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A Study To Compare The Effect Of Proprioceptive Training Versus High Resistance Training With Neuromuscular Electrical Stimulation In Anterior Cruciate Ligament Reconstruction.

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ABSTRACT
BACKGROUND ANDOBJECTIVES
Injury to the anterior cruciate ligament(ACL) not only causes mechanical instability but also leads to persistent weakness and functional deficit in the form of diminished proprioception of the knee joint and "Functional recovery" is often incomplete even after "anatomic" arthroscopic ACL reconstruction, as some patients with a clinically satisfactory repair and good ligament tension continue to complain of a feeling of instability and giving way, although the knee does not sublux on clinical testing. ACL remnants have been shown to have proprioceptive fibers that could enhance functional recovery.
The objective of this study is to assess and compare the effect of proprioceptive training versus high resistance training with neuromuscular electrical stimulation in anterior cruciate ligament reconstruction.
METHODS:
In this study, 40 participants with ACL reconstruction were randomly divided into 2 groups i.e., group A and group B with 20 subjects in each group. Group A was given proprioceptive training with neuromuscular electrical stimulation and group B was given resistance training with neuromuscular electrical stimulation for thrice a week with home exercises in 6 months follow-up period. All patients were evaluated with lysholm and tegner activity scale, VAS, Goniometer and modified SEBT before and after the intervention.
RESULTS:
The results of this study indicated although there were small differences between the proprioceptive training and high resistance training, the proprioceptive training group showed superior results in improving knee function after ACL reconstruction. Subject reported knee function [as measured with lysholm and tegner activity scale and visual analogue scale (VAS)] and objective measurement of neuromuscular control [as measured with modified star excursion balance test (SEBT), goniometer (knee flexion)] was significantly better after 6 months of proprioceptive training compared with 6 months of high resistance training.
CONCLUSION:
Although there was significant improvement in both groups, Group A shows better percentage of improvement than group B under various measurements such as lysholm and tegner activity scale, VAS, knee flexion range and modified SEBT.
KEYWORDS:
Anterior Cruciate Ligament Reconstruction, Proprioceptive Training, Neuromuscular Electrical Stimulation, High Resistance Training, LysholmAndTegner Activity Scale, Visual Analogue Scale, Modified Star Excursion Balance Test

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I. INTRODUCTION:

The anterior cruciate ligament (ACL) stabilizes the knee in the sagittal plane especially when the knee is flexed, which prevents the tibia from slipping forward. It allows physical activities, which incur shear, rotational, and compressive forces. Anterior cruciate ligament (ACL) injury is the most common ligament injury of the knee joint which causes the mechanical dysfunction of compactness of the joint, disturbing the flow of afferent information from ligament mechanoreceptors.

These disorders change the activities of individual muscle groups and impair motor coordination. Both kinematic and neuromuscular factors such as muscle activation, recruitment and firing patterns must be taken into consideration to accurately characterize complex stability. This leads to reduced muscle strength and muscle atrophy. Knee pain with trauma and inefficient lower extremity loading disturb the biomechanics of the

entire system, thus, affected patients may also have problems maintaining the balance and proprioception. Treating postural balance and proprioception allows the patient to achieve desired results of surgical treatment and helps prevent further injury[(1)].

It is one of the most frequently injured structures during high impact or sporting activities[(2)]. The ACL does not heal when torn, surgical reconstruction is the standard treatment in the field of sports medicine[(3).] This reconstruction aims to restore the kinematics and stability of the injured knee, to prevent future degenerative changes. Therefore, an adequate understanding of the complex anatomy, function, and biomechanics of the ACL is critical to elucidate the mechanisms of injury, understand the fate of chronic ACL deficiency, and to improve surgical reconstruction[(9)].The main goal of the rehabilitation after anterior cruciate ligament rupture or reconstruction is to restore knee function by enhanced neuromuscular control, which can be achieved by training of muscle strength, coordination, and proprioceptive ability. Neuromuscular training programs for patients with anterior cruciate ligament reconstruction aim to improve muscle activation, increase dynamic joint stability, and relearn movement patterns and skills used during daily activities and sports activities[(4)].

It has been suggested that the programs which focus too much on functional low-intensity and sports-specific exercises and that weight training intensity may be too low to increase muscle strength to a satisfactory level . Individuals, who perform high-intensity resistance training (HRT) as part of their rehabilitation after anterior cruciate ligament reconstruction, will achieve greater improvements in leg extensor muscle power and greater improvements in knee function without any negative effect on mechanical instability[(5)].

II. METHODOLOGY

SOURCE OF DATA:

- KIMS Hospital inpatient and outpatient physiotherapy departments.
- KIMS Hospital and research centre inpatient and outpatient orthopedic department.
- Patients from other hospitals in bangalore.

METHODS OF COLLECTION OF DATA:

- Study design: A comparative study
- Sample size: 40
- Sampling method: A simple random sampling method
- Study duration: 12 months

MATERIALS USED:

- Bedsheet
- Pillow
- Treatment couch
- Consent form
- Assessment form
- Visual analogue scale
- Lysholm knee score and Tegnar activity scale
- Modified Star excursion balance test(SEBT)
- Goniometer
- Neuromuscular electrical stimulator
- Electrode gel
- Cotton
- Power cord
- Wobble board
- Theraband
- Weight cuff
- Foot step
- Agility drills
- Treadmill
- Swiss ball

Fig 1: Neuromuscular Electrical stimulation

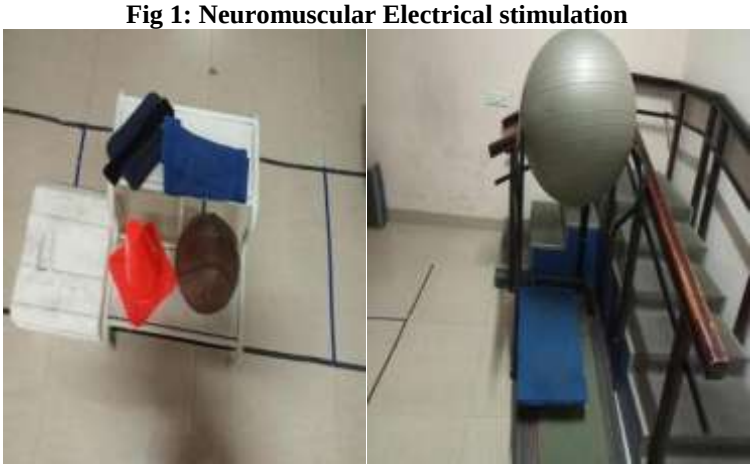


Fig 2: Materials Required

INCLUSION CRITERIA:

- Age group between 18-40
- Both male and female patients
- Unilateral involvement
- An isolated ACL injury that had been surgically reconstructed
- Normal hip and ankle joint function
- No neurologic diseases
- No vestibular or visual disturbances

EXCLUSION CRITERIA:

- Prior ligament surgery of injured knee.
- Concomitant lesion of posterior cruciate ligament.
- Inflammatory arthritis.
- Prior or concurrent injury or surgery to healthy knee.
- Cardiovascular,respiratory,systemic,metabolic condition limiting exercise tolerance.
- Refusal to participate in study.

METHODOLOGY:

- A study will be conducted on patients with anterior cruciate ligament(ACL) reconstruction.
- The subjects is assessed for inclusion and exclusion criteria.
- The intervention to be done is explained to the subjects in the language understood by the subjects/family members.
- A written informed consent is obtained.

Evaluation tools:

Patients who are diagnosed to have anterior cruciate ligament reconstruction surgery will be randomly assigned into two intervention groups. Each group consists of patients of both genders within the age group of 18-40 years. Referred patients will be evaluated using Lysholm knee score and Tegner activity scale, visual

analogscale (VAS),Goniometer and modified Star excursion balance test(SEBT) before commencing the treatment and after the training .The procedure will be explained to the subjects . clear information will be given to the subjects before performing the evaluation tests.

INTERVENTION:

Subjects were randomly allocated to two groups by using chit method-simple random sampling (20 in each group) namely: Group A and group B.

The patients of group A and group B will receive neuromuscular electrical stimulation(NMES). Neuromuscular electrical stimulation (NMES) to be effective in improving quadriceps strength following anterior cruciate ligament reconstruction (ACLR).

Subject is seated in a chair with the knee positioned in approximately 60̊ to 85̊ of flexion protocol include a 2500-HZ, alternating current (AC), time modulated to bursts of pulses applied at intensities that induced at least 50% of maximum voluntary isometric torque. A typical contraction time was 10 seconds followed by 50 seconds relaxation, and each session induced 10-15 contractions.

Fig 3: Patient receiving Neuromuscular electrical stimulation

Group A: Neuromuscular electrical stimulation with proprioceptive training(PT)/neuromuscular training(NT) exercises.

The rehabilitation program starts immediately after surgery, 3 times a week with home exercises in 6 months follow up period. The initial focus was on improving postoperative pain and swelling, range of motion, and muscle strength.

The proprioceptive training program starts at the second week and was divided into 6 phases of each and consisted of balance exercises,dynamic joint stability exercises, plyometric exercises,agility drills,and sports specific exercises.

In addition to amount of pain and swelling, criteria used to determine readiness for progression were the ability to maintain balance of the position (static balance) before movements were superimposed on the position (dynamic balance) and awareness of the position of the body in space before tolerating movements or perturbations.

Balance exercises included single and double-leg stance on even, flat surfaces, with progression to balance on a mat, a wobble board[(7)].

Fig 4:Proprioceptive Training exercises

Group B:Neuromuscular electrical stimulation(NMES) with High resistance training exercises(HRT)

HIGH RESISTANCE TRAINING:

High-intensity resistance training as part of early rehabilitation after ACL-reconstruction may contribute to a faster recovery of leg extension muscle power without introducing any adverse effect on knee joint stability. The accelerated/amplified gains observed with high-intensity resistance training were caused by more marked greater muscular regrowth induced by this training modality.

Rehabilitation Protocol:

It starts immediately after a surgery, 3 times a week with home exercises in 6 months followup period, which started immediately after surgery. The initial focus was on improving postoperative pain and swelling, range of motion, and muscle strength. Full range of motion and weight bearing according to the person's tolerance was allowed and the participants performed isometric quadriceps contractions and dynamic exercises for the hamstring muscles.

A 30-minute progressive, weight training program was initiated 8 weeks after the ACL-reconstruction and was conducted subsequent to the group-based program. The resistance (training loads) was increased when

the individual could do more repetitions than the number specified in the weight training protocol .The exercises were performed at a slow speed to ensure full control of the movement. During weight training pain was allowed, but if the participants reported pain of more than 5 on a visual analog scale(VAS), range of motion and/or load was reduced[8].

The high resistance training (HRT)- program included bilateral and unilateral exercises, that is, leg press (from 90 to 0 degrees in knee), knee flexion in the prone position (0–90 degrees), and seated knee extension (90–0 degrees). The first two weeks of the weight training program served as a familiarization period and thereafter loading increased by lifting weights to failure from 20 to 8 RM with a 2-minute rest period between the sets.

Fig 5:High Resistance Training exercises

OUTCOME MEASURES

- Lysholm and tegner
- Visual analog scale
- Modified Star excursion balance test
- Universal Goniometry

STATISTICAL ANALYSIS:

Data was analyzed using the statistical package **SPSS 26.0** (SPSS Inc., Chicago, IL) and level of significance was set at **p<0.05**

III. RESULTS:

Following are the statistical analysis:

- Descriptive statistics was performed to assess the mean and standard deviation of the respective groups.

Normality of the data was assessed using Shapiro Wilkinson test.

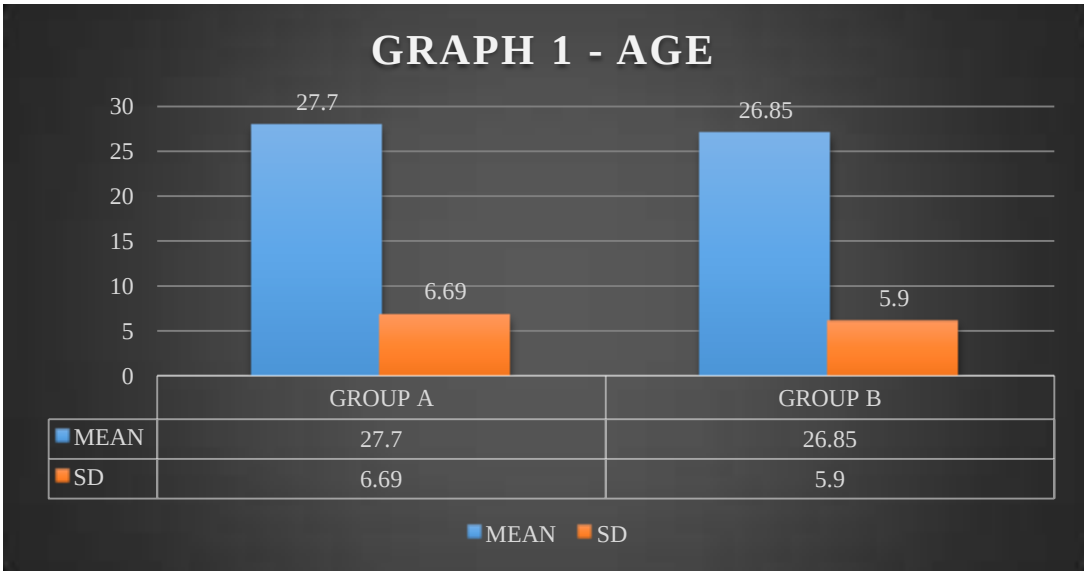
- Inferential statistics to find out the difference between the groups was done using Mann whitney u test and within group analysis was done using Wilcoxon sign rank test.
- Chi square test was used to detect the frequency difference between the groups.
- To assess the effect of proprioceptive /neuromuscular training with neuromuscular electrical stimulation in anterior cruciate ligament reconstruction paired ‘t’ test is used.
- To assess the effect of high resistance training with neuromuscular electrical stimulation in patients with anterior cruciate ligament reconstruction paired ‘t’ test is used.

- To compare the effect of proprioceptive / neuromuscular training with neuromuscular electrical stimulation and high resistance training with neuromuscular electrical stimulation unpaired 't' test is used.

TABLE 1- COMPARISON OF AGE

		GROUP A	GROUP B
AGE	MEAN	27.7	26.85
	SD	6.69	5.90
T VALUE		0.42	
P VALUE (INDEPENDENT T TEST)		0.67	

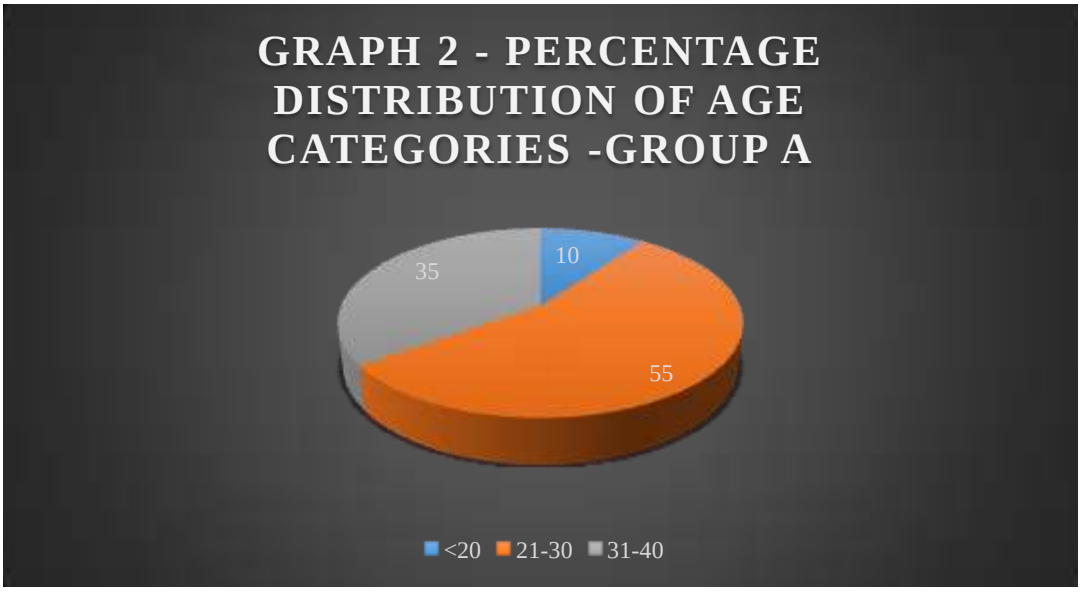
P<0.05 is statistically significant



Mann whitney u test did not report any difference between the groups (p>0.05)

TABLE 2- FREEQUENCY AND PERCENTAGE OF AGE DISTRIBUTION-GROUP A

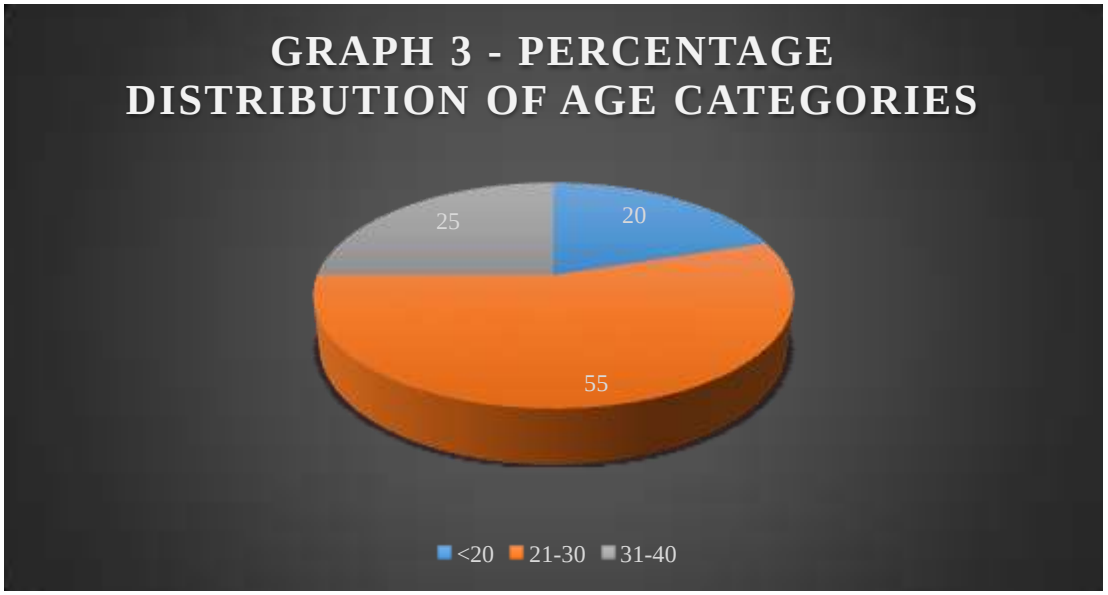
	FREQUENCY	PERCENTAGE
<20	2	10
21-30	11	55
31-40	7	35



Graph shows age distribution of the study participants with respect to group a. Overall age ranges between 18-39. Majority of the participants (55%) belong to 21-30 age group and the remaining were in the category of 31-40(35%) and <20 (10%).

TABLE 3- FREEQUENCY AND PERCENTAGE OF AGE DISTRIBUTION-GROUP B

	FREQUENCY	PERCENTAGE
<20	**4**	**20**
21-30	**11**	**55**
31-40	**5**	**25**



Graph shows age distribution of the study participants with respect to group b. Overall age ranges between 18-38. Majority of the participants (55%) belong to 21-30 age group and the remaining were in the category of 31-40(25%) and <20 (20%).

TABLE 4-COMPARISON OF FREQUENCY AND AGE DISTRIBUTION BETWEEN GROUP A AND GROUP B

	GROUP A		GROUP B	
	FREQUENCY	**PERCENTAGE**	**FREQUENCY**	**PERCENTAGE**
<20	**2**	**10**	**4**	**20**

21-30	**11**	**55**	**11**	**55**
31-40	**7**	**35**	**5**	**25**

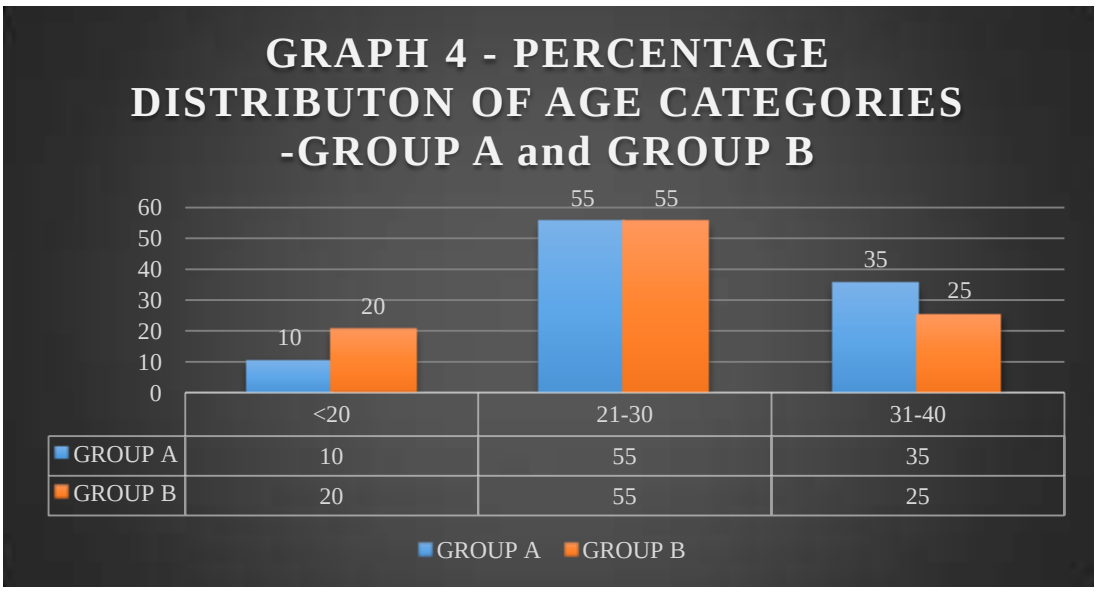
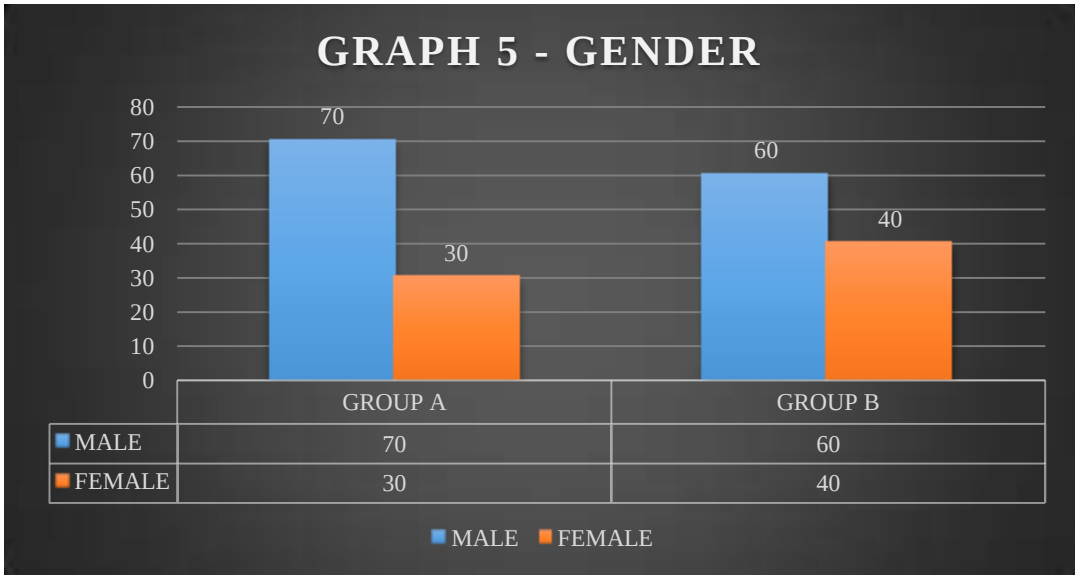


TABLE 5- COMPARISON OF GENDER

		GROUP A	GROUP B
GENDER	**MALE**	**14 (70%)**	**12 (60%)**
	FEMALE	**6 (30%)**	**8 (40%)**
X^2 VALUE		**18.18**	
P VALUE (CHI SQUARE TEST)		**0.0002***	

P<0.05 is statistically significant



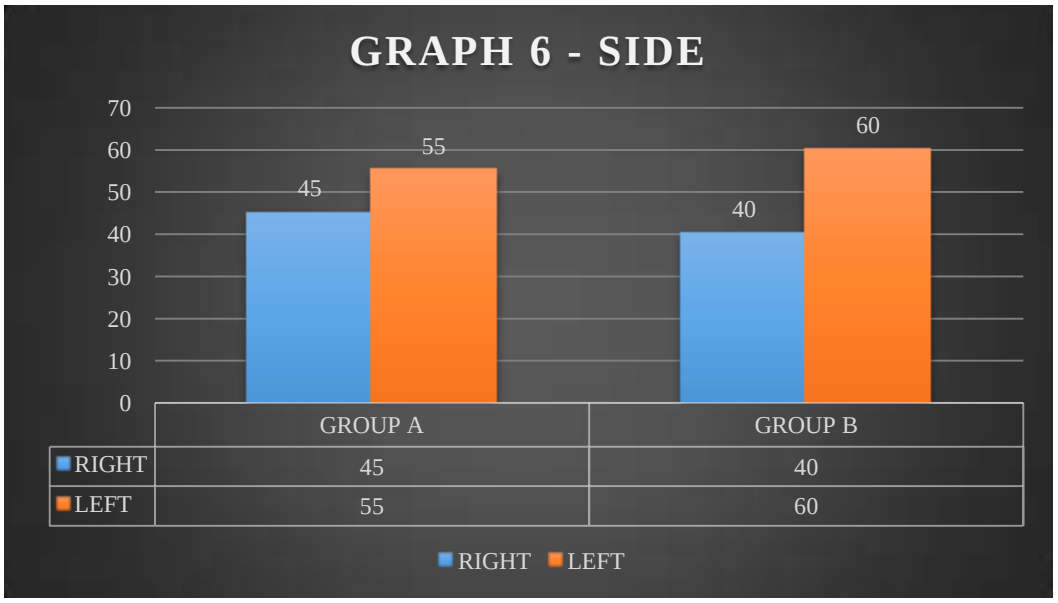
Chi square test reported difference in frequency of gender between the groups(p<0.05).

TABLE 6- COMPARISON OF SIDE

		GROUP A	GROUP B
SIDE	**RIGHT**	**9 (45%)**	**8 (40%)**
	LEFT	**11 (55%)**	**12 (60%)**
X^2 VALUE		**0.57**	

P VALUE (CHI SQUARE TEST)	**0.45**

P<0.05 is statistically significant

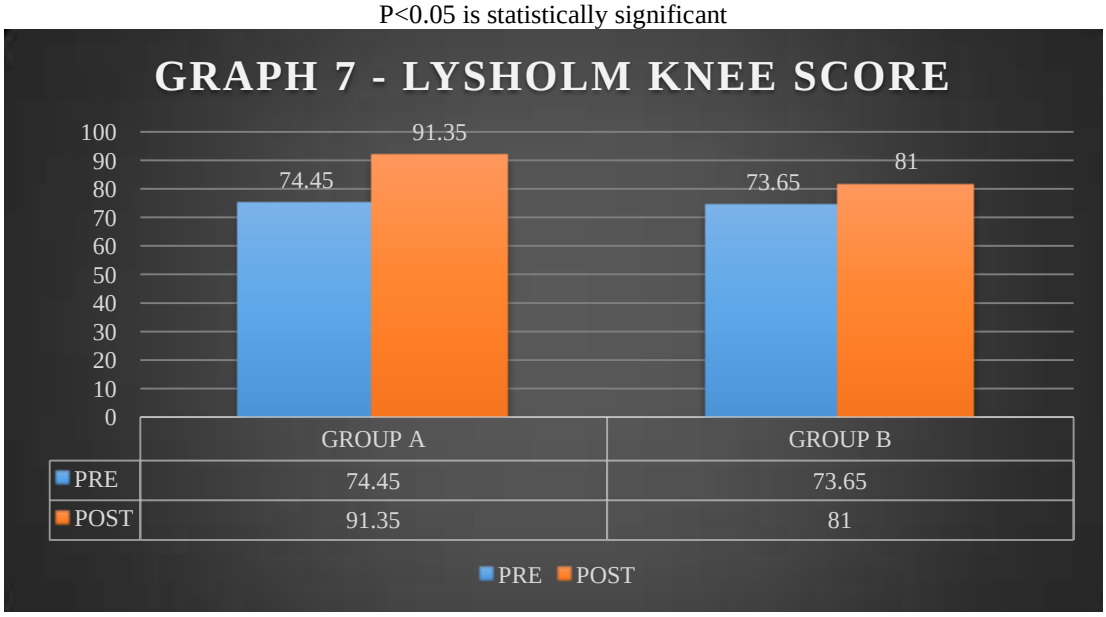


Chi square test did not report any difference in frequency of side between the groups(P>0.05).

TABLE 7- LYSHOLM KNEE SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	GROUP B (HRT+NMES)	P VALUE (MANN WHITNEY U TEST)
LYSHOLM KNEE	PRE	74.45±10.04	73.65±10.39	0.78 (t=0.27)
	POST	91.35±6.58	81±9.17	0.0002*(t=4.131)
% DIFFERENCE		22.7%	9.9%	
T VALUE		6.48	2.39	
P VALUE (WILCOXON SIGN RANK TEST)		0.0001*	0.02*	

P<0.05 is statistically significant

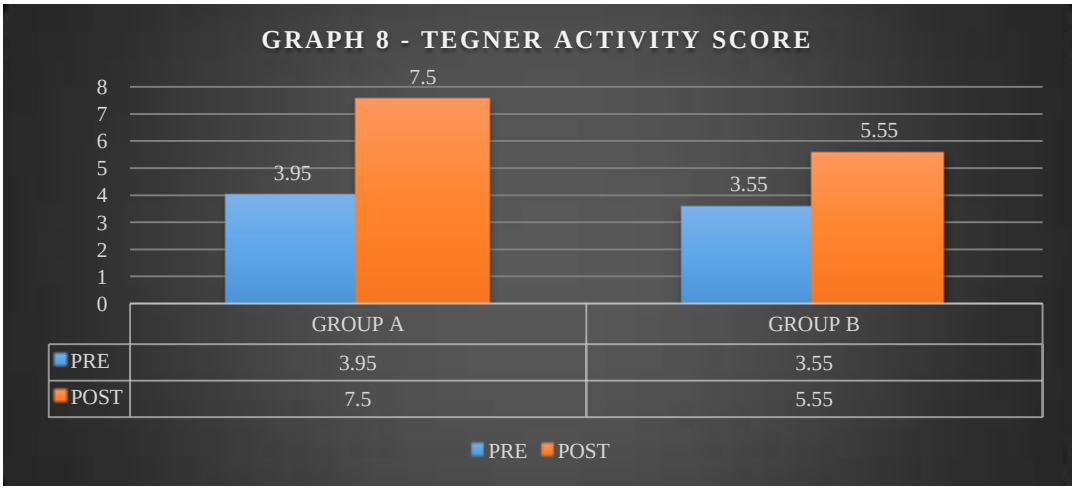


Regarding lysholm knee scale, wilcoxon sign rank test analysis reported statistically significant lower mean value difference with respect to group-b compared t group-a (p<0.05). Group a reported higher percentage of change from pre mean values compared to group -b(22.7% vs 9.9%).between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groups at post intervention.(p<0.05).

TABLE 8- TEGNER ACTIVITY SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	GROUP B (HRT+NMES)	P VALUE (MANN WHITNEY U TEST)
TEGNER ACTIVITY	PRE	3.95±0.80	3.55±0.92	0.15 (t=1.46)
	POST	7.5±1.32	5.55±0.92	0.0001*(t=5.42)
% DIFFERENCE		89.8%	56.4%	
T VALUE		10.4	6.87	
P VALUE (WILCOXON SIGN RANK TEST)		0.0001*	0.0001*	

P<0.05 is statistically significant

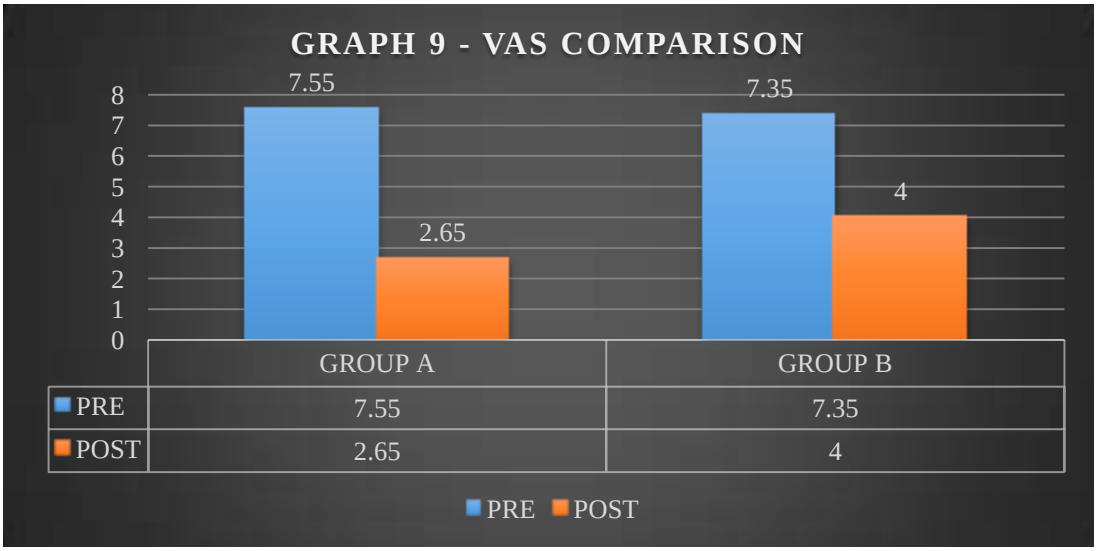


Regarding tegner activity scale, wilcoxon sign rank test analysis reported statistically significant lower mean value difference with respect to group A compared to group A ($p<0.05$).Group a reported higher percentage of change from pre mean values compared to group B(89.8% vs 56.4%).between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groups at post intervention.($p<0.05$).

TABLE 9- VAS SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	GROUP B (HRT+NMES)	P VALUE (MANN WHITNEY U TEST)
VAS	PRE	7.55±0.73	7.35±0.79	0.41 (t=0.83)
	POST	2.65±0.65	4±0.89	0.0001*(t=5.47)
% DIFFERENCE		64.9%	45.6%	
T VALUE		22.41	12.58	
P VALUE (WILCOXON SIGN RANK TEST)		0.0001*	0.0001*	

*P<0.05 is statistically significant

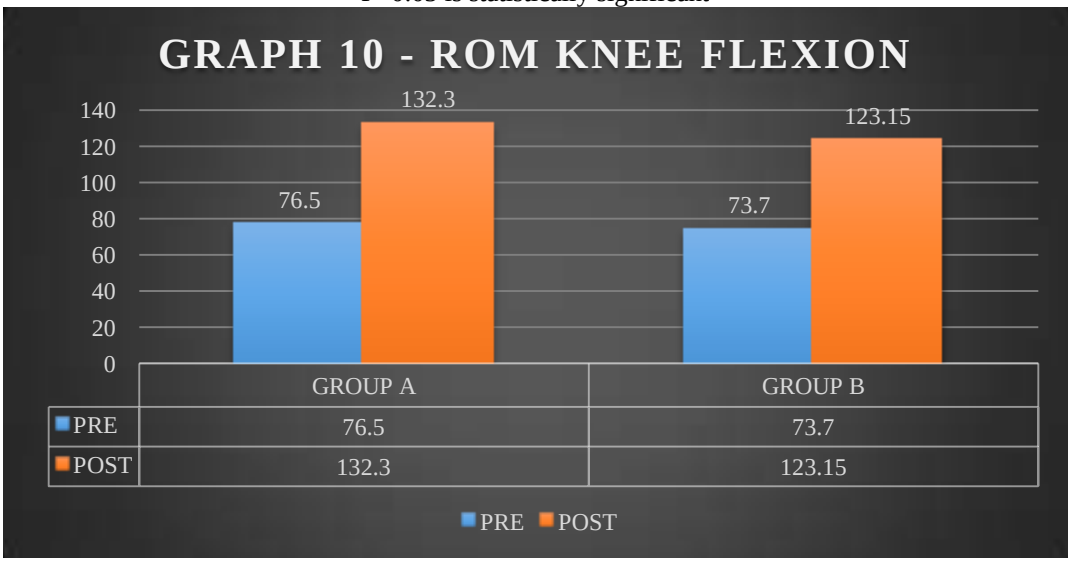


Regarding VAS scale, wilcoxon sign rank test analysis reported statistically significant lower mean value difference with respect to group-b compared t group-a ($p<0.05$). Group a reported higher percentage of change from pre mean values compared to group -b(64.9% vs 45.6%).between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groupsat post intervention.($p<0.05$).

TABLE 10- ROM KNEE FLEXION SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	GROUP B (HRT+NMES)	P VALUE (MANN WHITNEY U TEST)
ROM-KNEE FLEXION	PRE	76.5±6.51	73.7±13.53	0.40 (t=0.83)
	POST	132.3±3.16	123.15±10.65	0.0007*(t=3.71)
% DIFFERENCE		72.9%	67.1%	
T VALUE		34.65	12.88	
P VALUE (WILCOXON SIGN RANK TEST)		0.0001*	0.0001*	

P<0.05 is statistically significant

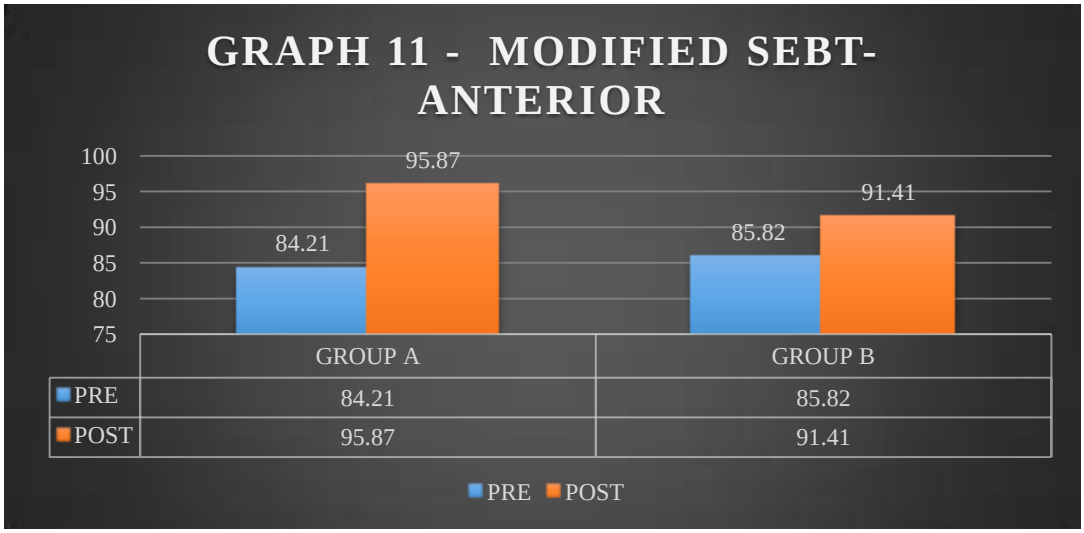


Regarding rom knee flexion scale, wilcoxon sign rank test analysis reported statistically significant lower mean value difference with respect to group-b compared t group-a ($p<0.05$). Group a reported higher percentage of change from pre mean values compared to group -b(72.9% vs 67.1%).between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groups at post intervention.($p<0.05$).

TABLE 11- MODIFIED SEBT (ANTERIOR) SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	GROUP B (HRT+NMES)	P VALUE (MANN WHITNEY U TEST)
SEBT-ANTERIOR	PRE	84.21±6.47	85.82±6.53	0.43 (t=0.79)
	POST	95.87±3.39	91.41±4.45	0.001*(t=3.57)
% DIFFERENCE		13.9%	6.5%	
T VALUE		7.24	3.18	
P VALUE (WILCOXON SIGN RANK TEST)		0.0001*	0.002*	

P<0.05 is statistically significant

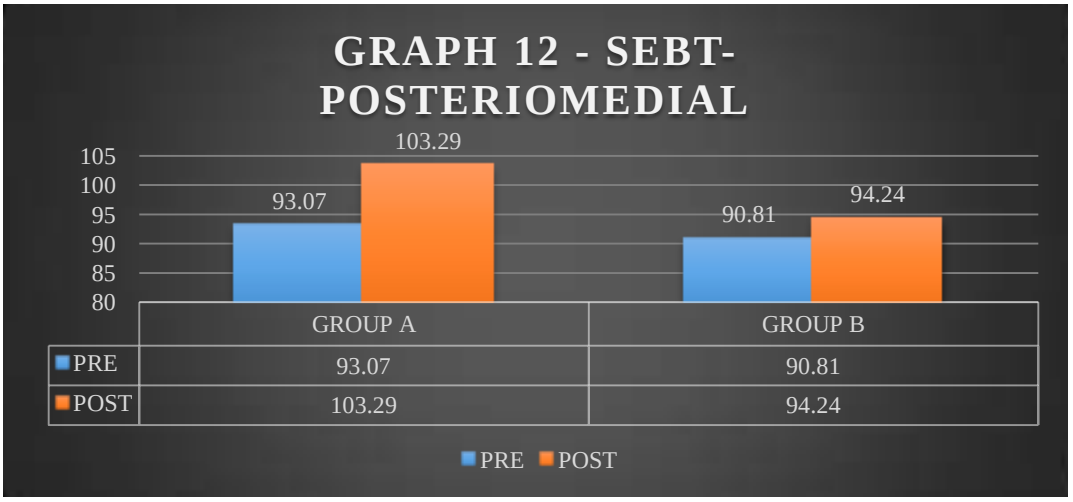


Regarding modified sebt- anterior scale, paired t test analysis reported statistically significant lower mean value difference with respect to group-b compared t group-a ($p<0.05$). Group a reported higher percentage of change from pre mean values compared to group-b (13.9% vs 6.5%).between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groups at post intervention.($p<0.05$).

TABLE 12- MODIFIED SEBT (POSTERIO MEDIAL) SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	GROUP B (HRT+NMES)	P VALUE (MANN WHITNEY U TEST)
SEBT-POSTERO MEDIAL	PRE	93.07±5.89	90.81±3.83	0.15 (t=1.47)
	POST	103.29±1.89	94.24±3.70	0.0001*(t=9.83)
% DIFFERENCE		10.9%	3.8%	
T VALUE		7.52	2.89	
P VALUE (WILCOXON SIGN RANK TEST)		0.0001*	0.001*	

P<0.05 is statistically significant

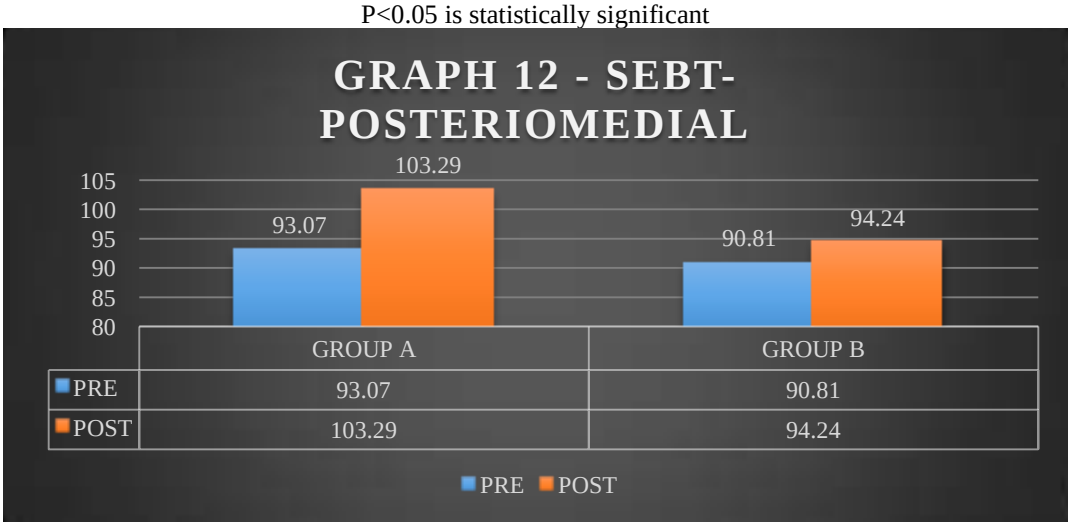


Regarding modified sebt- posterio medial scale, wilcoxon sign rank test analysis reported statistically significant lower mean value difference with respect to group-b compared t group-a ($p<0.05$). Group a reported higher percentage of change from pre mean values compared to group b(10.9% vs 3.8%). Between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groups at post intervention.($p<0.05$)

TABLE 12- MODIFIED SEBT (POSTERIO MEDIAL) SCORE COMPARISON (N=20)

		GROUP A (NMT+NMES)	**GROUP B (HRT+NMES)**	**P VALUE** (MANN WHITNEY U **TEST)**
SEBT-POSTERO MEDIAL	**PRE**	**93.07±5.89**	**90.81±3.83**	**0.15 (t=1.47)**
	POST	**103.29±1.89**	**94.24±3.70**	**0.0001*(t=9.83)**
% DIFFERENCE		**10.9%**	**3.8%**	
T VALUE		**7.52**	**2.89**	
P VALUE (WILCOXON SIGN RANK TEST)		**0.0001***	**0.001***	

P<0.05 is statistically significant



Regarding modified sebt-posterio medial scale, wilcoxon sign rank test analysis reported statistically significant lower mean value difference with respect to group-b compared t group-a ($p<0.05$). Group a reported higher percentage of change from pre mean values compared to group -b(10.9% vs 3.8%). Between group analysis by mannwhitney u test reported statistically significant higher mean value in group a compared to groups at post intervention.($p<0.05$)

IV. DISSCUSSION:

ACL injury not only causes mechanical instability of the joint but also disturbs the transmission of afferent proprioceptive impulses. Because ACL injuries are associated with well documented impairment of neuromuscular function, physiotherapy forms an important component of ACL rehabilitation.The present study

was conducted to compare the effect of proprioceptive / neuromuscular training with neuromuscular electrical stimulation (NMES) versus high resistance training with neruomuscular electrical stimulation(NMES) in ACL reconstructed patients. Evidence from the various literatures demonstarted the effect of neuromuscular electrical stimulation (NMES) as an adjunct to rehabilitation .Further the present study was supported by Fitzerald GK et al (2021) from Pittsburg conducted a single masked Randomized clinical trial on ACL reconstructed patients.

V. CONCLUSION:

The present study showed significant differences in the outcome measures of lysholm and tegner activity scale, knee range of motion, visual analogue scale and modified star excursion balance test (SEBT) in Group A and Group B. But there was more statistically significant difference in the pre and post total scores of Group A.

The present study also showed that the neuromuscular electrical stimulation (NMES) along with proprioceptive / neuromuscular training had shown superior sensitivity in the percentage wise improvement in the ACL reconstructed patients

Hence the Group A (Proprioceptive / neruomuscular training with neuromuscular electrical stimulation) has proven as a better technique than Group B (High Resistance Training with neuromuscular electrical stimulation) in subjects with Anterior Cruciate Ligament Reconstruction.

VI. LIMITATIONS OF THE STUDY

- This study was carried out on small sample size.
- There are many surgical techniques used to reconstruct the torn ACL. In addition , the same surgical technique performed by different surgeons may have slightly different outcome measures, which limits the study.

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