# Additional effect of neuromuscular electrical stimulation on knee extension lag, pain and knee range of motion in immediate postsurgical phase (0–2 weeks) in primary total knee arthroplasty patient

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**Background:** There are various studies on younger adults which have shown that neuromuscular electrical stimulation (NMES), at sufficient intensities, combined with active exercises had better improvement in muscle strength and functional performance than exercises alone. But very limited research is available for giving NMES in the early acute stages post total knee arthroplasty (TKA). So, the short-term effect of NMES had not yet been researched upon widely. As there were conflicting evidences in giving NMES post TKA, this study was proposed to assess the short-term effect of early NMES on knee joint pain, range of motion (ROM) and extension lag on patients undergoing bilateral TKA.

**Methods:** The study included 28 bilateral TKA patients following osteoarthritis (OA) knee within the age group of 50–75 years (60.82±5.69). The knees of 28 bilaterally operated patients were randomly divided into two groups; 1 knee was allocated in the experimental group and the other knee of the same patient became the control. The experimental group was given NMES with exercises, while the control group was given only exercises for 7 days. The patients were asked to continue to follow exercises even after the discharge, i.e., beyond 7 days. The patients were measured for pain; knee flexion ROM and extensor lag both before and after intervention.

**Results:** There was a significant improvement in pain, knee ROM and extensor lag post intervention $P<0.05$ in both the groups. But there was no significant difference between the groups with respect to pain, knee ROM and extensor lag, $P>0.05$.

**Conclusions:** The NMES and exercises worked equally in case of patients operated for TKA. Hence our results concluded that there was no additional effect of NMES on extensor lag, knee ROM and pain when applied for 7 days in patients operated with TKA.

**Keywords:** Neuromuscular electrical stimulation (NMES); total knee arthroplasty (TKA); early rehabilitation; extension lag

Submitted May 21, 2019. Accepted for publication Sep 15, 2019.
doi: 10.21037/atm.2019.09.79
**View this article at:** http://dx.doi.org/10.21037/atm.2019.09.79

## Introduction

Knee joint osteoarthritis (OA) is the second most existing disease in India with the prevalence of 22% to 39%. It is more commonly seen in females than in males, also the disease tremendously increases with the age leading to pain, inflammation, impairments in mobility, etc. (1,2). Total knee arthroplasty (TKA) is the treatment for the individuals with end stage disease (3). TKA is a surgical procedure in which the weight bearing surfaces of the knee joint are changed with an implant which consists of 3 components- femoral component, tibial component, a centre plate and it may or may not consist of a tibial extension rod. TKA is a procedure done to relieve pain and disability of the patients (4).

Despite the recent advances in the TKA, there are numerous studies suggesting that TKA is not achieving the goal of reducing pain and restoring function (5-7). Few of the complications that arise post TKA are pain in and around the knee joint, loss of knee joint range of motion (ROM), reduced quadriceps muscle activation giving rise to an extension lag (8). There are also functional limitations like reduced walking speed, difficulty in ascending and descending stairs, etc. The satisfaction index is found to be low in patients with post TKA resulting in pain and poor functional outcomes due to weakness in quadriceps muscle strength, and voluntary activation (3). It is found that because of constant deficits in residual quadriceps femoris muscle strength after TKA can prevent patients from returning quickly and fully to functional activities. It is seen that the muscle activation failure is not only due to knee pain during muscle contraction in the patient population, but due to failure of voluntary muscle activation (attributed to reflex inhibition) and atrophy contributed to strength loss (force generation capacity) (9,10). Studies have shown almost 19% to 23% deficits in knee flexor and extensor muscle power. This significant reduction in muscle strength should be taken into consideration during rehabilitation programs, because in day to day activities it is important to have the muscle power, needed to produce effective force quickly to generate desirable and prevent undesirable movements (11).

It is seen that, post TKA the quadriceps muscle strength drops by 50% to 60% of the pre-operative levels, despite introducing early rehabilitation i.e., within 2 days after surgery (9,12). Hence, improving pain and muscle weakness should be the primary aim while treating patients post TKA. Physiotherapy management post TKA includes, cryotherapy and electrotherapy, exercises and hydrotherapy to reduce pain and improve strength and function (13,14). Various studies on younger adults have shown that neuromuscular electrical stimulation (NMES), at sufficient intensities, combined with active exercises had better improvement in muscle strength and functional performance than exercises alone (15). A case series reported that, use of high intensity NMES on quadriceps muscle in early stage of rehabilitation, improves its strength drastically in patients with TKA (16).

In most of the studies performed, NMES was given at a later stage of the rehabilitation program post a TKA (16,17). Very limited research is available for giving NMES in the early acute stages post TKA. So, the short-term effect of NMES had not yet been researched upon widely. As, there were conflicting evidences in giving NMES post TKA, this study was proposed to assess the short-term effect of early NMES on knee joint pain, ROM and extension lag on patients undergoing bilateral TKA.

## Methods

The study included 28 bilateral TKA patients following OA knee within the age group of 50–75 years (60.82±5.69). Patients who perceived pain between 4 to 10 on visual analogue scale (VAS) i.e., moderate to severe, both males and females were included in the study (12 males, 16 females). Patients suffering from any cardiovascular or neurological conditions, surgical complications post TKA, where rehabilitation protocol needed to be altered and contraindication to NMES where excluded from the study. The study was done in a hospital setup. The study was approved from the Institutional Review Board. The study was explained to all the patients and a written informed consent was taken from all the patients.

The knees of 28 bilaterally operated patients were randomly divided into two groups: experimental and control group; 1 knee was allocated in the experimental group and the other knee of the same patient became the control. Experimental group was given NMES with exercises, while control group was given only exercises. The intervention was given for 7 days which started on day 3 post operatively (post op) and continued till day 9 post operatively. The patients were assessed for pain on VAS, knee ROM in side lying and knee extension lag in supine lying with an angle frame, before the intervention on day 3 and on day 9 after the intervention (18,19). Both the groups were advised to apply ice packs every two hours till day 9 to reduce pain and swelling (13).

Experimental group: in addition to exercises NMES was given to this group. The Empi PHOENIX NMES was used which consisted of 4 programs, P1-Endurance, P2-Strength, P3-Modulated TENS and P4-Edema. In this study, we used program P2 for strength. The waveform was symmetrical square biphasic asynchronous. There were three phases in this program, warm up, work phase and cool down phase. It was a battery operated machine. The warm up treatment time consisted to 2 min with a continuous cycle, frequency 6 Hz. In the work phase, the treatment time was 15 min, cycle type was intermittent. Frequency of work was 75 Hz and that of rest was 4 Hz with work time to be 4 s and rest time was 10 s. This was followed by cool down with a treatment time of 3 min and cool down frequency is 3 Hz. The cycle was continuous. The pulse duration was 300 µs throughout the program (20).

The patient was in supine lying with an angle frame below the knee on slot 1, which maintained the knee flexion in 15° of flexion. Four electrodes of NMES were placed over maximum bulk of quadriceps femoris muscle, and patient was asked to perform active terminal knee extension along with NMES (whenever the current is perceived) as many repetitions as the subject could perform. NMES was given for 20 min. Gradually as the knee joint ROM increased the angle frame slots were increased till the third slot. So, till day 9 all the subjects could perform knee extension on angle frame on slot 3 which was 45° of knee flexion.

Control group: Exercises were started from day 1 post operatively which continued till day 9 (14,16,21,22).

In Supine position: (I) ankle toe movements, 10 repetitions; (II) isometric contraction of quadriceps, hamstrings, gluteus maximus, 10 repetitions with 6 s hold; (III) straight leg raise, 10 repetitions; (IV) hip abduction, 10 repetitions; (V) hip knee flexion, 10 repetitions; (VI) posterior capsular stretching, 30 s × 3 sets.

Progression to Side line position: (I) hip abduction, 10 repetitions; (II) knee flexion, 10 repetitions.

Bed side sitting: dynamic activation of quadriceps, 10 repetitions.

Walking with aid of walker weight bearing as per tolerance.

## Results

The results were analysed using SPSS version 18. Within group analysis for VAS was done using Wilcoxon signed rank test and between for the same was done using Mann Whitney U test. While within group comparison for knee ROM and extension lag was done using paired *t* test and between group analyses was done using unpaired *t* test. The significance level was set at $P \leq 0.05$.

As there was no baseline matching for extensor lag, no statistical test was performed. Hence, the percent change was calculated, which was 71% in the exp group and that in control group, was only 67%.

## Discussion

This study was done to find out the additional effect of NMES on extensor lag, knee ROM and pain in TKA patients. There was significant improvement in both the groups with respect to extensor lag, knee ROM and pain $P \leq 0.05$ (*Tables 1,2*). It was seen that pain and knee flexion range improved in both the groups but there was no significant difference between the groups $P > 0.05$ (*Table 3*). Individually in the groups, the pain and knee flexion range did improve from the baseline values i.e., the exercises and NMES did have an effect on pain and knee flexion range. The improvement in pain and ROM can be attributed to the improved quadriceps muscle strength and thereby improving the stability of the knee joint (23).

Furthermore, a study done by Lim *et al.* 2008 (24) reported that quadriceps strengthening has a positive effect on pain and function in patients with OA knee. There is also another study done by Amin *et al.* 2009 (25) which stated that subjects having better quadriceps strength had less knee pain and enhanced physical function as compared to those with the lower strength. Strong muscles help in stabilizing the joints in a proper alignment, reduce shocks that are transmitted to the joints and also help in reducing the effect of impact by spreading the forces to a larger area so it may be said that improving muscle strength would help in reducing pain and disability.

The extension lag also improved from baseline to day 9 in both the groups, the percent change in experimental group was 71% as compare to control which was only 67%. Hence it could be attributed to NMES which helps in activating a larger portion of type II muscle fibers than through volitional exercise at comparable intensities (26,27).

Besides, afferent input from NMES may help in facilitating plastic changes throughout sensorimotor networks in the central nervous system, ultimately improving strength and motor control (28). These neural changes have been specifically sought for patients following neurologic injury. For example, in patients following stroke, a 77% improvement in quadriceps force and nearly 20%

 

**Table 1** Mean and SD of the outcome measures in experimental group

| Outcome measures | Pre intervention, mean ± SD | Post intervention, mean ± SD | P value |
|---|---|---|---|
| Pain (VAS) | 6.79±1.23 | 3.68±0.90 | 0.00* |
| Knee flexion ROM (degree) | 39.75±23.79 | 82.43±13.05 | 0.00* |
| Extensor lag (degree) | 14.04±8.25 | 4.04±4.51 | 0.00* |

*, P≤0.05 is statistically significant. VAS, visual analogue scale; ROM, range of motion.

**Table 2** Mean and SD of the outcome measures in control group

| Outcome measures | Pre intervention, mean ± SD | Post intervention, mean ± SD | P value |
|---|---|---|---|
| Pain (VAS) | 6.29±1.36 | 3.79±1.03 | 0.00* |
| Knee flexion ROM (degree) | 44.96±22.84 | 83.43±13.15 | 0.00* |
| Extensor lag (degree) | 8.54±3.34 | 2.75±2.74 | 0.00* |

*, P≤0.05 is statistically significant. VAS, visual analogue scale; ROM, range of motion.

**Table 3** P values between groups

| Outcome measures | Pre intervention P value | Post intervention P value |
|---|---|---|
| Pain (VAS) | 0.10 | 0.79 |
| Knee flexion ROM (degree) | 0.40 | 0.77 |
| Extensor lag (degree) | 0.00* | – |

*, P≤0.05 is statistically significant. VAS, visual analogue scale; ROM, range of motion.

improvement in motor unit recruitment were achieved through NMES treatment, compared to minimal changes in a group of patients not receiving NMES (29).

The knee extensor lag in the experimental group reduced by 10º while in control group the reduction was only by 5.79º. Our study results are in agreement with Gotlin *et al.*, 1994 (30) where they reported that when NMES applied within the first week after TKA reduced the knee extensor lag by 2 degrees compared with controls, who had an increase in extensor lag by 3 degrees in the same time frame.

Even though it has been difficult to establish the underlying muscular and neural mechanisms responsible for improved muscle performance with NMES, some theories have been postulated. The first is related to the intensity of the muscle contraction produced during stimulation. It has been recommended that, individuals with negligible muscle recruitment require at least 50% to 60% of maximal voluntary effort to over-burden the muscle adequately to promote hypertrophy, because higher the power more prominent is the hypertrophy (31,32). Similar to high-intensity voluntary muscle contractions, electrically induced muscle contractions at high intensities produce muscle hypertrophy and in turn help in increasing the strength (33,34). Electrically induced muscle contractions help in activation of a greater amount of type II muscle fibers than volitional exercise at the same intensity (35,36). As type II muscle fibers are larger than type I fibers, there is greater activation of these fibers which help in increasing the force production (37). There are evidences suggesting, that NMES affects functional motor performance measures via peripheral afferent inputs that change the excitability of the motor cortex (28,38). Stimulation of these peripheral afferent nerves can cause extended changes in the excitability of the human motor cortex, which can help explain improvements in muscle function with NMES (39,40).

However, there was no significant difference between the groups; our results are in agreement with other studies where they found similar outcomes. A systematic review done by Volpato *et al.*, 2016 (41) found studies where pain and ROM did not have a statistically significant difference between the groups, Stevens-Lapsley *et al.* 2012 (42) and Petterson *et al.* 2009 (17) reported no statistically significant difference between NMES and exercise groups (P>0.01). In a study done by Mizusaki Imoto *et al.* 2013 (43), where they found that there was no significant difference between NMES+ ex and exercise group alone with respect to pain and knee flexion ROM. Hence, in the present study, the training intensities and the time period where NMES was given were lower than those expected to produce muscle hypertrophy. Therefore, we can conclude that, altered motor unit recruitment may explain some of the improvements in muscle function.

As there was no baseline matching for extensor lag, the results of this study are inconclusive of whether NMES has an additional effect on extensor lag, pain and knee ROM after TKA. Hence it would be appropriate to do the study on a larger sample which will give us more definitive results.

## Conclusions

The present study was done to understand the additional effect of NMES along with exercises on extensor lag, knee flexion ROM and pain after TKA. There was a significant improvement with NMES and exercises with respect to extensor lag, knee ROM and pain, but when compared between the groups, both the groups performed equally well. Hence our results concluded that there was no additional effect of NMES on extensor lag, knee ROM and pain when applied for 7 days in patients operated with TKA.

## Acknowledgments

None.

## Footnote

*Conflicts of Interest*: The authors have no conflicts of interest to declare.

*Ethical Statement*: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was approved from the Institutional Review Board (IRB-SIOR/Agenda043/09). The study was explained to all the patients and a written informed consent was taken from all the patients.

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**Cite this article as:** Dabadghav R, Potdar A, Patil V, Sancheti P, Shyam A. Additional effect of neu-romuscular electrical stimulation on knee extension lag, pain and knee range of motion in immediate postsurgical phase (0–2 weeks) in primary total knee ar-throplasty patient. Ann Transl Med 2019;7(Suppl 7):S253. doi: 10.21037/atm.2019.09.79

 