ROLE OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION IN POST OPERATIVE ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION REHABILITATION

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ABSTRACT

Introduction and aim : This prospective comparative study investigated the role of transcutaneous electrical nerve stimulation (TENS) in postoperative rehabilitation of 80 patients (n=80) who underwent anterior cruciate ligament reconstruction (ACLR) with hamstring grafts. The primary goal was to assess whether TENS, when combined with cryotherapy and conventional exercises, could enhance quadriceps strength, reduce pain, and improve functional outcomes compared to standard rehabilitation alone.

Materials and methods : Participants were allocated into two equal groups (Group A: TENS + cryotherapy + exercises; Group B: cryotherapy + exercises). TENS was administered for 15 minutes daily for one week, and cryotherapy was provided for 10 minutes at least five times per day. All patients were allowed immediate weight-bearing post-ACLR, followed by routine physiotherapy and assessments at baseline, 3 months, and 6 months. Thigh circumference (as a surrogate for quadriceps bulk), VAS (Visual Analog Scale) for pain, along with IKDC (International Knee Documentation Committee) scores had been measured.

Results : Both groups demonstrated improvements in quadriceps circumference, reduced pain, and enhanced knee function over time. Although Group A showed a slightly greater increase in thigh circumference and a more pronounced improvement in IKDC scores, statistical significance had not been attained by these intergroup differences (p>0.05). Likewise, VAS scores decreased comparably in both groups.

Conclusion : While TENS showed a modest trend toward improved quadriceps activation and pain relief, its overall impact on ACLR rehabilitation outcomes was not statistically significant. Larger studies with longer follow-up durations have been warranted to improve clarify therapeutic role of TENS in postoperative ACLR rehabilitation.

Keywords: ACL reconstruction, TENS, arthrogenic muscle inhibition (AMI), postoperative rehabilitation, quadriceps strength

Introduction

The prevalence of ACL injuries was around 29-30 per 100,000 persons worldwide, and it had been rising to as high as 51.2 per 100,000, particularly in females along with younger age groups. [1-3] The primary aim of restoring joint function and stability post-ACL injury makes the surgeon opt for ACL reconstruction (ACLR) as the preferred choice of management. However, complications such as quadriceps atrophy, extensor deficit[4] of the knee, pain, poor functional outcomes, instability, and gait abnormalities[5] can occur due to weakness of quadriceps muscle after ACL reconstruction surgery.[6] This is connected with a greater risk of early development of osteoarthritis of the knee, thereby imparting a major challenge to both the surgeon and the patient in the post-operative rehabilitation.[7,8,24.]

Quadriceps atrophy is not just a local phenomenon. This presynaptic reflex inhibition, which has been linked to AMI, results in failure of quadriceps activation after joint distension.[9] AMI affects ability to contract the quadriceps muscle due to variations in discharge of articular sensory receptors. This results in disruption of the spinal reflex excitability pathway that disables the brain from allowing voluntary contraction of the quadriceps.[9]

There are multiple therapeutic modalities that have been suggested for AMI, which change the motor nerve excitability with disinhibitory mechanisms.[10] This improves quadriceps activation by targeting joint mechanoreceptors, PNS (peripheral nervous system) around joint (Group III and IV afferent nerves), or else CNS (central nervous system).[9,10]

In patients with quadriceps insufficiency, TENS, a sensory-targeted modality, has been demonstrated to enhance quadriceps activation. By activating sensory nerves along with triggering pain gate mechanism, it diminishes pain by blocking joint's inhibitory afferent signal.[11,12]

Aim

This study aims to compare the usage of TENS in post-operative ACLR rehabilitation with a control group, thereby understanding its role in therapeutic effectiveness in rehabilitating the quadriceps muscle and obtaining a better functional outcome.

Materials and methods

This is a prospective comparative study done at our institute between January 2022 to January 2024 after obtaining Institutional ethics committee approval in patients above 18 years of age with isolated anterior cruciate ligament injury operated only with hamstring graft. Patients with history of any inflammatory joint diseases or history of any previous ipsilateral knee injury or surgery, or with chronic history of ACL injury of more than a year and history of neuromuscular diseases were excluded from the study. Groups A and B, each consisting of 40 patients, had been created from 80 individuals who had ACL reconstruction. Throughout the post-ACLR rehabilitation, patients who were in Group A received TENS for 15 minutes a day for one week along with other exercises and cryotherapy for 10 minutes at least 5 times a day, whereas Group B patients received only cryotherapy and exercises.

All patients were subjected to immediate weight bearing post surgery. The patient will undergo physiotherapy and therapeutic methods for one week, followed by follow-ups in twelve weeks and twenty-four weeks for the VAS (Visual Analogue Scale) and IKDC scoring (International Knee Documentation Committee Scoring System). For measurement of quadriceps, the thickness of thigh component was measured by thigh circumference from the midpoint of the thigh's length across ASIS (anterior superior iliac spine) along with the superior pole of patella. For categorical data, descriptive analysis had been conducted by frequency and proportion; for continuous variables, it was done by mean and standard deviation. The statistical analysis had been conducted utilizing IBM SPSS version 22.

Results

Table 1: Distribution of participants in two groups A, underwent TENS and B, without TENS, n=80

	Frequency, n	Percentage, %
Group A - TENS	40	50.0
Group B - No TENS	40	50.0

Table 1 shows the distribution of participants across two groups. Group A underwent Transcutaneous Electrical Nerve Stimulation (TENS), and Group B did not. Of the 80 participants, 50% (n=40) were in Group A, while 50% (n=40) were in Group B.

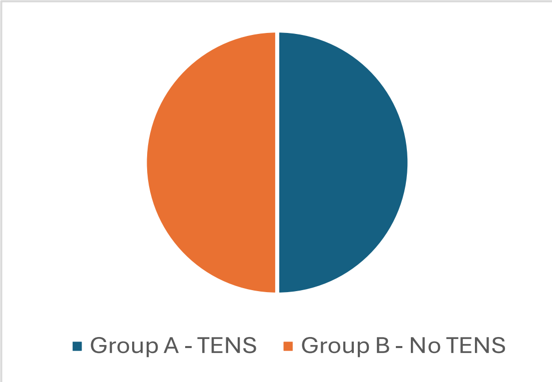

Figure 1 shows the distribution of participants across 2 groups, Group A (TENS) along with Group B (No TENS). The pie chart illustrates that 50% (n=40) of participants were in Group A, while 50% (n=40) were in Group B.

Table 2: Sex Distribution of participants in two groups A, underwent TENS and B, did not undergo TENS, n=80

	Group A – TENS, n=40		Group B - No TENS, n=40		P values*
	Frequency, n	Percentage, %	Frequency, n	Percentage, %	
Male	36	90.0	30	75.0	0.08
Female	4	10.0	10	25.0	

*Chi Square test

Table 2 illustrates sex distribution of individuals. In Group A, 90% were male, while 10% were female. In Group B, 75% were male, and 25% were female. There was no statistically significant difference in the sex distribution between the two groups, as indicated by p-value of 0.08.

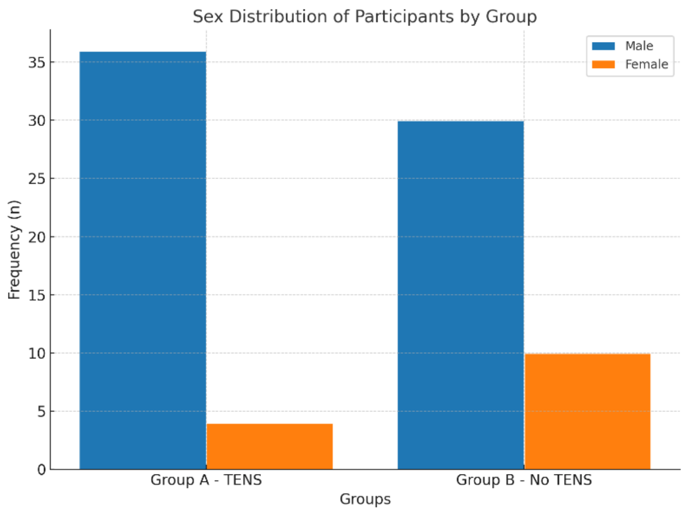

Figure 2 represents the sex distribution of participants in both groups. Group A included 90% males and 10% females, while Group B comprised 75% males and 25% females. The bar chart reflects that males were predominant in both groups, though Group B had a slightly higher proportion of females.

Table 3: Duration of illness among participants in two groups A, underwent TENS and B, did not undergo TENS, n=80

	Group A – TENS, n=40		**Group B - No TENS, n=40**		**P values***
	Frequency, n	**Percentage, %**	**Frequency, n**	**Percentage, %**	
<6	33	82.5	24	60.0	**0.03**
>6	7	17.5	16	40.0	

*Chi Square test

Table 3 represents the duration of illness among the participants. In Group A, 82.5% had an illness duration of less than six months, while 17.5% had a duration of more than six months. In Group B, 60% had a duration of less than six months, while 40% had a duration of more than six months. P-value had been 0.03, showing a statistically significant difference in illness duration among the groups.

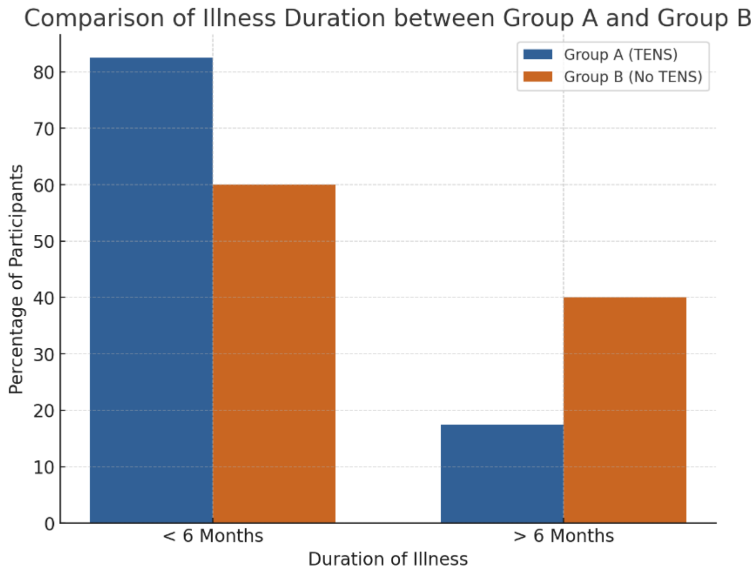

Figure 3 compares the duration of illness between the two groups. Group A had 82.5% of participants with an illness duration of less than six months, while Group B had 60% of participants with a similar duration. The remaining percentages reflect participants with more than six months of illness duration. The chart indicates a statistically significant difference in illness duration among the groups.

Table 4: Mode of injury among participants in two groups A, underwent TENS and B, did not undergo TENS, n=80

	Group A – TENS, n=40		Group B - No TENS, n=40		P values*
	Frequency, n	Percentage, %	Frequency, n	Percentage, %	
RTA	23	57.5	18	45.0	0.26
Fall	17	42.5	22	55.0	

*Chi Square test

Table 4 describes the mode of injury. In Group A, 57.5% of the participants were injured due to road traffic accidents (RTAs), while 42.5% were injured from falls. In Group B, 45% were injured due to RTAs, and 55% were injured from falls. With a p-value of 0.26, there had been no significant difference between the two groups in terms of mode of injury involved.

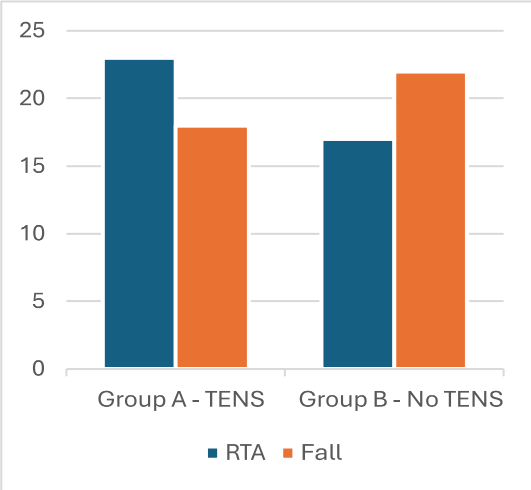

Figure 4 illustrates the mode of injury in both groups. In Group A, 57.5% of participants were injured due to road traffic accidents (RTAs), while 42.5% were injured from falls. In Group B, 45% were injured due to RTAs, and 55% were injured from falls. The bar chart shows that Group B had a higher proportion of injuries caused by falls compared to Group A.

Table 5: Age of participants in two groups A, underwent TENS and B, did not undergo TENS, n=80

	Group A – TENS, n=40		**Group B - No TENS, n=40**		**P values***
	Mean	**SD**	**Mean**	**SD**	
Age	30.4	8.0	32.3	11.0	0.36

*Unpaired t-test

Table 5 presents the age distribution among participants. Mean age in Group A had been 30.4years (SD = 8.0), while in Group B, it was also 32.3 years (SD = 11.0). The p-value had been 0.36, representing no significant difference in age among the groups.

Table 6: Thigh circumference – Left among participants who had left ACL injury in two groups A, underwent TENS and B, did not undergo TENS, n=36

	Group A – TENS, n=18		**Group B – No TENS, n=17**		**Difference**		**P values***
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SE**	
Baseline	36.9	6.5	46.2	7.2	-9.2	2.3	**<0.001**
3 months	38.2	7.0	46.7	6.9	-8.6	2.3	**<0.001**
Difference in differences					0.7	3.3	0.84

*Difference in difference

Table 6 describes the thigh circumference on the left side at baseline and after 3 months. In Group A, the baseline mean was 36.9 cm, and after 3 months, it increased to 38.2 cm, showing a difference of 1.3 cm. In Group B, the baseline mean was 46.2 cm, and after 3 months, it increased to 46.7 cm, showing a difference of 0.5 cm. Even if the baseline differences and 3 month difference of -9.2 cm and -8.6 cm were significant (p-value of less than 0.001), difference in differences among baseline and 3 months for Group A along with Group B was 0.7 cm with a standard error (SE) of 3.3 cm, ensuing in a p-value of 0.84, showing no statistically significant difference.

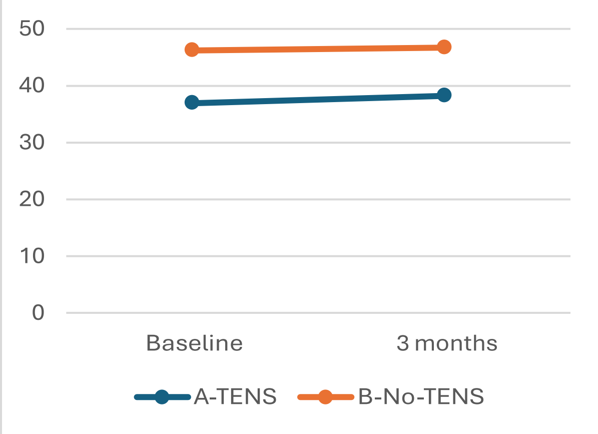

Figure 6 compares the thigh circumference on the left side between Group A as well as Group B at baseline and after 3months. In Group A, the thigh circumference increased by 1.3 cm, while in Group B, it increased by 0.5 cm over 3 months. The difference in differences between baseline and 3 months was not statistically significant.

Table 7: Thigh circumference – Right among participants who had Right ACL injury in two groups A, underwent TENS and B, did not undergo TENS, n=45

	Group A – TENS, n=25		**Group B – No TENS, n=20**		**Difference**		**P values***
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SE**	
Baseline	36.5	8.1	43.9	7.0	-7.5	2.2	**<0.001**
3 months	37.6	8.3	44.2	6.7	-6.6	2.2	**<0.001**
Difference in differences					0.9	3.2	0.79

*Difference in difference

Table 7 describes the thigh circumference on the right side at baseline and after 3 months. In Group A, the baseline mean was 36.5 cm, and after 3 months, it increased to 37.6 cm, showing a difference of 1.1 cm. In Group B, the baseline mean was 43.9 cm, and after 3 months, it increased to 44.2 cm, showing a difference of 0.3 cm. Even if the baseline differences and 3-month difference of -7.5 cm and -6.6 cm were significant (p-value of less than 0.001), difference in differences among baseline and 3months for Group A and Group B was 0.9 cm with a standard error (SE) of 3.2 cm, cause a 0.79 p-value, representing no statistically significant difference.

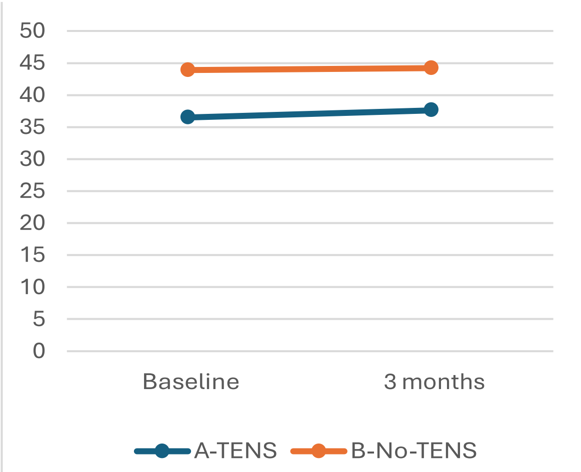

Figure 7 compares the thigh circumference on the right side between Group A along with Group B at baseline and after 3months. Group A exhibited a rise of 1.1cm, while Group B exhibited a rise of 0.3cm. Difference in differences was not statistically significant.

Table 8: IKDC among participants in two groups A, underwent TENS and B, did not undergo TENS, n=80

	Group A – TENS, n=40		Group B - No TENS, n=40		Difference		P values*
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SE**	
Baseline	46.2	10.7	52.7	12.6	-6.5	2.3	**<0.001**
3 months	44.8	9.2	46.1	8.5	-1.2	2.3	0.61
6 months	56.7	7.2	57.6	6.1	-0.9	2.1	0.66
Difference in differences – baseline to 3 months					5.3	3.3	0.10
Difference in differences – 3 months to 6 months					0.3	2.5	0.91
Difference in differences – baseline to 6 months					5.5	3.0	0.06

*Chi Square test

Table 8 compares the IKDC scores between groups at baseline, after 3months, as well as after 6months. In Group A, baseline mean was 46.2, and after 6 months, it increased to 56.7, showing a difference of 10.5. In Group B, the baseline mean was 52.7, and after 6 months, it increased to 57.6, showing a difference of 4.9. Even if the baseline differences of -6.5 were significant (p-value=0.01), difference in variances among baseline and 6months for Group A and Group B was 5.5 with a SE (standard error) of 3 concluding in a p-value=0.06, indicating borderline no significant difference.

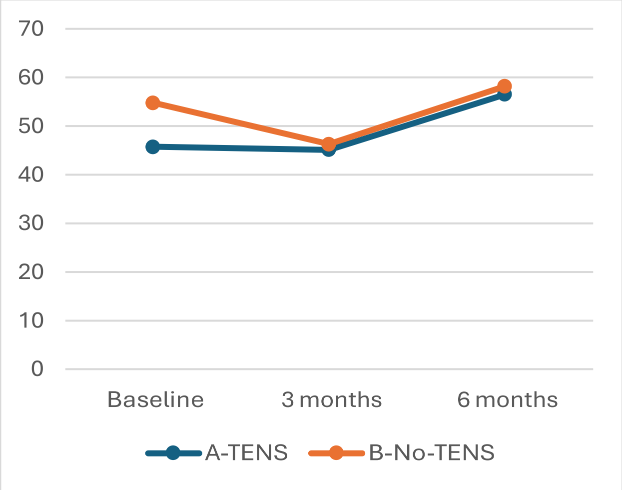

Figure 8 shows the IKDC scores for Group A along with Group B at baseline, after 3months, after 6months. Group A showed a rise of 10.5 points, though Group B showed a rise of 4.9 points over 6months. The difference in differences between baseline and 6 months indicated a borderline no significant difference (p-value of 0.06).

Table 9: VAS among participants in two groups A, underwent TENS and B, did not undergo TENS, n=80

	Group A – TENS, n=40		**Group B - No TENS, n=40**		**Difference**		**P values***
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SE**	
Baseline	3.8	1.7	3.6	1.4	0.2	0.3	0.56
3 months	3.4	1.6	3.5	1.2	-0.02	0.3	0.94
6 months	1.8	0.7	2.0	0.7	-0.2	0.3	0.52
Difference in differences – baseline to 3 months					-0.2	0.5	0.64
Difference in differences – 3 months to 6 months					0.15	0.4	0.67
Difference in differences – baseline to 6 months					-0.4	0.4	0.36

*Chi Square test

Table 9 represents the Visual Analog Scale (VAS) scores for pain at baseline, after 3months and after 6months. In Group A, baseline mean was 3.8, and after 6 months, it decreased to 1.8, showing a difference of -2.0. In Group B, the baseline mean was 3.6, and after 6 months, it decreased to 2.0, showing a difference of -1.6. Even if the baseline differences and 6-month differences of 0.2 and -0.2 were not significant, the difference in differences among baseline as well as 6months for Group A and Group B was -0.4 with a SE of 0.4, concluding in a p-value of 0.36, indicating no statistically significant difference.

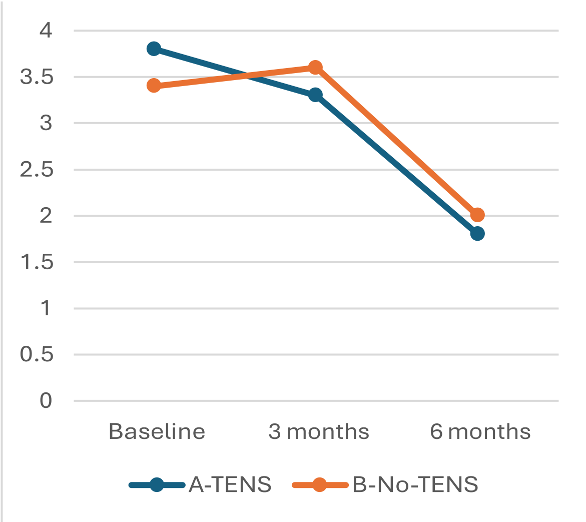

Figure 9 shows the VAS scores for Group A and Group B at baseline, after 3months, along with after 6months. Group A showed a difference of -2.0 points, while Group B showed a difference of -1.6 over 6 months. The difference in differences between baseline and 6 months indicated a no significant difference (p-value of 0.36).

Discussion

The present study aimed to assess the role of Transcutaneous Electrical Nerve Stimulation (TENS) in post-operative rehabilitation of patients following Anterior Cruciate Ligament Reconstruction (ACLR).

Patient Demographics and Characteristics

The participants demographics had been evenly distributed throughout the 2 groups. The sex distribution showed a predominance of male patients in both the TENS (90%) and non-TENS (75%) groups (Table 2). This is consistent with the general population of ACL injury patients, where male athletes tend to be overrepresented, particularly in high-impact sports. Traveling as well as outdoor activities, that are primarily done by males, are reasons for the greater prevalence of male patients.[13] However, there are studies that suggest that ACL injuries are more common among the female population[14-18] suggesting potential gender variation in both extrinsic (for example, bracing, shoe-surface interaction, visual and physical perturbations) along with intrinsic (hormonal, neuromuscular, anatomical, and biomechanical) factors.[19] The duration of illness also demonstrated a significant difference, with Group A having a higher proportion of patients within six months of injury (82.5% vs.
60% in Group B). This could imply a more acute nature of ACL injuries in Group A, which might influence the outcomes of rehabilitation. However, this variation was controlled during statistical analysis, and the results of TENS were analyzed across the groups effectively.

Mode of Injury

In both groups, the mode of injury had been predominantly related to RTAs (road traffic accidents), subsequent to accidental falls and sporting injuries, although the differences between groups were not statistically significant (Table 4). This finding aligns with existing literature, which suggests that motor vehicle accidents are a most frequent cause of ACL injuries as well as also by high impact sports injuries.[13,20]

Functional Outcomes and Rehabilitation

Primary goal of ACLR rehabilitation has been to restore function, particularly quadriceps strength, [21] and alleviate pain. The difference in thigh circumference between the two groups was observed both at baseline and after three months of rehabilitation (Tables 6 and 7). At baseline, Group A demonstrated a significantly lower thigh circumference compared to Group B, which may reflect pre-operative muscle atrophy. Despite some improvements in both groups, variance between 2 groups had not been statistically significant after 3months, as indicated by the p-values (0.84 and 0.79, respectively). This suggests that while TENS group showed some increase in quadriceps muscle thickness, the effect may not be clinically meaningful in terms of muscle hypertrophy.

IKDC scores showed a positive trend in both groups over six months (Table 8), with Group A demonstrating a greater increase (10.5 points) than Group B (4.9 points). Though, variance in differences between groups had shown borderline significance (p=0.06), indicating that TENS may have provided a slight advantage in functional outcomes. The consequences are in line with prior research that suggests electrical stimulation modalities may aid in enhancing functional recovery, but the benefits may be modest or require a longer duration of therapy.[22]

Pain Management

In terms of pain reduction, as measured by the Visual Analog Scale (VAS), both groups experienced improvements, but again, no statistically significant difference was found among groups (Table 9). At baseline, Group A reported a higher mean pain score (3.8) compared to Group B (3.6), and by six months, pain scores in both groups had decreased. The decrease in pain was slightly more pronounced in Group A, but p-value of 0.36 suggests that this variance was not clinically significant. TENS can reduce pain through its gating effect on nociceptive input, though its long-term effects on post-surgical pain remain inconclusive. [22]

Study limitations

While the present investigation offers valuable insights into use of TENS in post ACLR rehabilitation, there are few limitations**.**

1. Sample Size: This investigation comprised merely 80 participants, perhaps constraining generalizability of results to a wider population.
2. Short Duration of TENS Intervention: TENS was applied for only 15 minutes daily for one week, which might not be inadequate to identify significant long-term benefits.

3. Limited Follow-Up Period: This investigation followed participants for up to 6months post-surgery. A longer follow-up might be required to evaluate sustained effects of TENS on functional outcomes and pain management.
4. Measurement of Quadriceps Muscle: Thigh circumference was used as a measure of quadriceps muscle strength and size. More precise imaging techniques (e.g., MRI, ultrasound) could provide more accurate assessments of muscle hypertrophy and activation.
5. Subjective Outcome Measures: Reliance on patient-reported outcomes like VAS and IKDC scores introduces a potential for bias or variability in pain perception and functional reporting.[23]

Conclusion

Transcutaneous electrical nerve stimulation therapy demonstrated a trend toward improved outcomes in quadriceps activation and functional recovery after ACLR, the results did not achieve statistical significance in many of the key measures. These findings suggest that TENS may provide some benefit in the rehabilitation process, but its overall impact remains unclear. Additional research with bigger cohorts as well as extended follow-up periods is necessary to validate these results and enhance rehabilitation protocols for post-ACLR patients.

Abbreviations

AMI – Arthrogenic Muscle Inhibition
TENS – Transcutaneous Electrical Nerve Stimulation
IKDC – International Knee Documentation Committee
VAS – Visual Analogue Scale
ACLR – Anterior Cruciate Ligament Reconstruction
RTA – Road Traffic Accident
ACL – Anterior Cruciate Ligament

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Author contributions

Conceptualization : Prabhakaran A and Hari Kishore R ; Methodology : Mahadi Begum S ; Validation : Prabhakaran A and Hari Kishore R ; Formal Analysis : Hari Kishore R , Vishnu Harikrishnan and Mahadi Begum S ; Resources : Mahadi Begum S ; Data Curation : Mahadi Begum S ; Writing – Original Draft Preparation : Mahadi Begum S; Writing – Review &amp : Hari Kishore R , Vishnu Harikrishnan and Prabhakaran A ; Editing : Mahadi Begum S ; Supervision : Hari Kishore R

Conflicts of interest

None.

Data availability

Upon reasonable request, the corresponding author will make the datasets created and/or examined during the current work available.

Ethics approval

Prior to their participation in the study, each participant provided their informed consent for inclusion. The Institutional Human Ethics Committee's guidelines were followed when conducting this study.

Use of AI

The authors acknowledge the use of AI-based tools for assisting in text structuring, grammar refinement, and statistical validation. The use of AI is less than 15 %. All intellectual contributions, interpretations, and conclusions remain the responsibility of the authors .

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