International Journal of Physiotherapy and Research,
Int J Physiother Res 2018, Vol 6(6):2914-21. ISSN 2321-1822
DOI: https://dx.doi.org/10.16965/ijpr.2018.152

Original Research Article

A STUDY ON THE EFFECTIVENESS OF ELECTRICAL MUSCLE STIMULATION TO QUADRICEPS ON PAIN, ISOMETRIC CONTRACTION, FUNCTIONAL MOBILITY AND QUALITY OF LIFE IN POST OPERATIVE REHABILITATION IN TOTAL KNEE ARTHROPLASTY

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ABSTRACT

Background: Total Knee Arthroplasty alleviates pain from osteoarthritis, but deficits persist in quadriceps strength post replacement. This causes decline in the functional status of an individual. Thus, we aim to evaluate the efficacy of Electrical stimulation on quadriceps muscle for pain, maximum voluntary isometric contraction, knee range of motion, functional mobility and quality of life along with rehabilitation protocol Total Knee Arthroplasty

Design: Randomized, single blinded, parallel group, active controlled trial

Setting: Inpatient department in tertiary joint replacement care center

Participants: Patients who underwent Total Knee Arthroplasty

Main Outcome measures: Maximum Voluntary Isometric Contraction of quadriceps, knee range of motion, pain, Functional performance measure by 30 second sit to stand test and quality of life by SF-12 questionnaire.

Results: At 4 weeks, there was significant association between ES and quadriceps strength ($p=0.00$), knee range ($p=0.00$), 30 second sit to stand ($p=0.00$). There was no significant difference seen in pain between the group ($p<0.05$) but difference in the groups ($p=0.00$) was seen. Quality of life ($p<0.05$) had no significant difference post Total Knee Arthroplasty

Conclusion: Electrical stimulation combined with exercises is effective in improving pain, knee range of motion, quadriceps strength andfunctional performance post Total Knee Arthroplasty

KEY WORDS: Electrical muscle stimulation, Quadriceps, functional mobility, quality of life, total knee arthroplasty.

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Access this Article online	Journal Information
Quick Response code	**International Journal of Physiotherapy and Research** ICV for 2016 86.93 ISSN (E) 2321-1822 | ISSN (P) 2321-8975 **https://www.ijmhr.org/ijpr.html** **DOI-Prefix:** https://dx.doi.org/10.16965/ijpr
DOI: 10.16965/ijpr.2018.152	**Article Information** Received: 09 May 2018 Accepted: 20 Jun 2018 Peer Review: 10 May 2018 Published (O): 11 Dec 2018 Revised: None Published (P): 11 Dec 2018

INTRODUCTION

Osteoarthritis (OA) and its physical manifestations are a global issue. In the cohort of individuals older than 60 years of age, an estimated 10% of the world's population suffers from limitations attributable to OA. OA related

impairments are responsible for over 18 million physician visits each year. Knee OA is characterized by degenerative radiographic findings including joint space narrowing, the presence of osteophytes and sub-chondral bone sclerosis. Such findings contribute to pain in weight bearing activities, restricted range of motion and functional decline. Conservative measures are often implemented to alleviate pain and minimize functional limitations. However, when conservative management fails to alleviate OA related symptoms, Total Knee Arthroplasty (TKA) is often indicated [1].

TKA is surgical treatment for relieving pain and improving function. Even though TKA provides significant pain relief and improves self reported function; this fails to improve the quadriceps muscle strength to the normal level for age-matched healthy population. Patients with end stage knee OA exhibit relatively 20% more activation deficits in the involved quadriceps than in the uninvolved limb suggesting that the neural mechanisms contribute to the weakness of the quadriceps even prior to TKA surgery. These central activation deficits are reported to account for two times greater strength loss than muscle atrophy earlier than surgery [2].

Pain, swelling, joint range of motion and patellar mobility are common acute impairments following TKA. Patients exhibit 60% reduction in quadriceps femoris muscle force production from pre-operative baseline levels 1 month after TKA [1]. In the first month following surgery, quadriceps strength further decreases by up to 60% compared with the pre-operative levels. Function also decreases dramatically in the first month, with the performance on the stair climbing test decreasing by 90% and walking distance on the 6 minute walk test decreasing by 40%. Six months after surgery, Patients exhibit significant strength and functional deficits compared with their healthy peers. Compared with healthy adults after TKA have 40% lower quadriceps strength, walk 30% less distance on 6 minute walk test and take 110% longer on the stair climbing test. Combined impairment of strength and functional deficit predispose individuals to increasing disability with age as well as an increased risk of falling and loss of functional independence [3].

Thus, in acute early post op phase important role in physiotherapy management is to focus on quadriceps inhibition for better recruitment of quadriceps. Weakness of the quadriceps muscle results in important functional consequences such as decreased gait speed, balance, difficulty with stair climbing and rising from a chair and risk of falls[1].Quadriceps strength plays important role for patient satisfaction and restoration of functional activity following TKA [4].

Electrical stimulation is used widely in research and clinical settings to preserve or restore muscle mass and function during prolonged periods of disuse or immobilization. Stimulation is being delivered in close proximity of muscle motor point transcutaneously with therapeutic goal of achieving strong muscle contraction. When repeated contractions of sufficient training intensity are delivered to the motor point for sustained intervention period, the training adaptation is applied [5]. Thus, stimulation is often used as a quadriceps strengthening modality to train patients without sufficient volitional quadriceps activation by engaging neurophysiological mechanisms which are believed to facilitate strength gains and provide general physical stress to neuromuscular system of the quadriceps muscle [2].

Thus, our aim is to study the effectiveness of initiation of ES immediate post operatively to addition to exercise rehabilitation protocol after TKA to see its effect on maximum voluntary activation of quadriceps, pain, range of motion and quality of life for enhancement in improved functional mobility which is considered to be important for obtaining maximum benefit post Total Knee Arthroplasty

Purpose: Increasing incidence of knee OA and increasing demand for TKA, stresses the need for better understanding for post-operative care to decrease the disability associated with knee OA[6] due to reduce quadriceps muscle strength. As quadriceps muscle plays prime role in weight bearing functional activities it gets affected by osteoarthritis and impairment in quadriceps muscle performance causes profound disability [7]. Prevalence of OA increases with age[8].Aging contributes to decrease in total number of type I and type II fibers. Atrophy of type II fibers is present which are largely responsible for

decreased force producing ability of elderly individuals [9-12]. Hence, it is necessary to overcome age related deficits in force production but also counter muscle weakness which attributes to osteoarthritic disease following TKA [5].

AIM: To compare the effectiveness of Electrical stimulation(ES) on quadriceps post TKA as an adjunct to standard rehabilitation protocol on maximum voluntary isometric contraction, pain, knee range of motion, functional mobility and quality of life.

OBJECTIVES: 1. To evaluate the efficacy of ES on quadriceps muscle stimulation on pain, maximum voluntary isometric contraction, knee range of motion, functional mobility and quality of life post TKA. **2.** To compare the effectiveness of ES along with standard rehabilitation protocol and standard rehabilitation protocol exercises alone on pain, maximum voluntary isometric contraction, knee range of motion, functional mobility and quality of life post TKA.

METHODOLOGY

Study Population: Patients undergone unilateral or bilateral Total knee replacement

Place of study: Inpatient department in tertiary care center

Sample size: Sample size will be calculated using the formula [13].

$$\text{Sample size} = \frac{2SD^2 (Z\alpha/2 + Z\beta)^2}{d^2}$$

SD- Standard deviation from previous study or pilot study

Zα/ 2- 1.96 (from Z table) at type I error of 5%

Zα/ 2- 0.84 (from Z table) at 80% power

d= effect size (difference between two mean values)

Sample size=35

35 participants were included in the study

Study design: Randomized, single blinded, parallel group, active controlled trial

Sampling technique: Simple Randomization using computer generated random table allocation

Duration of the study: Six months

Inclusion criteria: Patients of both gender of age group between 50-80 years who have undergone Total Knee Arthroplasty secondary to severe osteoarthritis.

Exclusion Criteria: Post traumatic TKA, Significant neurological impairments, Revision TKA, Any lower limb deformity, Dermatological conditions and impaired sensation affecting the thigh.

Procedure:

Post approval by the institutional ethical committee, a written informed consent was taken from the participants in the language they understand prior to the study. Participants demographic data was collected and clinical evaluation was carried out, Taking in consideration of inclusion criteria participants participated in randomized control trial and became participant of any one of the group. Pain, supine knee range of motion, maximal voluntary isometric contraction, 30 second sit to stand test were assessed by assessor who was qualified therapist prior to the commencement of the study.

According to random allocation participants were allocated in any one of the two groups as follows:

1. 13 participants were allocated to group in which ES (low frequency- surge faradic) was started along with standard rehabilitation protocol.

2. 14 participants were allocated to standard rehabilitation protocol.

Group I Intervention:

Participants in Group I were treated with Electrical stimulation (ES) on quadriceps muscle with following dosage [14] Biphasic current, symmetrical waveform for 15 contractions.

Frequency: Two times a day at maximum tolerable intensity.

Period: 4 weeks (from 48 hours post surgery).

A portable stimulator was used for the electrical stimulation.

Stimulation was given to the quadriceps with participants in high sitting position. Self-adherent, flexible rectangular electrodes (8 × 13.5 cm) was placed over the motor point of the quadriceps muscle to reduce the current threshold. Electrode size for ES is important because it has

a direct effect on the density of the current. Small electrodes result in a high current density and can cause painful stimulation. Selection of appropriate electrode size, therefore, is essential for comfortable stimulation, and application of the electrode over the motor point of the muscle reduces the current threshold required. Thus, in the study large, rectangular electrodes were used to maximize tolerance to treatment. Reapplication by the participant was done over the distal medial and proximal lateral portions on the anterior thigh to ensure the correct position. Electrical stimulation from the portable electrical stimulator was applied to the resting muscle, and the participant was instructed to relax during the induced muscle contraction. The intensity was set to the maximal intensity tolerated during each session, and participants were repeatedly encouraged to increase the intensity as tolerated and marked to ensure consistent reapplication by the participant.

Intervention began 48 hours after surgery in participants assigned to the ES group. A total of 15 ES repetitions were performed during each session, twice a day for 4 weeks after TKA. Initial familiarization with the ES device occurred during post-operative period till the time of discharge. An emphasis was placed on the importance of using the stimulator at an intensity that was tolerable, but slightly uncomfortable, although there was no minimum intensity required for the study protocol. In addition, participants were repeatedly instructed to continue to increase the intensity as much as tolerated within and between sessions. Most participants demonstrated safe and proper use of the stimulator. When there were concerns about participants implementation or tolerance to ES, a study physical therapist paid a home visit within the first week of discharge to monitor a home treatment session. Participants also were given paper logs to track adherence. Along with ES, participants underwent standard rehabilitation protocol which was to be done two times a day. Hand-out of standard rehabilitation protocol was given for reference to the participants.

Group II Intervention:

In this group, participants underwent standard exercise rehabilitation protocol followed in the present hospital.

Standard exercise rehabilitation protocol for both the groups as tolerated by the participants are:

Sr. No	Exercises	Frequency
1	Ankle toe movements	All exercises 10 repetitions each and later followed with 5 second holds Twice a day
2	Static Quadriceps	
3	Static Hamstrings	
4	Supine heel slides	
5	Supine hip abduction	
6	Active assisted to active supine hip flexion with knee extension	
7	Vastus Medialis Obliterans activation	
8	Side lying hip abduction with pillow between both the knees	
9	Active assisted to active dynamic quadriceps	

Ambulation: Walking with walker as tolerable

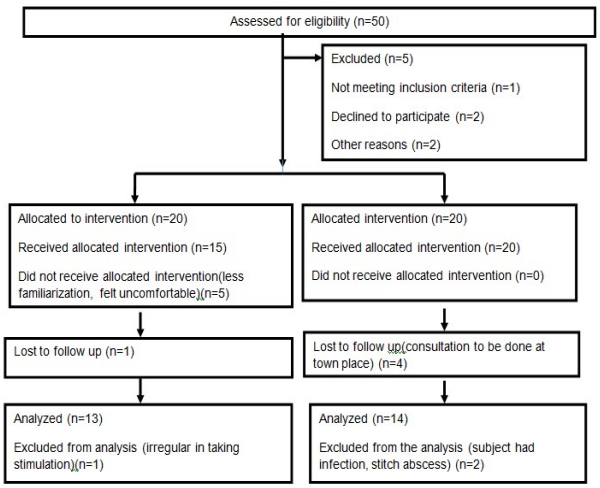
15 days post suture removal of surgery, prone knee bends and prone hip extension ten repitations each were added in standard rehabilitation protocol.

Post 4 weeks, assessor evaluated the patient for maximal voluntary isometric contraction, pain, knee range of motion , 30 second sit to stand test and scoring of SF-12questionnaire

Blinding: Assessor was blinded. Measurements were taken by another trained physiotherapist pre and post intervention

Electrical stimulation can be applied on quadriceps muscle as it is not contraindicated to be used near “passive implants” like wires, pins, plates, nails, screws and various arthroplasties[15]

CONSORT FLOW CHART



Outcome Measures

Maximum Voluntary Isometric Contraction (MVIC): Isometric quadriceps muscle strength

(primary outcome) was done by FET hand held Dynamometer. Participants were positioned with hip at 110 degree and knee flexed at 60 degree. The fulcrum of FET hand held Dynamometer was placed at inferior aspect of tibia when participants performed dynamic quadriceps. Participants was verbally encouraged to "kick as hard as he can" by causing isometric contraction of quadriceps. Testing was repeated up to 3 times, with 1 minute of rest between trials. The trial with the highest maximal voluntary isometric contraction was considered by the assessor [16].

Knee Range Of Motion (KROM): It was measured using long arm full Goniometer. Participants were positioned in supine lying. Passive knee range of motion was carried out passively in supine lying with fulcrum at lateral knee joint line, proximal arm of goniometer aligned with greater trochanter and the distal arm aligned with the lateral malleolus. Best of the three readings was noted by the assessor.

Reliability of goniometer for supine Knee Range of Motion:

Interrater reliability = 0.97-0.99

Intrarater reliability = 0.92-0.99 [17]

Pain: The10 point Numerical pain rating scale was used to rate the participants level of pain. Participants were given brief explanation about the scale. The scale anchored at 0 saying "no pain" and 10 as "worst imaginable pain" and participants were asked to rate their perception of pain levels ranging from "0" to "10". The test –retest has shown high reliability (r=0.95)[18]

Functional Performance Measure: It was measured using 30 second sit to stand activity. It was helpful in testing lower body strength and dynamic balance. A chair of 44cm (17inches) was used where participants were timed for 30 seconds in which they had to carry sit to stand activity with help of mobility aid. Scoring was done depending upon number of sit to stand activity carried out by the participants in 30 seconds [18].

Quality of Life: Quality of life was assessed by SF-12 questionnaire. It is a multidimensional generic measure of health related quality of life questionnaire which is widely used in clinical trials and routine outcome assessment. Questionnaire measured two components namely-physical composite score (PCS) and mental composite score (MCS) for assessing quality of life.

Evaluation of Maximum voluntary isometric contraction, supine Knee Range of Motion, pain, functional performance scale and quality of life measures was carried out post 48 hours of surgery before commencement of the intervention and after 4 weeks of surgery post intervention in control as well in intervention group.

Statistical Analysis: Using Microsoft excel 2010 and also using SPSS software in which Intra group-Wilcoxon Signed Rank Test, Inter group-Mann-Whitney U Test

RESULTS

Significant difference (p=0.00) is seen in maximum voluntary isometric contraction between both the groups.(Graph 1)

Significant difference (p=0.02) is seen in knee range of motion between both the groups. (Graph 2)

Significant difference (p=0.02) is seen in 30 second sit to stand functional performance between both the groups.(Graph 3)

No significant difference (p=0.08) is seen in pain between the groups but significant difference (p=0.00) is seen within the groups.(Graph 4)

No significant difference is seen in quality of life where physical composite scale (p=0.2) and mental composite scale (p=0.4). (Graph 5)

Table 1: Mean standard deviation and p values of control and experimental group taken post 48 hours of surgery (pre) and 4 weeks after TKA (post).

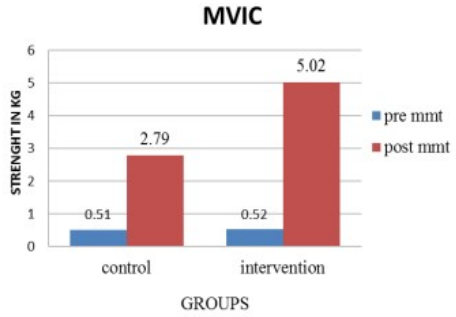
	Control			Experimental		
	Pre	Post	P Value	Pre	Post	P Value
MVIC	0.51±0.21	2.79±0.42	0.00*	0.52±0.29	5.02±0.31	0.00*
KROM	41.86±8.03	90.57±8.72	0.00*	41.31±4.78	102.92±5.01	0.00*
S2S	6.43±1.02	8.57±1.50	0.00*	6.08±1.39	11±1.35	0.00*
PAIN	6.57±1.03	3.07±0.83	0.00*	6.92±1.12	2.54±0.66	0.00*
SF 12 PCS	27.33±3.06	44.12±5.88	0.00*	27.70±3.91	102.92±5.01	0.00*
SF 12 MCS	33.41±3.61	51.11±6.75	0.00*	33.86±4.04	41.36±5.45	0.00*

Table 2: P value between the control and experimental group.

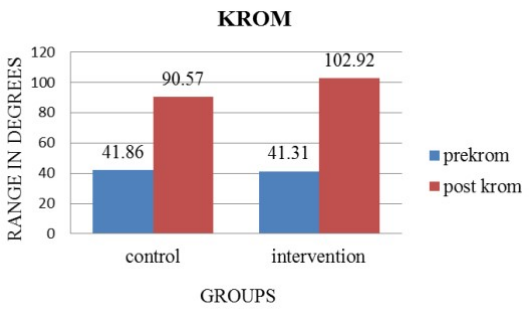
Outcome Measures	P Value Between Groups
MVIC	0.00*
KROM	0.02*
S2S	0.00*
PAIN	0.08
SF 12 PCS	0.2
SF 12 MCS	0.4

*: p value is significant and less than 0.05

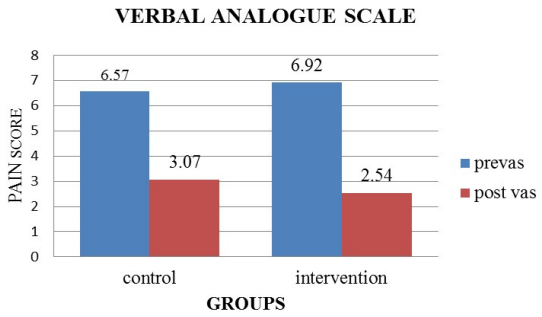
Graph 1: Comparison of maximal voluntary isometric contraction between control and experimental group.



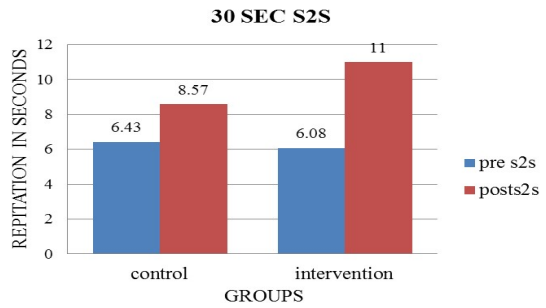
Graph 2: Comparison of KROM between control and experimental group.



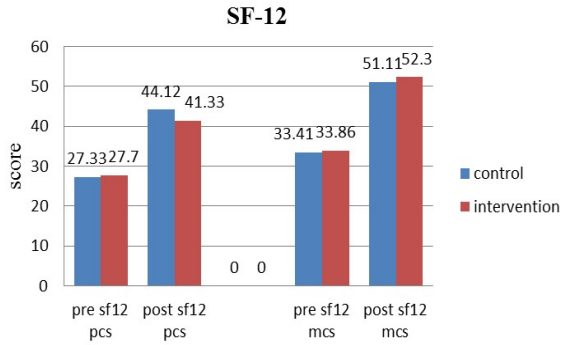
Graph 3: Comparison of PAIN between control and experimental group.



Graph 4: Comparison of 30 SEC S2S between control and experimental group.



Graph 5: Comparison between SF-12 scores between control and experimental.



PCS: Physical Composite Score
MCS: Mental Composite Score

DISCUSSION

Maximum Voluntary Isometric Contraction, Knee Range of Motion and 30 seconds Sit to stand activity after TKA were significantly better after 4 weeks intervention in the Electrical Stimulation group. In age related osteoarthritis, quadriceps muscle atrophy of type I and type II muscle fibers occurs. Muscle weakness is markedly observed because of the atrophy of type II muscle fibers. Electrical stimulation affects type II muscle fibers mainly. Thus addition of electrical stimulation in the post-operative treatment of exercise programs potentializes muscle strength enhancement [2].

This can be attributed to the fact that application of ES to neuromuscular junction and surrounding muscle fibers causes muscle contraction. This causes increase in muscle strength by using electrically induced contraction which causes increase load on the muscle giving muscle a training effect [18]. Even in the study conducted by Lewek et al significant improvement in range of motion, muscle strength and pain resolution were observed in 12 sessions of electrical stimulation of the vastus medialis muscle after Total Knee Arthroplasty [19].

Studies have suggested that there exists a correlation between quadriceps muscle ES at higher intensity and increased activation of sensorimotor cortex regions of brain as ES influences motor performance by motor cortex excitability.ES evoked contractions recruit deep muscle fibers within the muscle and target superficial nerves more than deep ones because of proximity to stimulating electrodes. Mapped patterns of muscle activation after repeated ES evoked isometric contractions and found that with increasing intensity, activation of number of motor units increase and contribute to greater force output. However lower levels of stimulations that target peripheral afferent nerves can induce prolonged changes in excitability of

human cortex.

Electrically elicited muscle contraction causes activation of large proportion of type II (higher force producing motor units) at relatively low levels of stimulation. With ES with more recruitment of Type II fibers there results in greater muscle fatigue due to ES as compared with voluntary contractions because of greater metabolic demand. But muscle fatigue is thought to be necessary stimulus for muscle hypertrophy and therefore greater activation of type II fibers occurs which maximizes force production but at the expense of increased muscle fatigue [20].

Our study showed that there was significant difference in the p values of functional mobility i.e. 30 second sit to stand activity in pre and post values between both the groups(p=0.00).

In our study experimental group demonstrated faster rising from chair which led to improvement in functional performance, the previous study done by Asakawa et al also showed the similar results in which they have concluded that due to stimulation of quadriceps muscle there is decrease in pain, reduce reflex inhibitory response and increased knee extensor strength which leads to greater influence on function of lower limbs such as faster rising in the chair [18].

Our study showed that according to verbal analogue scale a significant reduction of pain levels were indicated in both groups (p=0.00), but difference between both the groups was not significant (p=0.08). This attributes to the fact that improvement of knee pain results from factors that may be biological or psycho-social in origin. Among biological factors, suggest that quadriceps weakness contributes to worsen knee pain [18-21].

Thus, in our study improvement in quadriceps strength can be correlated in reducing the knee pain and improving functional mobility.

No significant difference was seen in quality of life for physical composite score (PCS) (p=0.2), but difference between the control and experimental groups was seen. Parent et al done a study on 65 TKA patients have reported significant improvements in WOMAC physical function and SF physical functionality scores at post-operative second month. Shields et al in their study assessed the quality of life preoperatively and at 3 and 6 month post-operatively using the SF-36 form and found that there is a greatest improvement at third month is observed in the pain, physical functionality, and vitality subscales which showed improvement. They also suggested that the greatest improvement occurs in the first three months ,since the scores slightly changed from the third month to the sixth month [2]. Papakostidou et al in their study observed that, six weeks after the surgery, despite in the improvement in patient's pain and relief in their depressive status, function still remained unsatisfactory. This can be attributed to the fact that functional aspect of quality of life observed through WOMAC and Knee Society Score showed improvement only after three months post total knee replacement [2].

CONCLUSION

We conclude that use of ES in combination of exercise was effective and this protocol also exhibited dramatic improvement in weak and inhibited quadriceps by improvement in muscle activation and strength which led in the improvement of functional mobility post Total Knee Arthroplasty.

CLINICAL SIGNIFICANCE: Low frequency current offers a visual feedback and training effect to quadriceps muscle by improving neural drive of a muscle. Electrically elicited isometric contraction can be used as a supplement when there is failure of muscle to act immediately post surgery.

ABBREVIATIONS

OA - Osteoarthritis
TKA - Total Knee Arthroplasty
ES - Electrical Stimulation
KROM - Supine Knee Range of Motion
MVIC - Maximum Voluntary Isometric Contraction
S2S - 30 second Sit to stand activity
SF12 PCS - SF12 physical composite score
SF12MCS - SF12 mental composite score

ACKNOWLEDGEMENTS

The authors would like to take this opportunity to thanks Dr. Rachana Dabadghav for her immense support in statistical analysis. The

authors would also like to thank Dr. Parag Sancheti and Dr. Ashok Shyam, members of the ethical committee to approve this study. The authors would also like to thank all the subjects who willingly participated and gave their valuable time for the study.

Conflicts of interest: **None**

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How to cite this article: Chetna Varma, Sanket Nagarale, Ashok Shyam, Parag Sancheti. A STUDY ON THE EFFECTIVENESS OF ELECTRICAL MUSCLE STIMULATION TO QUADRICEPS ON PAIN, ISOMETRIC CONTRACTION, FUNCTIONAL MOBILITY AND QUALITY OF LIFE IN POST OPERATIVE REHABILITATION IN TOTAL KNEE ARTHROPLASTY. Int J Physiother Res 2018;6(6):2914-2921. **DOI:** 10.16965/ijpr.2018.152