left side was (136.3 ± 9.88) and group B left side (140.3 ± 6.24) with p value 0.0661 which was statistically not significant. There was no significant difference in the mean of AKE ROM on pre intervention (day 1) hence the baseline was comparable.

The pre intervention Active Knee Extension Range of Motion (AKE ROM) was measured for both the sides, right and left for males and females for both groups. For males in group A, AKE ROM on right side was (133.84 ± 7.85) for females it was (136.29 ± 8.43), on comparison there was no any significant difference p-value 0.4242. On comparison

of left side for males it was (134.69 ± 11.16) for females it was (137.52 ± 8.52) there was no any significant difference p-value 0.4460.

For Group B right side male it was (139.62 ± 6.39) and for female (137.85 ± 8.95) with p value 0.4480 which is not a significant difference. Group B left side for male it was (141.62 ± 6.77) and for females (139.42 ± 6.12) with p value 0.4802 which was statistically not significant. There was no significant difference in the mean of AKE ROM on pre intervention (day 1) hence the baseline was comparable for males and females showed in Table 8.

Descriptive parameters like mean, median, SD were calculated for Active Knee Extension Range of Motion of right side of Group A and B in Tables 4, 5 and Figure 9. Similarly for left side for Group A and B shown in Tables 6,7 and Figure 10.

On comparison change in AKE ROM between Group A with Group B for left and right side, Group A showed extremely significant improvement in AKE ROM on Hamstring tightness on day 5^{th},10^{th},15^{th} $p<0.001$ in Figures 11 and 12. This suggests extremely significant improvement on Active Knee Extension test in students with hamstring tightness.

Separately for male and females also comparison was done from baseline i.e. pre-intervention day to day 15, for Group A right and left side and Group B right and left side. And the result was extremely significant with p-value <0.001, showed in Table 8.

When the mean of difference in AKE ROM compared between males and females on day 5,10 and 15 for Group A right and left side and for Group B right and left side, there was not a significant difference. It was explained in Figure 12. Thus we can say that the AKE ROM improved equally in both males and females in both groups.

Khuman et al. [28] have done study on immediate effects of single session Post Isometric Relaxation Muscle Energy technique *vs.* Mulligan's Bent Leg Raise technique on pain and hamstring flexibility in knee osteoarthritis participants: A randomized controlled study. The finding shows that a single session PIR-MET intervention as well as BLR leads to significant improvement in pain as well as hamstring flexibility compared to control intervention. The PIR-MET group shows 9.63 degree reduction in knee flexion ROM which was in accordance with an earlier study which provided MET for 6 weeks. BLR technique group demonstrated 13.2 degree reduction in knee flexion ROM which had similar previous finding. Mulligan's BLR technique involves hip flexion results in caudal loading of lumbosacral nerve roots and sciatic nerve in the pelvis which has unloaded cranially during hip extension [20,29]. Flexion's of hip joint during BLR leads to lumbar flexion and further opens the intervertebral foramina and the central canal which facilitates the neural structure to move caudally [30-32]. Such neural structure movements could diffuse intraneural oedema thereby restoring the pressure gradients and relieving neural hypoxia [33]. This improvement in neural mechanics would be probably the mechanism of improvement in pain after BLR techniques [34].

Hall et al. [19] have done study on Mulligan bent leg raise technique a preliminary randomized trial of immediate effects after a single intervention. This study provided preliminary evidence that a single intervention of Mulligan's BLR technique, resulted in improvement in range of SLR 24 hours later but not immediately after the intervention.

Improvement of SLR range, by the BLR technique, might be due to mobilization of the painful, sensitized, nerve tissues, similar to the "slider" effects described by Butler, Hall and Elvey [20,24].

According to Butler and Shacklock, Mulligan's BLR technique utilizes passive flexion at the hip which results in caudal loading of the lumbosacral nerve roots and sciatic nerve in the pelvis, followed by active hip extension. During hip extension, there is unloading of these neural tissues, and they move in the cranial direction [20,29].

With hip flexion during BLR, there is obligatory lumbar flexion. With lumbar flexion, the lateral intervertebral foramina and central canal open further facilitating caudal movement of the neural structures. This movement of neural structures could be effective in dispersing intraneural edema, thus restoring pressure gradients and relieving hypoxia [30,32,35].

Improved mechanics of the neural structures would be one mechanism for improvements noted post BLR. BLR also involves isometric contraction of hip extensors followed by stretch of the same muscles also referred to as 'Post Isometric Relaxation'. Post-isometric relaxation refers to the assumed effect of reduced tone experienced by a muscle or a group of muscles after brief periods following an isometric contraction. Improvements noted in Group A (BLR group) could also be attributed to the effect of isometric contraction on the connective tissues. Combination of contraction and stretches may be responsible for improving the viscoelasticity which in turn improves tissue extensibility [32,35,36].

Stretching of the muscle pulls out the sarcomeres to a length where there is too little overlap of myofilaments for maximum tension to be developed. Adding on sarcomeres could result in sarcomere length being restored to the optimum. An increase in muscle length appears to relate more to the physical application of tension than to thermal or chemical responses of the tissue to exercise [4].

Another beneficial effect of the BLR technique might be a change in stretch tolerance of the hamstrings. Raghav et al. [4] demonstrated that the increased range of SLR, following stretching, is mediated via an increase in hip flexion and hamstring length, and not related to increased hamstring viscoelastic properties.

It has been found that there is no increase in hamstring extensibility after 4 weeks of hamstring muscle stretching in subjects with spinal cord injuries. It seems reasonable to extrapolate that increase in hamstring extensibility is closely connected to central neurophysiological processing, which is severely impaired in subjects with spinal cord injuries. Thus it might be assumed that the BLR technique triggers neurophysiological responses influencing the muscle stretch tolerance [37,38].

Vijay and Ratnam [39] studied the Immediate effect of active release technique *vs.* Mulligan Bent Leg Raise in subjects with hamstring tightness: a randomized clinical trial. Result of the study demonstrated that ART and Mulligan BLR increases immediate post-intervention hamstring flexibility and range of motion. Both the groups showed improvement in popliteal angle and sit and reach flexibility measurements.

Hing et al. [40] have done a systematic review on mulligan mobilization with movement and concluded that out of 25 studies, 24 studies showed positive results. The most common effects studied were increase in strength, reduction in pain levels, increase in PPT (pressure pain threshold), improved neural tests, and improved function. The clinical benefit of this technique is therefore confirmed and well supported by research.

Vicenzino et al. [41] in 2007 conducted a review on Mulligan's mobilization-with-movement, positional faults and pain relief. Total

19 studies were included in the review. Result indicated that there is a trend of data that supports the rapid ameliorative effects on pain and function during and initially after a single treatment application and also after a course of treatment. The predominant explanation provided for this rapid pain relieving effect is mechanical in nature and based on the proposed existence of bony positional faults and the ability of MWM to correct these faults.

In present study Hold Relax PNF also improves AKE ROM but improvement is not as significant as BLR**.** Nazarudin et al. [16] studied the effect of static, proprioceptive neuromuscular facilitation and dynamic stretching on the activation of hamstring muscle among preadolescence and concluded that PNF group showed greater increased as compared to dynamic group, also suggest that PNF should practice among preadolescence because it effectively activates hamstring muscles.

In the hold-relax (HR) procedure the range limiting muscle is first lengthened to the point of limitation or to the extent that is comfortable for the patient. The patient then performs a pre stretch, end-range, isometric contraction (for 5 to 10 seconds) followed by voluntary relaxation of the tight muscle. The limb is then passively moved into the new range as the range-limiting muscle is elongated [14].

Practitioners in the clinical and athletic training settings have reported that the HR and CR techniques appear to make passive elongation of muscles more comfortable for a patient than manual passive stretching. It has been assumed that the sustained, prestretch contraction is followed by reflexive relaxation accompanied by a decrease in electromyographic (EMG) activity in the range-limiting muscle, possibly as the result of autogenic inhibition [14]. 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. 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 motor neuron, decreasing the nerves excitability and decreasing the muscles efferent motor drive. 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 [18].

Hindle et al. [18] assessed the efficacy of PNF stretching *vs.* static stretching on hamstring flexibility performed with or without exercise in a study of 40 undergraduate student athletes. Each stretching method was performed for five minutes after 60 minutes of exercise or no exercise. The results showed that those who exercised and received PNF stretching experienced more of an increase in flexibility when compared to the baseline group and the group without exercise and PNF. However, there were no differences observed in the static stretching groups (baseline, with exercise, and without exercise).

PNF is a stretching technique utilized to increase ROM and flexibility. PNF increases ROM by increasing the length of the muscle and increasing neuromuscular efficiency. PNF stretching has been found to increase ROM in trained, as well as untrained, individuals. Effects can last 90 minutes or more after the stretching has been completed [18].

Improvement in range of SLR must be greater than 6 degree to state that a real change in SLR range has occurred. Consequently, the change in range produced by the BLR is of clinical relevance only 24 hr after the intervention [24].

Robert [42] original theory which states that, the effectiveness of Mulligan is based on a mechanical model documented in his first teaching text. This concept is related to minor positional faults that occur secondary to injury that lead to malt racking of the joint, resulting in symptoms such as pain, stiffness, or weakness. Thus the results of the present study supports the hypothesis that there is a significant improvement with Mulligan Bent Leg Raise as compared to Hold Relax PNF in improving functional ability and Active knee extension range of motion in high school students with hamstring tightness.

Conclusion

The present study was attempted to find out the comparison on the effectiveness of Mulligan Bent Leg Raise and Hold Relax PNF in High school students with bilateral Hamstring muscle tightness. It was concluded that, Mulligan Bent Leg Raise technique was highly effective over Hold Relax PNF in reducing bilateral Hamstring muscle tightness.

Clinical Implication

Mulligan's Bent Leg Raise technique can be incorporated with other physiotherapy exercises in patients with Hamstring tightness in improvement of ROM. Non symptomatic patients those who have hamstring tightness we can treat them with MBLR to prevent injury and to maintain good posture.

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