IJPSR (2026), Volume 17, Issue 2 (Research Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 17 November 2024; received in revised form, 24 December 2025; accepted, 22 January 2026; published 01 February 2026

EFFECTIVENESS OF CRYOTHERAPY AND TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION ALONG WITH POST-OPERATIVE REHABILITATION FOR ARTHROGENIC MUSCLE INHIBITION IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

K. Dhanya Mugan, A. Prabhakaran, R. Krishnagopal and Pradeep Kumar Theeppainthan *

Department of Orthopaedics, Mahatma Gandhi Medical College & Research Institute, Pillayarkuppam - 607402, Puducherry, India.

Keywords:

Anterior cruciate ligament, Cryotherapy, TENS, Arthorgenic Muscle inhibition, Rehabilitation

Correspondence to Author:
Dr. Pradeep K. Theeppainthan

Research Scholar,
Department of Orthopaedics,
Mahatma Gandhi Medical College & Research Institute, Pillayarkuppam - 607402, Puducherry, India.

E-mail: prad.ajith92@gmail.com

ABSTRACT: Introduction: The anterior cruciate ligament (ACL) is the most frequently injured ligament of the knee, not just among athletes but even in general population. Surgical treatment restores stability and limits progressive degeneration and long-term instability of the knee. Hence surgery is the preferred treatment for athletes and patients with physically demanding occupations. Despite the best efforts of physicians and rehabilitation professionals, often these goals are not achieved, as many patients return to normal life with lingering neuromuscular deficits and often are plagued with symptoms associated with the premature development of osteoarthritis. Quadriceps weakness is among the persistent neuromuscular deficiencies associated with ACL injury and presents a major rehabilitation challenge for patients and clinicians. Rehabilitation of the quadriceps musculature following ACL reconstruction (ACLR) often has been the subject of much debate. **Materials And Methods:** A total of 47 patients were included after fulfilling inclusion criteria between July 2019 to December 2021, all patients underwent ACL reconstruction using hamstring graft were subjected to Cryotherapy and TENS followed by that physiotherapy was given for early rehabilitation. Muscle thickness was measured at the intervals before surgery, 4th week and 12th week using ultrasound. Patients were assessed using VAS (Visual analogue score) and IKDC for functional outcome. **Results:** *Vastus medialis* and *Vastus medialis* obliques showed statistical significance with p value<0.05. Though other muscles did not show statistical significance it showed an increasing trend in thickness. Patients who underwent surgery within 6 months of injury had a better outcome than patients who underwent surgery between 6-12 months. Functional outcome of who underwent ACLR with isolated ACL injury showed statistical significance when compared with ACL with meniscus injury. **Conclusion:** Rehabilitation following ACL reconstruction has shifted from a protocol- based paradigm to a progression-based program with escalating difficulty. Early rehabilitation with additional modalities (TENS and Cryotherapy) showed better functional outcome by inhibiting Arthrogenic muscle inhibition. Early Weight bearing post ACLR plays a vital role in the rehabilitation of quadriceps muscle. Patients who underwent ACLR within short period of injury showed promising results with better functional outcome.

INTRODUCTION: Knee injuries can be considered to be a modern epidemic [1]. They are more common among people between 10 and 29 years of age and occur more often among men (57%). Soft tissue injuries of the knee most frequently involve the menisci with or without ligaments. The incidences of these injuries are 0.3 and 0.7 per 1000 individuals / year, respectively [1]. The anterior cruciate ligament (ACL) is the ligament most frequently damaged, and the medial

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.17(2).757-66

This article can be accessed online on www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.17(2).757-66

meniscus is the most frequently damaged meniscus [2]. The anterior cruciate ligament (ACL) is the most frequently injured ligament of the knee, not just among athletes but even in general population. Surgical treatment restores stability and limits progressive degeneration and long-term instability of the knee. Hence surgery is the preferred treatment for athletes and patients with physical demanding occupations. Despite the best efforts of physicians and rehabilitation professionals, often these goals are not achieved, as many patients return to normal life with lingering neuromuscular deficits and often are plagued with symptoms associated with the premature development of osteoarthritis. Quadriceps weakness is among the persistent neuromuscular deficiencies associated with ACL injury and presents a major rehabilitation challenge for patients and clinicians [3].

Rehabilitation of the quadriceps musculature following ACL reconstruction (ACLR) often has been the subject of much debate. In fact, strengthening of the quadriceps was downplayed because of concerns that exercise may place excessive strain on the ACL graft, while today, early, aggressive strengthening of this muscle group is advocated, as evidence has mounted that most quadriceps exercises are safe and necessary to maximize knee joint function [4]. Arthrogenic muscle inhibition is defined as type of neuronal or reflexive inhibition that prevents the Central Nervous System from activating the quadriceps muscle hindering the patient's ability to contract the muscle [4].

The quadriceps although not damaged cannot be fully activated to its optimum level as some sort of protective mechanism in order to prevent the body from further injury. Normal afferent firing of the quadriceps becomes disrupted and those change in turn disrupt spinal reflex excitability pathways, inhibiting the brain to voluntarily activate the muscle. The study aims to measure bilateral quadriceps muscle thicknesses using ultrasound device and compare it to normal side and to discuss current rehabilitation approaches to restore quadriceps muscle function after ACL reconstruction with therapeutic methods like Transcutaneous Electrical Nerve Stimulation (TENS) and Cryotherapy [5-8]. Proper neuromuscular activation of the quadriceps muscle is essential for maintaining quadriceps strength and lower extremity function. Quadriceps activation failure is a common characteristic observed in patients with knee pathologies, and it is defined as an inability to voluntarily activate the entire alpha motor neuron pool innervating the quadriceps. One of the more popular techniques used to assess quadriceps activation is the superimposed burst (SIB) technique. The SIB technique is a force-based technique which uses a supramaximal, percutaneous electrical stimulation to activate all of the motor units in the quadriceps during a maximal, voluntary isometric contraction of the quadriceps. Central activation ratio (CAR) is the formula used to calculate quadriceps activation level (CAR = voluntary force/SIB force) with the SIB technique.

People who are voluntary active 95% or more (CAR= 0.95– 1.0) of their motor units are defined as being fully activated [9]. Therapeutic exercises aimed at improving quadriceps strength in patients with knee pathologies are limited in their effectiveness due to a failure to fully activate the muscle. Within the past decade, several disinhibitory interventions have been introduced to treat quadriceps activation failure in patients with knee pathologies. TENS and Cryotherapy are sensory-targeted modalities traditionally used to treat pain, but they have been shown to be two of the most successful treatments for increasing quadriceps activation levels in patients with quadriceps activation failure [10-13].

Both modalities are hypothesized to positively affect voluntary quadriceps activation by disinhibiting the motor neuron pool of the quadriceps. In essence, these modalities provide excitatory afferent stimuli to the spinal cord, which thereby overrides the inhibitory afferent signaling that arises from the involved joint [10].

However, it remains unknown as to whether one is more effective than the other for restoring quadriceps activation levels in patients with knee pathologies. By knowing the capabilities of each disinhibitory modality, clinicians can tailor treatments based on the rehabilitation goals of their patients. This study is done to rehabilitate quadriceps muscle as early as possible and to get a better functional outcome by inhibiting arthrogenic muscle inhibition by TENS and Cryotherapy. The

aim of the study is to find the effectiveness of Cryotherapy and TENS along with postoperative rehabilitation to reduce arthrogenic muscle inhibition following ACL reconstruction.

MATERIALS AND METHODS: It is an observational done at our hospital between January 2021 and April 2022, where all patients with anterior cruciate ligament injury coming to the OPD and Emergency medical services department were the study population. Patients with isolated anterior cruciate injury with or without meniscal injury and patients, who have been operated with hamstring only graft, were included in this study. Patient with history of previous ipsilateral knee injury/surgery, patient with chronic history of ACL injury >1year patients with neuromuscular diseases, patients who had surgeries on contralateral limb, patients with history of any inflammatory joint disease like synovitis, Rheumatoid arthritis, gouty arthritis, reactive arthritis, psoriatic arthritis, septic arthritis were excluded from this study.

After patient selection anesthesia fitness was obtained and the patient underwent Arthroscopic ACL reconstruction surgery, by using hamstring tendons. Post surgery patient was subjected to Cryotherapy for 10 minutes for at least 5 times per day, which decreased arthrogenic muscle inhibition by decreasing the nerve conduction velocity, slowing the discharge rate of joint mechanoreceptor. Followed by that TENS was given for 15 minutes, which reduced the presynaptic inhibition, which contributes to AMI mediation, VAS (Visual analog scale) SCORE was calculated. Patients were subjected to Physiotherapy and immediate weight bearing post surgery. After 1 week of therapeutic methods and physiotherapy, the patients were followed up again after 4 weeks and 12weeks for ultrasonography and 24 weeks for VAS and IKDC (International knee documentation committee scoring system) scoring. It is a score ranging from 0 to 100,0 being the least and 100 being the highest level to evaluate the function of knee joint.

Patients were positioned in supine position. For measurement of quadriceps thickness, using ultrasound the thickness of each quadriceps component was measured in a random order. Specifically, the measurements were made along with the length of the thigh from the superior pole of the patella to the anterior superior iliac spine (ASIS). The rectus femoris and *Vastus intermedius* were measured at the midpoint of the line between the superior pole of the patella and the ASIS. The *Vastus lateralis* was measured laterally, at 10% of patient's thigh circumference from the midpoint. The *Vastus medialis* was measured medially, at 12.5% of the patient's thigh circumference from 20% of the length the line between the superior pole of the patella and the ASIS [5]. The *Vastus medialis* obliqus was measured 4 cm superior and 3 cm medial from the border of the patella. The image was adjusted until the muscle boundary was visible on the screen and the depth of the image was measured when the femur was centered on the screen. The ultrasound images were recorded three times per muscle by a single examiner. Once all the muscle thicknesses were measured, the images were saved for further analysis.

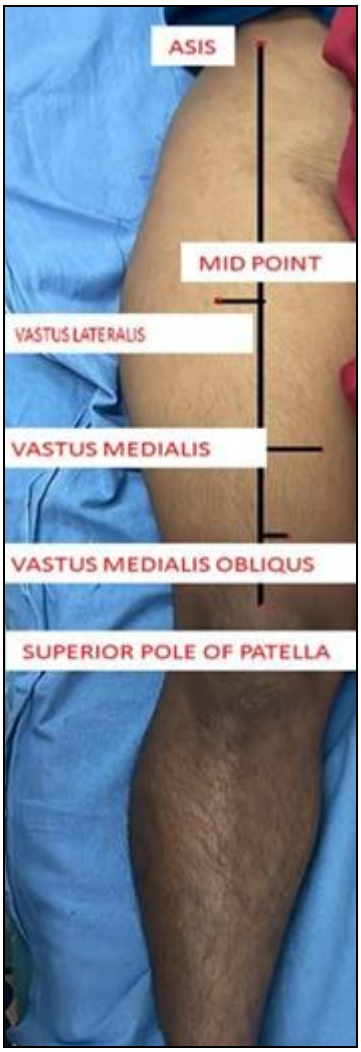


FIG. 1: USG THIGH MUSCLE MEASUREMENT

Rehabilitation Protocol:

Stage 1: 0-2 weeks.

- Patella mobilization
- Motion with long knee brace 0-90degrees
- Quadriceps sets/straight leg raising in all planes
- Passive extension
- Prone hangs
- Pillow under heel
- Partial weight bearing 50-75% with crutches.
- Sleep in brace locked in full extension.

Stage 2: 2-4 weeks.

- Motion control brace-full range motion
- Passive, active and active assisted ROM knee flexion
- Progress ROM to 120 degrees by 4th week
- Progress SLR
- Wall sits at 45 degree angle with tibia vertical, progressed overtime
- Knee extension 90 to 60 degrees with manual resistance by therapist.

Stage 3: 4-10 weeks.

- Progress to full ROM by 6weeks
- Begin lunges
- Continue strengthening of lower extremity muscle groups especially through full range of hamstring/quadriceps.

Stage 4: 12-16 weeks.

- Continue flexibility exercises
- Quadriceps strength progression

Stage 5: 16-18 weeks.

- Jogging program once the quadriceps strength is achieved around 65%.

Stage 6: 5-6 months.

- Sports specific drills
- Agility training

Stage 7: 6 months.

- Return to normal life routine.

Descriptive analysis was carried out by frequency and proportion for categorical variables and mean & standard deviation for continuous variable.

RESULTS: A total of 47 patients with ACL injuries who came to our hospital outpatient department and Emergency medicine service department who fulfilled the inclusion and exclusion criteria were selected in this study after getting informed consent.

The study population had 10.64% (n=5) of female population and 89.36% (n=42) of male population. The mean age in the study population was 31.26 +/- 8.23 years of age. 46.81% (n=22) had left knee injury, 53.19% (n=25) patients had right side injury. Most of the patients had road traffic accident as the commonest mode of injury 60% (n=28) and the second commonest was slip and fall 40% (n=19). Patients who were operated within 6 months since the time of injury was 82% (n=39) and those had surgery between 6 months to 1 year of duration was 18% (n=8).

TABLE 1: DESCRIPTIVE ANALYSIS OF IKDC PRE OP, 3MONTHS, 6 MONTHS IN STUDY POPULATION

Parameter	Mean ± SD	Median	Minimum	Maximum
Ikdc Pre Op	45.67 ± 10.61	45.50	18.39	65.70
Ikdc 3Months	45.12 ± 8.98	44.83	34.48	68.80
Ikdc 6Months	56.54 ± 7.04	56.32	42.50	70.10

TABLE 2: DESCRIPTIVE ANALYSIS OF VAS PRE OP, 3MONTHS, 6 MONTHS IN STUDY POPULATION

Parameter	Mean ± SD	Median	Minimum	Maximum
VAS Preop	3.81 ± 1.69	4.00	1.00	6.00
VAS 3Months	3.3 ± 1.65	3.00	1.00	6.00
VAS 6Months	1.83 ± 0.73	2.00	1.00	3.00

TABLE 3: MEAN COMPARISON OF VARIABLES AT PREOP, 1MONTHS, 3MONTHS IN STUDY POPULATION AMONG RIGHT SIDE INJURY PATIENTS

Parameter	Follow-up (Mean and SD)			P Value
	Pre-op	At 1 Month	At 3 Month	
Thigh Circumference Left (Normal side)	38.32 ± 7.9	38.48 ± 7.85	38.56 ± 7.9	0.994
Thigh Circumference Right	36.28 ± 7.7	36.96 ± 7.88	37.48± 7.86	0.863
Vastus Medialis_Left (Normal side)	2.79 ± 0.88	2.96 ± 0.86	2.98 ± 0.87	0.700
Vastus Medialis Right	2.33 ± 0.83	2.78 ± 0.62	2.84 ± 0.76	0.037
Vastus Lateralis Left (Normal side)	2.45 ± 0.85	2.54 ± 0.81	2.57 ± 0.82	0.869
Vastus Lateralis Right	2.34 ± 0.68	2.59 ± 0.65	2.61 ± 0.67	0.290
Vastus Medialis Oblique Left (Normal side)	1.77 ± 0.61	2.05 ± 0.58	2.06 ± 0.59	0.154
Vastus Medialis Oblique Right	1.85 ± 0.49	1.98 ± 0.49	2.11 ± 0.58	0.213
Vastus Intermedius Left (Normal side)	1.74 ± 0.56	1.77 ± 0.55	1.81 ± 0.52	0.884
Vastus Intermedius Right	1.76 ± 0.62	1.81 ± 0.57	1.83 ± 0.55	0.897
Rectus Femoris Left (Normal side)	1.94 ± 0.7	2.01 ± 0.71	2.02 ± 0.71	0.917
Rectus Femoris Right	1.94 ± 0.56	1.97 ± 0.66	2.03 ± 0.7	0.873

TABLE 4: MEAN COMPARISON OF VARIABLES AT PRE OP, 1MONTHS, 3MONTHS IN STUDY POPULATION AMONG LEFT SIDE INJURY PATIENTS

Parameter	Follow-up (Mean and SD)			P - value
	Pre-op	At 1 Month	At 3 Month	
Thigh Circumference Left	37.32± 6.04	37.56± 6.46	36.94 ± 6.09	0.952
Thigh Circumference Right (Normal side)	38.76 ± 6.72	38.32± 6.72	37 ± 6.07	0.698
Vastus Medialis Left	2.44 ± 0.59	2.57 ± 0.79	2.73 ± 0.66	0.413
Vastus Medialis Right (Normal side)	2.61 ± 0.55	3.04 ± 1.1	3.17 ± 0.52	0.062
Vastus Lateralis Left	2.17 ± 0.84	2.23 ± 0.77	2.48 ± 0.79	0.471
Vastus Lateralis Right (Normal side)	2.56 ± 1.37	2.22 ± 0.62	2.19 ± 0.55	0.373
Vastus Medialis Oblique Left	1.64 ± 0.35	1.9 ± 0.42	2.04 ± 0.49	0.009
Vastus Medialis Oblique Right (Normal side)	2 ± 0.46	2.03 ± 0.5	2.18 ± 0.49	0.503
Vastus Intermedius Left	1.5 ± 0.38	1.68 ± 0.34	1.79 ± 0.31	0.036
Vastus Intermedius Right (Normal side)	1.7 ± 0.29	1.67 ± 0.39	1.66 ± 0.35	0.898
Rectus Femoris Left	1.66 ± 0.42	1.89 ± 0.47	1.93 ± 0.28	0.059
Rectus Femoris Right (Normal side)	1.97 ± 0.47	2.06 ± 0.59	1.95 ± 0.4	0.723

TABLE 5: COMPARISON OF MEAN OF IKDC BETWEEN ACL + MENISCUS WITH ISOLATED ACL INJURY

Parameter	Meniscus (Mean± SD)		P-value
	Yes (N=19)	No (N=28)	
IKDC PRE OP	43.53 ± 8.77	47.11 ± 11.63	0.261
IKDC 3 Months	44.46 ± 8	45.58 ± 9.7	0.680
IKDC 6 Months	53.21 ± 7.56	58.8 ± 5.76	0.006

TABLE 6: DESCRIPTIVE ANALYSIS OF IKDC SCORING FOR DURATION SINCE INJURY <6 MONTHS PRE OP, 3 MONTHS, 6MONTHS IN STUDY POPULATION

	Mean	Std. Deviation	N
IKDC PRE OP	44.324103	10.2922500	39
IKDC 3Months	45.246923	9.2009906	39
IKDC 6Months	56.971795	7.1594799	39

TABLE 7: PAIRWISE COMPARISONS OF IKDC SCORING FOR DURATION SINCE INJURY <6 MONTHS PREOP, 3MONTHS, 6MONTHS IN STUDY POPULATION (N=47)

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.923	1.921	1.000	-5.734	3.888
	3	-12.648*	1.745	.000	-17.018	-8.277
2						
	3	-11.725*	1.394	.000	-15.217	-8.232

1- IKDC PRE OP . 2 – IKDC 3 Months. 3 – IKDC 6 Months

TABLE 8: DESCRIPTIVE ANALYSIS OF IKDC SCORING FOR DURATION SINCE INJURY 6-12 MONTHS PREOP, 3 MONTHS, 6MONTHS IN STUDY POPULATION

	Mean	Std. Deviation	N
IKDC PRE OP	52.208750	10.2993820	8
IKDC 3 Months	44.527500	8.3515007	8
IKDC 6 Months	54.453750	6.4536411	8

TABLE 9: PAIRWISE COMPARISONS OF IKDC SCORING FOR DURATION SINCE INJURY 6-12 MONTHS PREOP, 3 MONTHS, 6 MONTHS IN STUDY POPULATION

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for difference[a]	
1	2	7.681	5.171	.543	-8.492	23.855
	3	-2.245	3.500	1.000	-13.191	8.701
2						
	3	-9.926	3.224	.054	-20.011	.158

1- IKDC PRE OP, 2 – IKDC 3 Months 3 – IKDC 6 Months

Completed sample size: 47

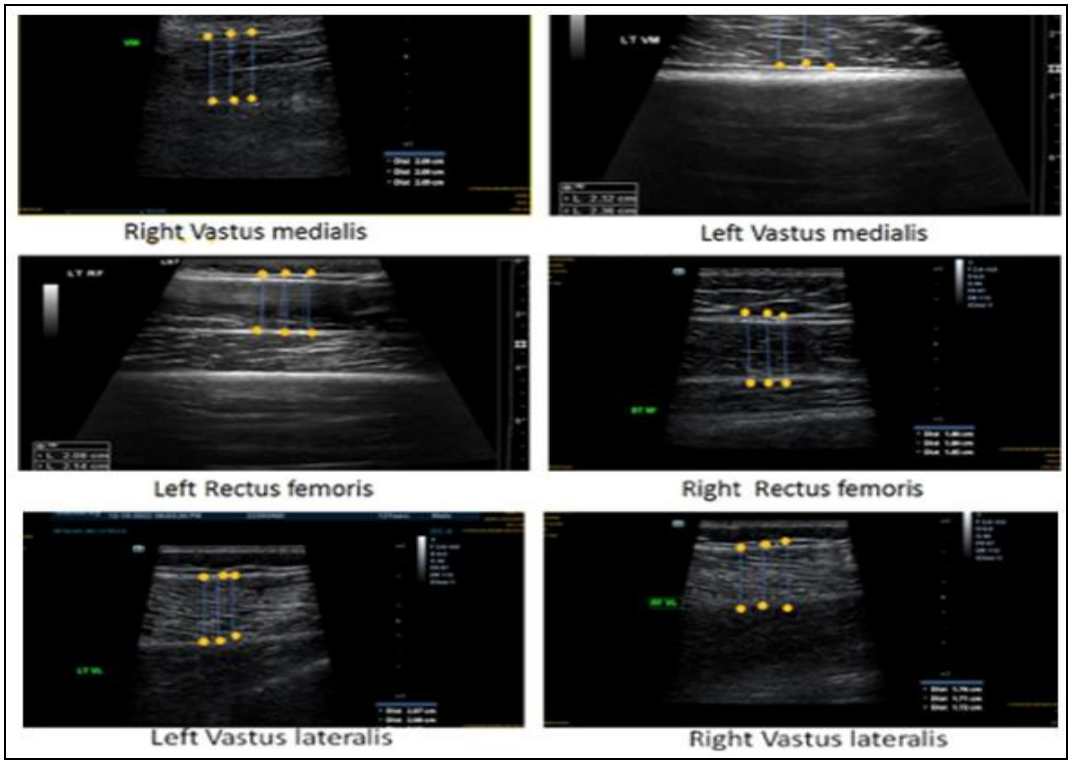
Failure: 1 (superficial surgical site infection)

Case Illustrations:

Case: 1 (36/M):

TABLE 10: ASSESSMENT OF MUSCLE THICKNESS AT PRE OP, AND POST OPERATIVE FOLLOW UP AT 1ST AND 3RD MONTH

Muscle	Pre-Operative		Post-Operative (1 Month)		Post-Operative (3 Months)	
Muscle thickness inches	Right	Left	Right	Left	Right	Left
	46	48	47	48	47	48
Vastus medialis (mm)	Right	Left	Right	Left	Right	Left
	2.06	2.3	2.16	2.33	2.27	2.32
Vastus lateralis (mm)	Right	Left	Right	Left	Right	Left
	1.74	1.68	1.88	2.00	1.99	2.00
Vastus medius Obliques (mm)	Right	Left	Right	Left	Right	Left
	1.58	1.66	1.69	1.67	1.78	1.65
Vastus intermedius (mm)	Right	Left	Right	Left	Right	Left
	1.71	2.13	1.81	2.10	1.95	2.10
Rectus femoris (mm)	Right	Left	Right	Left	Right	Left
	1.85	2.10	1.90	2.10	2.03	2.10



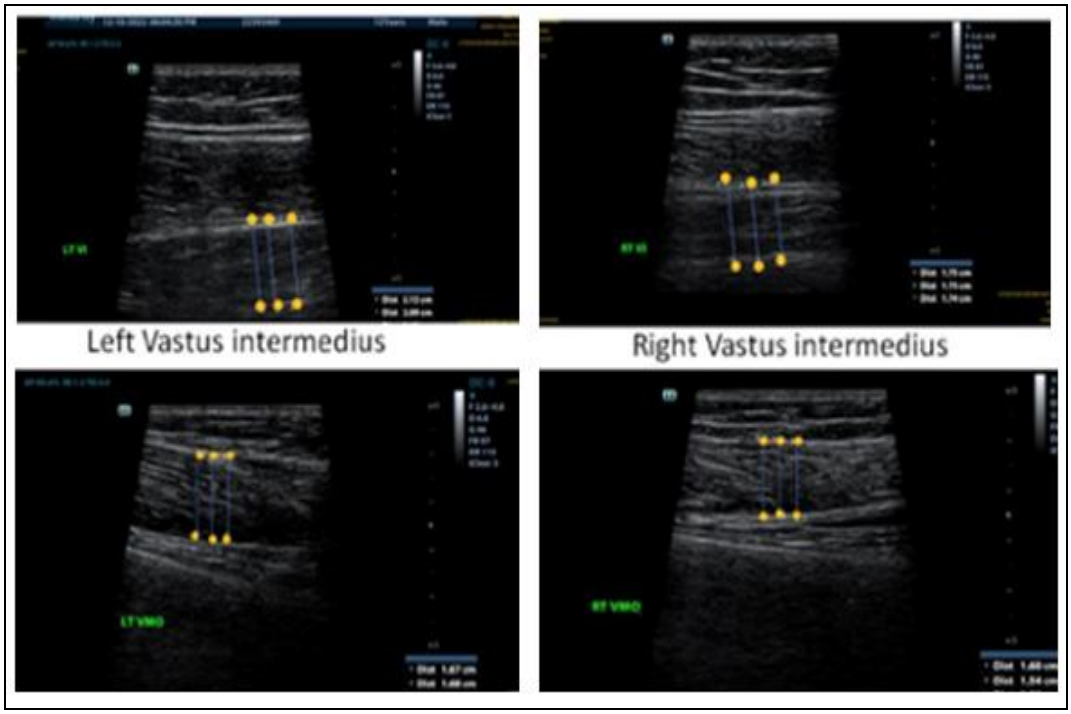
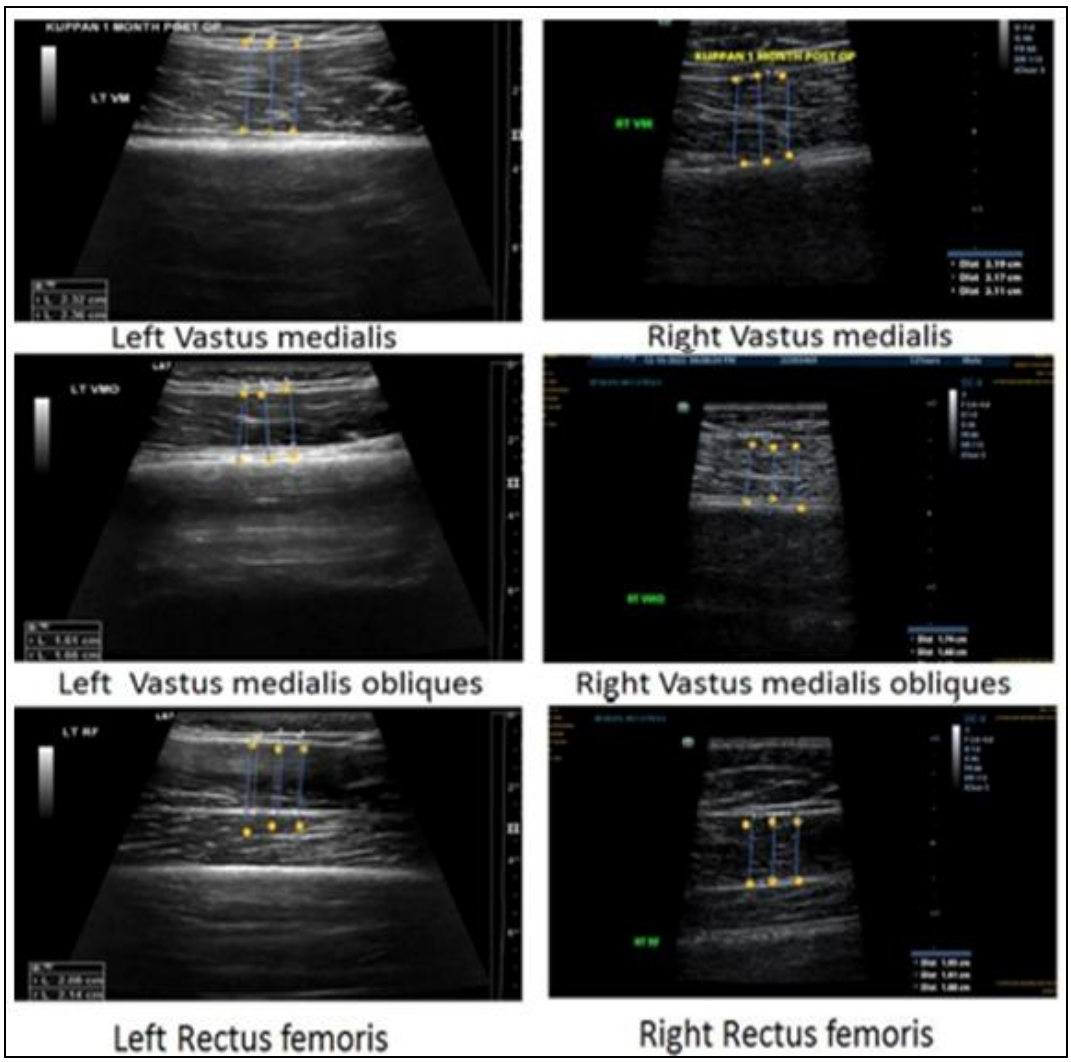


FIG. 2: PRE-OP ULTRASOUND IMAGES



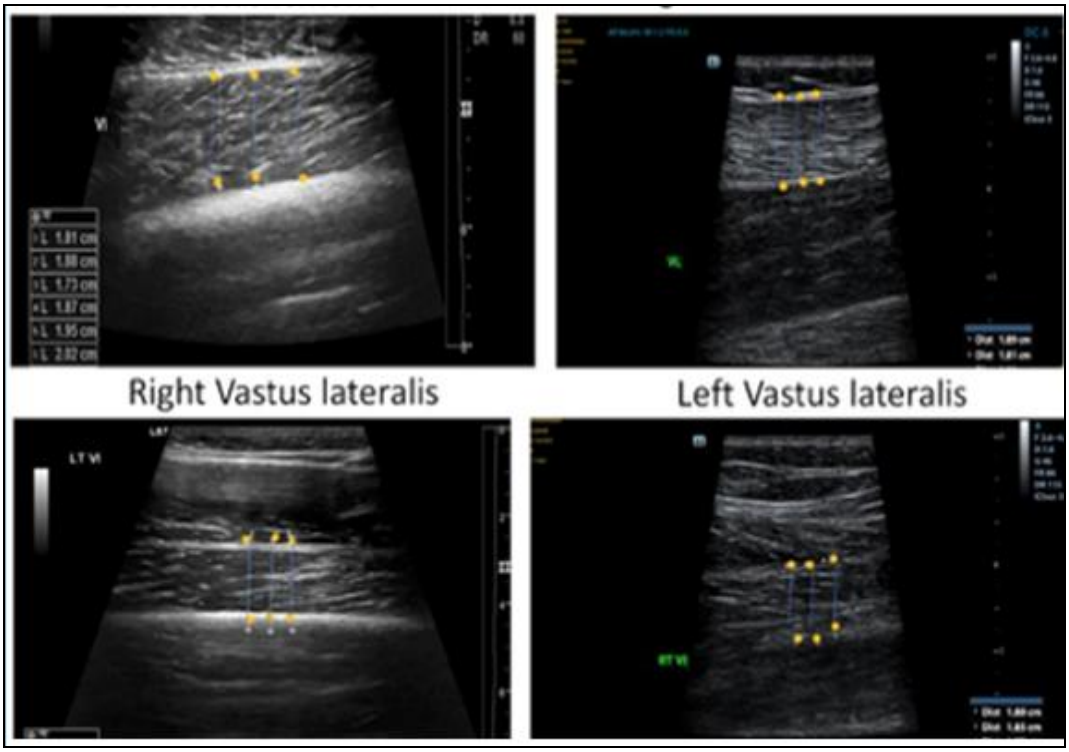
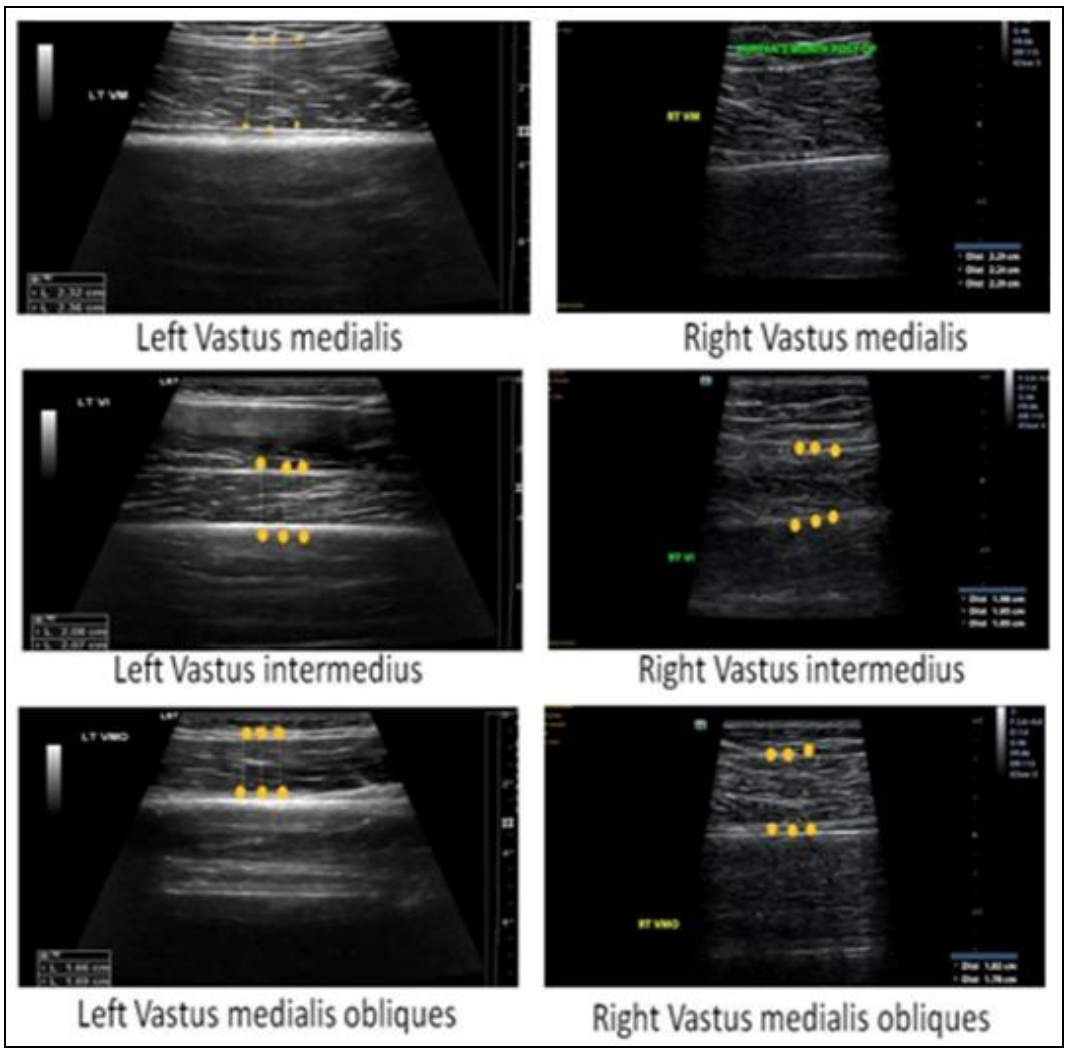


FIG. 3: POST OP 1 MONTH



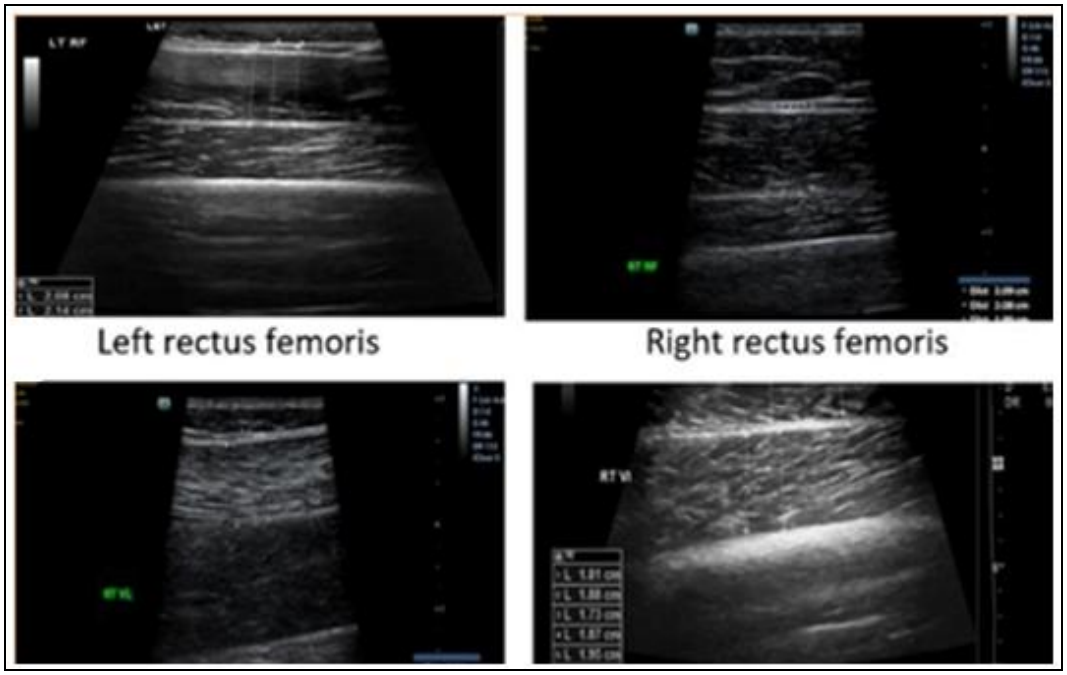


FIG. 4: POST OP 3 MONTHS

DISCUSSION: Knee is one of the most commonly injured joints due to its anatomical structure, exposure to external forces, and functional requirements. The anterior cruciate ligament (ACL) injury is a common sport-related injury affecting elite and recreational athletes, with up to 250,000 ACL ruptures occurring annually [14]. Anterior cruciate ligament reconstruction (ACLR) is considered the primary treatment option for ACL injuries. Despite the fact that ACLR corrects structural deficiency, patients who have undergone ACLR often exhibit quadriceps atrophy and muscle loss. Arthritis, surgery, and traumatic injury of the knee joint are associated with the long-lasting inability to fully activate the quadriceps muscle, a process known as arthrogenic muscle inhibition (AMI). A study by Shubam *et al* [15] on 48 patients with 42 (87.50%) male and 6 (12.50%) female which was consistent with our study population with 5(10.64%) females and 42(89.36%) males showing male dominance. The same study had a mean age group of 31.92 years which was similar to our study with mean age group 31.26. Both the studies showed right-side incidence. A study by Brian Forsythe [16] *et al* with 379 patient of which, 140 patients sustained ACL injury greater than six months prior to surgery experienced reduced likelihood to achieve patient-acceptable symptomatic state (PASS) on the IKDC ($p = 0.03$) and a greater likelihood to undergo revision ACL ($p = 0.001$). Similarly, in our study patients who underwent surgery after 6 months showed low functional outcome. In line of study by Hopkins *et al* [10] 30 minutes of ice application to the knee joint could completely reverse AMI of the *Vastus medialis.* In our current study similar method was used and it showed a very good improvement in decreasing the pain and patients could undergo early rehabilitation and showed better results with mean *Vastus medialis* before surgery at 1 month and 3 months' duration (3.84 ±0.7, 4.27 ±0.8, 4.29 ±0.8). The study by Joo-Hyun Lee [5] found that the *Vastus intermedius* (VI) muscle was significantly smaller in the reconstructed limb after ACLR compared to that in the healthy limb. Similarly, in our study the mean *Vastus intermedius* Before Surgery, 1 Month, 3 Months respectively was (2.5 ±0.5, 2.6 ±0.5, 2.64 ±0.5) and it did not show improvement. The same study showed decreasing trend of *Vastus medialis* muscle and *Vastus medialis* obliques whereas in our study, patients mean difference of *Vastus medialis* and *Vastus medialis* obliques across different follow-up time was statistically significant. (p value <0.05) and showed good improvement. Similar study by P. Radhakrishnan *et al* [17] with 30 cases of anterior cruciate ligament tear were treated with arthroscopic reconstruction with quadrupled semitendinosus and gracilis graft and had a similar functional outcome when compared with functional outcome of 28 patients who had isolated ACL injury treated with ACLR with hamstring graft.

Limitations: All the patient's individual muscles were measured using only ultrasound whereas MRI could give more accurate values. A small group of patients followed up for only 6 months.

CONCLUSION: Rehabilitation following ACL reconstruction has shifted from a protocol- based paradigm to a progression-based program with escalating difficulty. Early rehabilitation with additional modalities (TENS and Cryotherapy) showed better functional outcome by inhibiting Arthrogenic muscle inhibition. Early Weight bearing post ACLR plays a vital role in the rehabilitation of quadriceps muscle. Patients who underwent ACLR within a short period of injury showed promising results with better functional outcome.

ACKNOWLEDGEMENT: Nil

CONFLICTS OF INTEREST: Nil

REFERENCES:

1. Thomson LC, Handoll HH, Cunningham A and Shaw PC: Physiotherapist led programmes and interventions for rehabilitation of anterior cruciate ligament, medial collateral ligament and meniscal injuries of the knee in adults. Cochrane Database Syst Rev 2002; (2): CD001354.
2. Binfield PM, Maffulli N, Good CJ and King JB: Arthroscopy in sporting and sedentary children and adolescents. Bull Hosp Jt Dis 2000; 59(3): 125-30.
3. Palmieri-Smith RM, Thomas AC and Wojtys EM: Maximizing quadriceps strength after ACL reconstruction. Clin Sports Med 2008; 27(3): 405-24.
4. Rice DA and McNair PJ: Quadriceps arthrogenic muscle inhibition: neural mechanisms and treatment perspectives. Semin Arthritis Rheum 2010; 40(3): 250-66.
5. Lee JH, Cheon S, Jun HP, Huang YL and Chang E: Bilateral Comparisons of Quadriceps Thickness after Anterior Cruciate Ligament Reconstruction. Medicina (Kaunas) 2020; 56(7): 335.
6. Hart JM, Pietrosimone B and Hertel J: Ingersoll CD. Quadriceps activation following knee injuries: a systematic review. J Athl Train 2010; 45(1): 87-97.
7. Arvidsson I, Arvidsson H, Eriksson E and Jansson E: Prevention of quadriceps wasting after immobilization: an evaluation of the effect of electrical stimulation. Orthopedics 1986; 9(11): 1519-28.
8. Rice D, McNair PJ and Dalbeth N: Effects of cryotherapy on arthrogenic muscle inhibition using an experimental model of knee swelling. Arthritis Rheum 200915; 61(1): 78-83.
9. Park J and Hopkins JT: Quadriceps activation normative values and the affect of subcutaneous tissue thickness. J Electromyogr Kinesiol 2011; 21(1): 136- 140.
10. Hopkins J, Ingersoll CD, Edwards J and Klootwyk TE: Cryotherapy and transcutaneous electric neuromuscular stimulation decrease arthrogenic muscle inhibition of the *Vastus medialis* after knee joint effusion. J Athl Train 2002; 37(1): 25-31.
11. Pietrosimone BG, Hart JM, Saliba SA, Hertel J and Ingersoll CD: Immediate effects of transcutaneous electrical nerve stimulation and focal knee joint cooling on quadriceps activation. Med Sci Sports Exerc 2009; 41(6): 1175- 1181.
12. Pietrosimone BG, Saliba SA, Hart JM, Hertel J and Kerrigan DC: Ingersoll CD. Effects of transcutaneous electrical nerve stimulation and therapeutic exercise on quadriceps activation in people with tibiofemoral osteoarthritis. J Orthop Sports Phys Ther 2011; 41(1): 4-12.
13. Hart JM, Kuenze CM and Pietrosimone BG: Ingersoll CD. Quadriceps function in anterior cruciate ligament-deficient knees exercising with transcutaneous electrical nerve stimulation and cryotherapy: a randomized controlled study. Clin Rehabil 2012; 26(11): 974-981.
14. Prodromos CC, Fu FH and Howell SM: Controversies in soft-tissue anterior cruciate ligament reconstruction: grafts, bundles, tunnels, fixation, and harvest. Journal American Academy Orthopaedic Surgeons 2008; 16: 376-384.
15. Shubham Agarwal, Hemant Jain, Kishore Raichandani, Jagdish Godara and Sunil Choudhary: Early quadriceps wasting after anterior cruciate ligament reconstruction in young adults: A Prospective Study 2021. DOI: 10.7860/JCDR/2021/47254.14769
16. Forsythe B, Lu Y, Agarwalla A, Ezuma CO, Patel BH, Nwachukwu BU, Beletsky A, Chahla J, Kym CR, Yanke AB, Cole BJ, Bush-Joseph CA, Bach BR and Verma NN: Delaying ACL reconstruction beyond 6 months from injury impacts likelihood for clinically significant outcome improvement. Knee 2021; 33: 290-297. doi: 10.1016/j.knee.2021.10.010. Epub 2021 Oct 30. PMID: 34739960.
17. Radhakrishnan P, Kamalanathan C and Kumar AMS: Functional outcome of arthroscopic anterior cruciate ligament reconstruction using hamstring graft 2017.

How to cite this article:
Theeppainthan PK: Effectiveness of cryotherapy and transcutaneous electrical nerve stimulation along with post-operative rehabilitation for arthrogenic muscle inhibition in anterior cruciate ligament reconstruction. Int J Pharm Sci & Res 2026; 17(2): 757-66. doi: 10.13040/IJPSR.0975-8232.17(2).757-66.