EVALUATING THE EFFICACY OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION IN ALLEVIATING POSTOPERATIVE INCISIONAL PAIN CAUSED BY SPECIFIC SURGICAL INCISIONS FOLLOWING ABDOMINAL SURGERY: A COMPARATIVE STUDY

Authors: Dr.N.Junior Sundresh[1], Dr.S.Arul pragassame[2], Thiruppathi.Arjunan[3], Dr.R.Biju[4], E.Mastanaiah5

[1]Professor of Surgery, Government Medical College & Hospital, Cuddalore District, Tamil Nadu, India.
[2]Assistant Professor in Physiotherapy MPT, Ph.D., Department of Physical Medicine & Rehabilitation, Government Medical College & Hospital, Cuddalore District, Tamil Nadu, India.
[3]Research scholar, Department of Physiotherapy, Narayana Medical College & Hospital, Chinthareddypalem, Nellore, SPSR Nellore District, Andhra Pradesh, India.
[4]Professor and Head of the Department, Department of Orthopaedics, Narayana Medical College & Hospital, Chinthareddypalem, Nellore, SPSR Nellore District, Andhra Pradesh, India
[5]Assistant Professor, Department of Physiotherapy, Narayana Medical College & Hospital, Chinthareddypalem, Nellore, SPSR Nellore District, Andhra Pradesh, India

ABSTRACT:
Background: Abdominal surgery incision site pain reduces lung function and increases pain. Abdominal surgery-induced respiratory muscle dysfunction increases postoperative difficulties, morbidity, and hospital stay. After surgery, the impact of pain on pulmonary function and the effectiveness of physical therapy using various types of TENS, such as low and high TENS, are still unclear. This study examined the efficacy of several types of Transcutaneous Electrical Nerve Stimulation (TENS) for abdominal surgery postoperative pain.
Methodology: This comparative study randomly assigned 114 abdominal surgery patients allotted three groups (32 per group) to receive low TENS, high TENS, or control for 30 minutes a day from the 8th post-operative day to the end of the 4th week from the population group satisfying the inclusion criteria from the Department of Surgery and Department of Physical Medicine &Rehabilitation, Government Medical College & Hospital, Annamalai Nagar, Chidambaram, Cuddalore D. The study included randomly selected male and female adults aged 21-50 with abdominal surgery and post-abdominal incisional pain, NPRS pain score above 4, and TENS treatments. Group A and B received standard physiotherapy care, while Group C received standard medical and nursing care. In the 8th and 4th weeks after surgery, NPRS, FEV1, and FVC are measured.
Results: A total of 96 participants were recruited for this study, with an average age of 36.7 years and a standard deviation of 7.9. Out of the total, there were 52 males and 44 females. There was a statistically significant difference in pain scores between the groups during the study ($P < 0.001$). The TENS groups experienced notable decreases in postoperative pain in comparison to the control group ($P<0.001$). The TENS groups showed a notable enhancement in pulmonary functions, namely in FVC and FEV1. However, there was no significant change observed in the control groups ($P>0.001$). When comparing Low TENS to both High TENS and the Control group in terms of pain relief, there was a significant and more rapid improvement in reducing pain ($P< 0.001$). None of the subjects reported any negative effects for the entire duration of the study.
Conclusion: The current Comparative investigation found that all groups reduced post-abdominal incision pain and pulmonary impairment. High TENS reduced abdominal surgical incision pain faster than low TENS and control. TENS helps abdominal surgery patients reduce postoperative discomfort and improve FEV1 and FVC
Keywords: Abdominal Surgery, Incisional Pain, Numeric Pain Rating Scale (NPRS), Low TENS, High TENS, Pulmonary Function Test.

INTRODUCTION

Approximately 300 million persons worldwide undergo surgery on an annual basis. Acute postoperative pain is a common occurrence after surgery and can be effectively controlled. However, even minor procedures might raise the chances of experiencing persistent incisional pain after surgery[1]. An important clinical issue that impedes postoperative rehabilitation and quality of life is the occurrence of chronic pain after surgical procedures. Given that 22% of patients attending a chronic pain clinic attribute their pain to surgery, it can be concluded that surgery significantly contributes to chronic pain[2]. Persistent postoperative pain is defined as pain that continues beyond the expected three-month healing period following surgery. This pain can be localized to the surgical incision or referred to another area, such as along a nerve distribution or dermatome[3].

Upper abdominal surgery significantly increases respiratory muscle dysfunction. Even after laparoscopy, laparotomy reduces most excessive static inspiratory and expiratory pressures. However, the operation may require several days of recovery. Many reasons may cause respiratory muscle dysfunction. Diaphragm inflammation, irritation, and damage can cause local mechanical failure, reflex impediment, and pain. The significance of pain in respiratory muscle dysfunction after upper abdomen surgery is unclear[4,5,6,7]. Pulmonary dysfunction can be induced by pain that limits deep breathing and expectoration, negative patient posture, abdominal distension, and tight bandages. Breathing problems from inadequate respiratory excursions induce pulmonary dysfunction[8].

Transcutaneous electrical nerve stimulation (TENS) is a technique that involves the application of regulated low-voltage electrical stimulation to the nerves in order to alleviate pain. Electrodes are positioned on the skin to facilitate the conduction of electricity. TENS, or Transcutaneous Electrical Nerve Stimulation, is a pain treatment technique that is non-invasive, portable, compact, user-friendly, and safe[9]. TENS is utilized as an adjunctive pain treatment method alongside traditional analgesics throughout the postoperative phase, rather than being employed as a standalone method. TENS may offer benefits in managing postoperative pain by promoting quicker movement and reducing hospital stay duration[10]. Prior research has also provided evidence for the mechanism of inhibition that is mediated by segments. Thus, it seems that TENS stimulates both descending and segmental inhibition[11]. The analgesic effect of TENS is also achieved through the pain gate control theory, which involves reducing the nociceptive stimulation of large diameter afferent fibers in the dorsal horn[12]. Conventional Transcutaneous Electrical Nerve Stimulation (TENS) stimulates the A-α and A-β nerve fibers, hence reducing pain. TENS also stimulates the body's natural opioid system. The activation is induced by both high and low frequency stimulations[13].

Postoperative pain is frequently intense and concentrated in the area of the incision, but it can also radiate due to soft tissue damage caused by the surgical procedure. Both the location and intensity of the electrical stimulation have been found to influence the efficiency of Transcutaneous Electrical Nerve Stimulation (TENS) in lowering the requirement for opioid analgesics. Nevertheless, there are debates surrounding the most effective frequency of electrical stimulation while using TENS.

Insufficient data exists regarding the efficacy of different TENS methods in reducing post-incisional pain following abdominal surgery. This pain is often accompanied by postoperative pulmonary dysfunction, resulting from restricted lung expansion caused by the incision. This study examines the effectiveness of several TENS techniques in controlling postoperative incisional pain.

The objective of this study is to assess the impact of various forms of Transcutaneous Electrical Nerve Stimulation on the management of pain resulting from surgical incisions in individuals who have undergone abdominal surgery. A secondary objective is to assess the impact of moderate and high TENS levels on post-incision pain after abdominal surgery. In addition, evaluates the impact of pulmonary dysfunction on the efficacy of low-dose and high-dose Transcutaneous Electrical Nerve Stimulation (TENS) in treating of post-incision pain after abdominal surgery.

METHODOLOGY

Study design: Parallel Comparative study design was utilised in this study.

Study period This Study was conducted from June 2023 to December 2023.

Study area Department of Surgery and Department of Physical Medicine &Rehabilitation, Government Medical College & Hospital, Cuddalore District, Tamil Nadu, India

Study Population Study population was composed of Male and Female who were above 21to 50 Years of age in randomly selected from postoperative surgery ward from Government Medical College & Hospital, Cuddalore District, Tamil Nadu, India.

Sample size calculation Sample size is calculated according to Approximation using the Z statistic instead of the T statistic: Z_α = Standard normal deviation for $\alpha = 1.9600$. Z_β = Standard normal deviation for $\beta = 0.8416$.B $= (Z_\alpha + Z_\beta)^2 = 7.8489$. C $= (E/S_\Delta)^2 = 0.2500$.N = B/C = 31. 3955.The N thus calculated is rounded up to the next highest integer to give the group size. Group size N: 32[14,15].

Inclusion and exclusion criteria

Participants of both genders who expressed voluntary consent to undergo abdominal surgery were taken into consideration. Participants between the ages of 21 and 50 who were experiencing post-operative distress at the median and paramedian abdominal incisions comprised the sample at the time of the study. Those who reported pain levels above 4 on the eighth day following the procedure were included in the analysis. Individuals afflicted with chronic, unforeseeable illnesses. The absence of any abnormal cutaneous sensation and the absence of a history of mental or psychological disorder constituted exclusion criteria.

Sample Randomization

To ensure that each of the three groups had an equal number of participants, those individuals who had abdominal surgery were randomly assigned to one of the three groups using a single randomization approach. This was done following a fixed allocation procedure that utilized a computer-generated randomization sequence. A therapist who was not a participant in the clinical investigation was the one who carried out the randomization. Eighteen persons, both male and female, were not included in the survey out of a total of 114 respondents. In the end, 96 volunteers from the community were selected to take part in this research project. The overall attrition rate in this trial was eighteen percent.

MATERIALS USED

a) Transcutaneous Electrical Nerve Stimulation (ACUTENS 1000)[16]
b) Self-adhesive electrodes
c) Data collection sheets

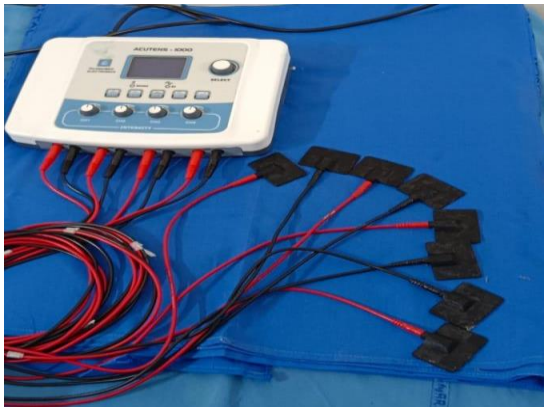


Figure1. ACUTENS1000

Sample Allocation Procedure:

For this study, 96 individuals who were enrolled in the Department of Surgery were enlisted. Pre-assessment was conducted on all subjects in the beginning. Data collection regarding general and medical history, as well as pain intensity as measured by the Numeric Pain Rating Scale (NPRS), constituted the primary aim. The patient was provided with an explanation of the objectives and was informed about the treatment. The participants were informed that the treatment would not interfere with their ongoing medical interventions. The subsequent are three distinct treatment groups:

In group A: Low TENS 32 participants were administered standard medical and nursing care, along with low frequency/high intensity transcutaneous electrical nerve stimulation (TENS)[17] at

a frequency of 4 Hz. The TENS treatment had a long pulse duration of 200µs, and the current was set between 15-50mA. This treatment was given three times a week for three weeks to manage post-abdominal incisional pain, specifically in cases of median or paramedian incisions.

Group.B:High.TENS

A total of 32 participants in group B received standard medical and nursing care, as well as low intensity electrical stimulation with a high frequency over 100Hz, short pulse duration of 50-80µs, and a current set between 10-30mA. The care of post-abdominal incisional (Median or Paramedian) pain is provided for three weeks, with three days allocated each week.

Participants in Group A & B received standard post-operative physiotherapy i.e. Breathing exercises, ergonomic advice and postural care during everyday activities.

Group C: Control group

In group C, a total of 32 participants received standard medical and nursing treatment without the use of Transcutaneous Electrical Nerve Stimulation (TENS) intervention.

Method of TENS Application[18]

With the surgeon's approval, individuals experiencing pain from their post-operative incision were chosen after the seventh postoperative day. The designated area was cleansed with soap and subsequently dried completely. Two self-adhesive electrodes (first unit channel) were positioned on one side of the incision, while two more electrodes (second unit channel) were inserted on the other side. The electrodes were placed at a distance of 2 cm from the suture line (Figure 2). The administration of Transcutaneous Electrical Nerve Stimulation (TENS) was performed using the ACUTENS1000 model. This TENS device is powered by batteries. The application of TENS did not consider the specific type of incision. The intensity of the amplitude was individually adjusted to generate a discernible tingling sensation, taking into account the subject's tolerance. The treatment was administered for 20 minutes using four electrodes positioned around the surgical incision. This was done once a week for a total of three days over two weeks. Pain was evaluated using a Numeric Pain Rating scale score before the administration of TENS on the 8th day following surgery, and thereafter after the application of TENS three times a week for 3 weeks.

Figure 2 TENS Electrode Placements

Data collection tool

The data collection tools comprised 2 domains: The very first domain was created to collect basic information such as Name, Age, and Gender, as well as demographic data related to the type of incision. The second domain, known as the Numeric Pain Rating Scale (NPRS), is a technique utilized to quantify a characteristic or attitude that is regarded to encompass a wide range of values and is challenging to measure directly. The degree of pain perceived by a patient varies throughout a continuum, spanning from a complete absence of discomfort to an extremely high level of pain. From the patient's perspective, this spectrum appears to be continuous, indicating that their pain does not have clear jumps as suggested by the categories of none, mild, moderate, and severe. The Numerical Pain Rating Scale (NPRS)[19] is commonly depicted as a horizontal line that is 11numerical in length (Fig.1). The scale is labeled with word descriptors at both ends, such as "minimal pain" on the left end and "severe Pain" on the right end. The patient marks the line that they believe correctly represents their subjective perception of their current condition. Participants who volunteered to take part in the study and who were experiencing moderate pain (defined as an intensity of four or above on the numerical Pain Rating Scale (NPRS) are included in Table1.[20]

Table 1. Grades of Numeric Pain Rating Scale

Pain	Rating
Minimal Pain	0-4
Moderate Pain	4-7
Severe Pain	7-10

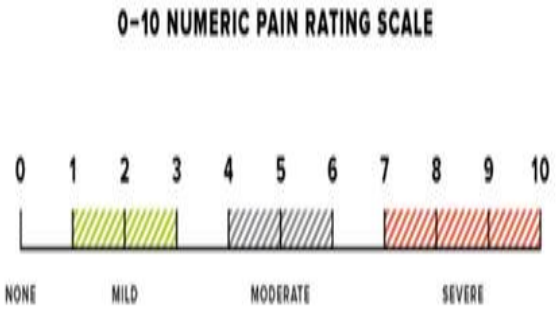


Figure 3 Numeric Pain Rating Scale

Procedure for PFT

Prior to therapy (TENS), 8th postoperative day, and end of fourth week postoperative pulmonary function assessments were taken. The Incentive spirometry apparatus (Figure. 2) was calibrated every morning before measuring. We sat erect with feet flat on the floor, wearing loose, tight clothes and a nose clip. Spirometry followed American Respiratory Society guidelines. Before forced expiration, normal breaths were taken, then a deep breath in through the mouthpiece, followed by a rapid, full inspiration. The patient was then instructed to empty their lungs, take a deep inhale, and blow out as hard and quickly as possible until there was no air left. The best of three technically sound movements was kept. Forced FVC and FEV1 were measured[21].

Figure 4 a Incentive Spirometry

Figure 4b Incentive Spirometry Technique

In comparison to the pulmonary function laboratory tests that are considered to be the gold standard, the measurements that were taken using portable spirometry have demonstrated a high level of reliability and validity[22].

Method of data collection

Once the Institutional Ethical Committee granted clearance, permission was acquired from the relevant authority. A preliminary assessment was conducted on the 8th day after the operation, which involved recording the patient's self-reported feeling of pain using the NPRS scale. The final assessment was conducted during the fourth week of the therapy regimen. Each session lasted for 30 minutes. The data collection was expected to take place between 10 am and 4 pm on weekdays.

Data Analysis

An analysis of the research data was performed utilizing SPSS Version 25.0[23]. In presenting the data, which were either continuous or categorical, both mean values and percentages were utilized. A comparison was made between groups based on the NPRS (Numeric Pain Rating Scale) scores of the participants before and after the treatment regimen. Applied descriptive statistics to the demographic information of every participant. A P-value of 0.05 represents a level of statistical significance.

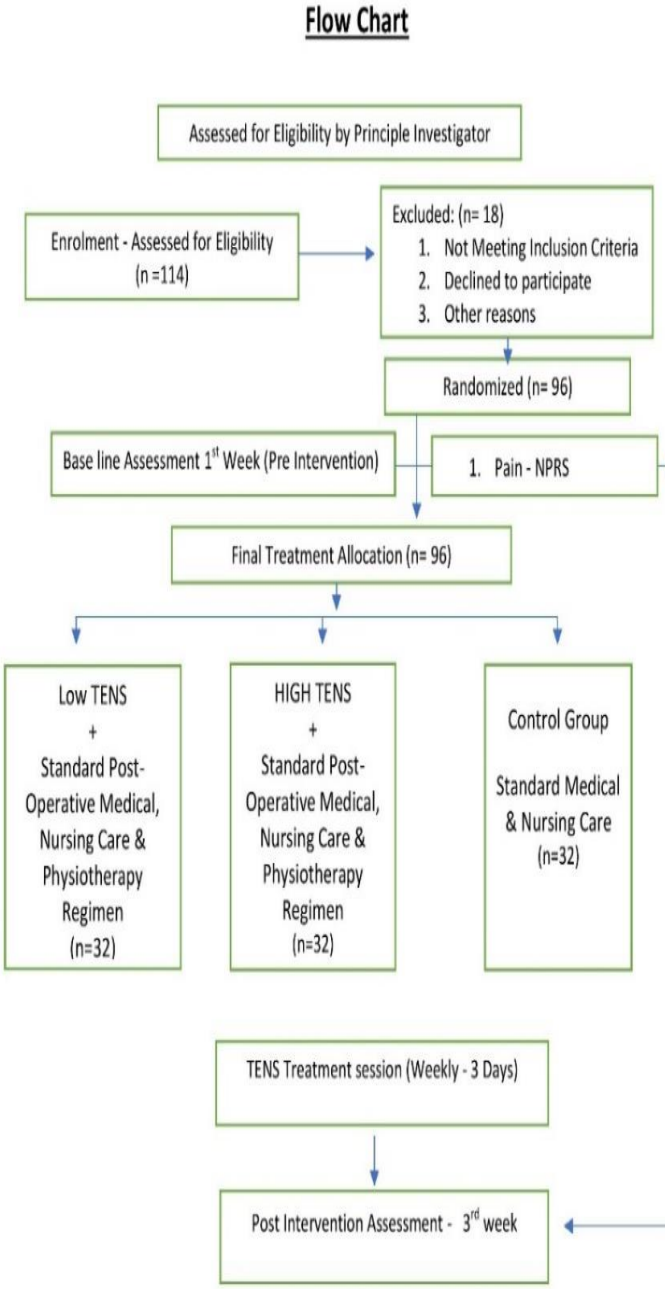
RESULTS

Participant's flow diagram

This study recruited and evaluated 114 individuals to determine their eligibility, with 18 participants being eliminated from the study. Out of the 9 potential volunteers, none of them met the

requirements to participate. 5 of them chose not to participate, while the remaining 4 had other reasons for not being able to join. Ultimately, a total of 96 individuals were assigned at random to three distinct groups, namely Group A, Group B, and Group C. Each group was assigned an equal number of 32 participants. Treatment was administered to all three groups according to their respective assignments, and a total of 96 participants were included in the analysis. The procedure is represented by a flow chart.

Table 2 Demographic Details



The provided demographic information indicates that the average age was 36.7 years with a standard deviation of 7.9. The mean age of males is 31.26 with a standard deviation of 5.66, while the mean age of females is 43.27 with a standard deviation of 4.48. The

Variables	Group - A (Low TENS)		Group - B (High TENS)		Group - C (Control)	
	n=32	%	n=32	%	n=32	%
Age						
21-30	5	15.62	8	25	7	21.8
31-40	16	50	11	34.3	12	37.5
41-50	11	34.3	13	40.6	13	40.6
Sex						
Male	19	59.3	18	56.2	15	46.8
Female	13	40.6	14	43.7	17	53.1
Incision Type						
Midline	24	75	19	59.3	20	62.5
Para-Median	8	25	13	40.6	12	37.5
Pain Level						
Minimal Pain	***	***	***	***	***	***
Moderate Pain	21	65.6	22	68.7	20	62.5
Severe Pain	11	34.3	10	31.2	12	37.5

male participants constituted the majority (54.16%), while females accounted for 45.83%. Out of all the participants, 40.62% belonged to the age group of 31-40. In this study, a total of 65.62% of the subjects underwent midline surgical incisions. Furthermore, a significant proportion of the contributors, specifically 34.3%, reported a Numeric Pain Rating score indicating the presence of severe pain.

Table 3 Mean Age Distribution

Variables	Group - A	Group - B	Group - C
Age			
Mean±SD	35.83 ± 7.35	36.53 ± 8.41	36.65 ± 8.24
Male	n = 19	n = 18	n = 15
Female	n = 13	n = 14	n = 17
t-Statistic	27.53	24.53	25.12
95% CI for Mean	33.1 to 38.4	33.49 to 39.56	33.67 to 39.62
Significance level	P<0.0001	P<0.0001	P<0.0001

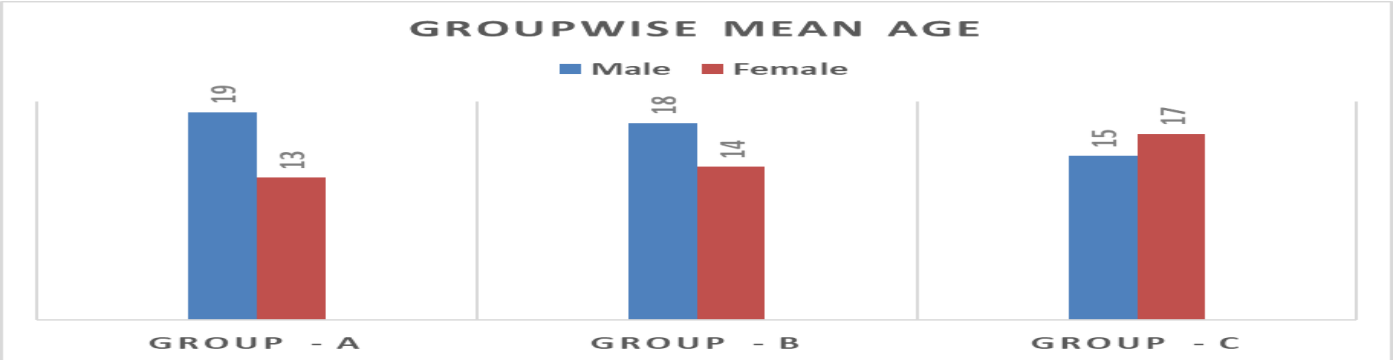


Figure 5 GroupWise Mean

Table 4 Comparative Results of Pain Assessment on Numeric Pain Rating Scale (NPRS)

Variables	Group - A		Group - B		Group - C	
Age	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test

Mean	6.90	2.62	6.68	2.34	6.87	5.68
S. D	1.02	0.90	1.09	0.78	1.07	0.69
95% CI	-4.76 to -3.79		-4.81 to -3.86		-1.63 to -0.74	
t-Statistic	-17.79		-18.31		-5.28	
Significance level	P<0.0001		P<0.0001		P<0.0001	

Comparative evaluations of Groups A, B, and C using the Numeric Pain Rating Scale were revealed by the results. In this set of comparisons, Group C, the responders from the control group, exhibited the least amount of difference.

Variables	**Group - A**		**Group - B**		**Group - C**	
Age	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Mean	6.90	2.62	6.68	2.34	6.87	5.68
S. D	1.02	0.90	1.09	0.78	1.07	0.69
95% CI	-4.76 to -3.79		-4.81 to -3.86		-1.63 to -0.74	
t-Statistic	-17.79		-18.31		-5.28	
Significance level	P<0.0001		P<0.0001		P<0.0001	

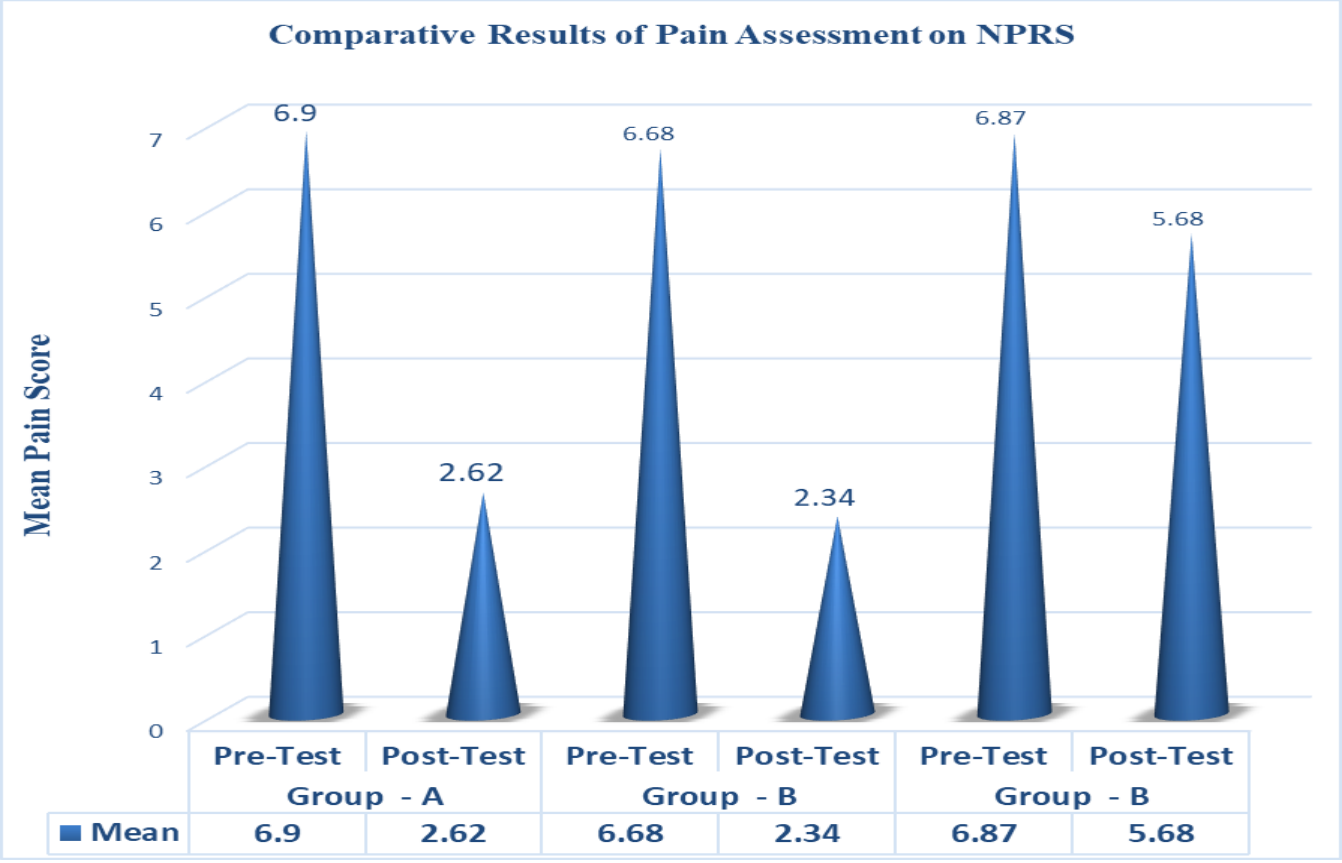


Figure 6 Comparative Results of Pain Assessment on NPRS

Table 5 Comparison of NPRS Scores between the groups prior to the Intervention

Variables	Group - A	Group - B	Group - C	H Statistic	p-Value
Age	Pre-Test	Pre-Test	Pre-Test	0.7196	0.6978 <0.05 Not Significant
Mean	6.90	6.68	6.87		
S. D	1.02	1.09	1.07		
Max	8	8	8		
Min	5	5	5		

A comparison of the Pre-NPRS-score (before to intervention) between the three groups was conducted using the Kruskal-Wallis test. The results showed that the scores were not significantly different H-Statistic H= 0.7196, (P=0.6978) and that the significance level was less than 0.05, indicating that all three groups were comparable.

Table 6 Comparison of NPRS Scores between the groups post-intervention

Variables	Group - A	Group - B	Group - C	p-Value
Age	Post-Test	Post-Test	Post-Test	63.166 <0.00001 Very Significant
Mean	2.62	2.34	5.68	
S. D	0.90	0.78	0.69	
Max	4	3	7	
Min	1	1	5	

The Kruskal-Wallis's test was used to compare the Post NPRS-score (Post intervention) among the three groups. The test yielded a P value of 63.166, indicating a highly significant result with a p-value of less than 0.0001. The data in the table shows a statistically significant effect after the intervention.

Table 7 Dunn's Multiple Comparison Test

	p-Value	Significance
Group - A (Low TENS) Versus Group - B (High TENS)	<0.05	.86671 Not Significant
Group - A (Low TENS) Versus Group - C (Control Group)	<0.05	40.934 Significant
Group - B (High TENS) Versus Group - C (Control Group)	<0.05	44.892 Significant

In addition, Dunn's Multiple Comparison test was carried out in order to determine which group had the most significant amount of improvement following the intervention. When compared to the control group, it is evident that any sort of Transcutaneous Electrical Nerve Stimulation (TENS) was effective (P value <0.05).

Table 8 Comparison of Difference of Pre-Post NPRS scores between the Interventional Group-A and Group-B

	Group - A	Group - B	Z-Score	p-Value
Difference of Mean (Pre-Post)	4.28	4.34	0.1611	.8728 P<0.5 Not significant

The Mann-Whitney test was used to assess the efficacy of Low TENS (Group A) versus High TENS (Group B) based on the data in the table. The study demonstrated that High TENS and Low TENS were equally helpful in reducing postoperative incisional pain. Both interventional groups (A and B) were effective in lowering postoperative incision pain compared to the control group (C). Within the interventional groups, High TENS and Low TENS were equally helpful in reducing postoperative incision pain.

Table 4 Comparative Results of Pulmonary Function Test on FEV1, FVC and FEV1/FVC Ratio

Variables	**Group - A**		**Group - B**		**Group - B**	
PFT	8th Day	4th Week	8th Day	4th Week	8th Day	4th Week
FEV1(L)	1.39±0.40	2.9±0.91	1.92±0.82	2.8±0.59	1.05±0.11	1.9±0.11
FVC (L)	1.95±0.56	2.54±0.34	1.47±0.44	2.54±0.34	1.09±0.14	1.21±0.42
FEV1/FVC %	71.73±6.70	81.71±7.01	70.11±8.90	93.20±6.14	55.13±2.10	59.11±2.36
p-value	<0.0001		<0.0001**		<0.4212	

An independent t-test was utilized in order to make comparisons between each group of respondents. In contrast to the control group, repeated measure analysis of forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) was utilized when the p-value was less than 0.05 at the time of the comparison. An evaluation was performed on the eighth post-operative day and again on the fourth week after the procedure was finished. In this study, groups A and B exhibited highly significant results, as indicated by a p-value of less than 0.0001, when assessed in comparison to the control group.

DISCUSSION

This study set out to compare the efficacy of low- and high-tensor transcutaneous electrical nerve stimulation (TENS) in alleviating pain felt by patients recovering from abdominal surgery. The secondary purpose was to investigate the effects of low and high transcutaneous electrical nerve stimulation (TENS) on pulmonary dysfunction as a means of managing pain specific to the area immediately surrounding an abdominal incision after surgery. The primary result of this study showed that, after 8 and 4 weeks postoperatively, the treatment program included transcutaneous electrical nerve stimulation significantly reduced pain and improved pulmonary function compared to the control group.

The majority of research examined the efficacy of transcutaneous electrical nerve stimulation (TENS) in alleviating pain following thoracic surgery with a posterolateral incision. Nevertheless, the results of these papers may be compromised by some methodological flaws, including the absence of information regarding randomization, the assessment of pain exclusively during periods of rest or cough, technical variability in TENS devices, the failure to compare parameters between evaluations conducted before and after TENS, and the absence of a placebo group. Additionally, protocols for conventional daily physical therapy were not described in the majority of these studies, which may have compromised the reliability of the pulmonary function data reported in some[24-29].

During the first day after surgery, almost all of the participants reported experiencing pain at the site where the surgical incision had been made. Every single patient who participated in this trial continued to take the postoperative pain medication as prescribed. According to the findings of the statistical analysis, the analgesic drug did not affect the majority of the procedures in any of the three groups. Effect size indices, as stated by Cohen, offer a broad approximation of the relative magnitudes of treatment effects. Moreover, he defined effect size indices as follows about a comparison of two means: Small (0.2), medium (0.5), and large (0.8)[30]**.** The utilization of these effect size indices facilitates the comparison of effect size magnitudes across studies that employ distinct outcome measures[31]**.** Due to these factors, we estimated the magnitude of treatment effects for each outcome parameter and interpreted the results using Cohen's thresholds. The effect sizes for pain intensity after the fourth week in Treatment Group A, Treatment Group B, and Control Group C were 4.28, 4.34, and 1.19, respectively. A substantial decrease in pain intensity was indicated by the effect size of 2.6. Furthermore, the control group exhibited a diminished effect magnitude by the fourth week of the treatment regimen. The effect size for the mere conclusion in the high TENS group (0.06) demonstrated a marginally positive shift in comparison to the low TENS group. The effect sizes for FEV1/FVC% after the fourth week were 9.98, 20.09, and 3.98, respectively, in favour of the Low and High TENS groups, in

comparison to the control group, which demonstrated a substantial positive change. After the fourth week, the effect size for FEV1/FVC% in the High TENS group was 10.11, which indicated a substantial increase in improvement compared to the control group and the Low TENS group.

Borges et al[32] evaluated the efficacy of active transcutaneous electrical nerve stimulation (TENS) and placebo TENS in alleviating post-laparotomy pain, which is consistent with our findings. When comparing placebo TENS and the control group to Active TENS for 30 minutes, the researchers observed a significant reduction in pain at the sites of abdominal, subcostal, umbilical, and subcostal incisions. In this study, active transcutaneous electrical nerve stimulation (TENS) demonstrated superior outcomes compared to placebo TENS and a non-interventionist control group.

However, several experiments found no pain relief from TENS. Kurata et al[33] examined post-C-section pain and transcutaneous electrical nerve stimulation (TENS). The clinical trial had three groups: control, active TENS, and placebo (n=180). Post-C-section pain scores were similar between groups, according to the study. Our findings were not supported by this study. Different target demographics may explain this variance. Transcutaneous electrical nerve stimulation (TENS) has not been found to reduce static pain after hysterectomy[34] or abdominal surgery[35]. This may be due to sample size, TENS administration method, and follow-up period. However, differing surgical procedures and other factors affect pain severity perception, and our findings were only consistent with a few past studies. After adding physiotherapeutic interventions, Group A and Group B's pain and lung function decreased significantly. This new information can clarify targeted pain therapies' benefits.

Similar to our research, 26 patients admitted for open abdominal surgery were evaluated by Ozsoy, Ismail, et al 2015[36]. Everything was measured on the third day following the operation. The peak expiratory flow during a cough manoeuvre (cough PEF) while seated was utilized to assess cough strength. The participants assessed the intensity of pain at rest (rest pain) while coughing (cough-evoked pain) while walking (walking-evoked pain), and while fearing dehiscence (fear of damaging the surgical incision) using a verbal rating scale ranging from zero to ten. After open abdominal surgery, movement-evoked pain was associated with cough intensity, as opposed to resting pain. Early postoperatively, the cough strength and outcome of pulmonary functions may be enhanced through the aggressive management of movement-evoked pain and the implementation of effective strategies to reduce patients' anxiety about dehiscence.

In line with our research, Rakel et.al[37] propose that the findings indicate that TENS (Transcutaneous Electrical Nerve Stimulation) decreases the severity of pain experienced while walking and deep breathing and enhances walking ability after surgery when used alongside pharmaceutical analgesia.

All participant groups' outcome indicators improved significantly, possibly due to their treatment method. The pain gate mechanism and endogenous opioid system are the main activation mechanisms. High TENS is thought to act by stimulating large-diameter afferent fibers in the spinal cords substantia gelatinosa, which suppresses input from small-diameter neurons[38,39].

The absence of pain following upper abdominal surgery may mostly reverse inspiratory muscle dysfunction, according to this study. Upper abdominal surgery severely impairs respiratory muscle function[40]. The current analysis confirmed this. Pulmonary dysfunction may be induced by pain when stretching the chest or abdomen or by surgery incisions.

We identified a strong correlation between pain severity and lung function in this investigation. Patient pain intensity following abdominal surgery underestimates the significant decline in pulmonary function. Abdominal surgery decreased pulmonary function. Ali et al[41] also found pulmonary function decreases that recover to 70% of preoperative values after seven days. Diaphragmatic dysfunction may cause breathing changes like no chest or abdominal movements. Asynchronous thoracic-abdominal movements,

Our investigation does not identify how pain causes pulmonary dysfunction. However, pain-induced pulmonary dysfunction may be caused in two ways. In anticipation of discomfort worsening, submaximal voluntary effort respiratory muscle activation may occur. The afferent limb of the reflex system that suppresses respiratory muscles following upper abdominal surgery, tiny afferent nerve fibers, can also cause pain.

We observed a link between the degree of pain and a decline in lung function. This is interesting in light of the findings of Taura et al[42], who discovered that FEV1 was reduced in patients with Visual Analogue Score (VAS) values greater than 5. If pain was a restricting factor in the genesis and production of muscle force in our study, a link between VAS and spirometry values should be expected. Our findings show that a decline in pulmonary function following abdominal surgery may not be solely due to post-operative pain. It has been demonstrated that various mechanisms may contribute to the decrease in pulmonary function following upper stomach surgery, such as diaphragmatic compression restraint (Simonneau et al 1983; Pansard et al 1993) 142,143 through the hindrance of the phrenic nerve (Reeve et al 1951)[43], diverse operation procedures and incision sites[44], and abs weakness[45].

Additional analgesia could include transcutaneous electrical nerve stimulation, a non-invasive, side-effect-free approach[46]. TENS is a non-pharmacologic pain management aid after abdominal surgery. This study suggests that TENS may help reduce post-operative pain and improve lung function in abdominal surgery patients.

Additionally, TENS enhanced FVC. TENS may improve FVC and chest expansion after abdominal surgery, reducing the risk of pulmonary dysfunctions caused by decreased air intake. Because the intensity of pain correlates with pulmonary function deterioration, pulmonary function tests should be conducted independently of pain intensity to establish clinical pulmonary status. Treatment adherence can affect research study outcomes. In the present investigation, the lead investigator assessed the patient and recorded TENS and PFT compliance 8th and 4th postoperative day intervention.

The present study offers several positives; yet, our research does have certain limitations, which are as follows:

LIMITATIONS:

1. The results may be slightly impacted by the lack of information regarding the optimal timing to begin Transcutaneous Electrical Nerve Stimulation (TENS) treatments for the improvement of incisional pain.
2. No independent pain measurement was conducted on any days other than the 8th and end of the 4th week post-operative days to assess incisional pain in all group participants.
3. There was a lack of clarity regarding whether the results would have varied when applied to various centres in diverse environments with bigger samples due to the limited sample size.

Despite these limitations, this study identified key areas for development in future studies and the physiotherapy landscape

outside the Cuddalore District. We need further research to establish a consensual screening process after abdominal surgery. The current investigation found that physiotherapists did not routinely test preoperatively. According to Boden et al.,[47] preoperative screening and psychological readiness education improve post-operative incision pain results. This study supports this claim by showing that the Government Medical College and Hospital, Cuddalore district, post-surgical ward landscape needs to adapt to benefit from empirical evidence. Current physiotherapy treatment barriers were not the subject of this investigation. Thus, the study did not examine how the identified impediments affected post-operative physiotherapist efficacy. However, the findings suggest a prospective study topic on how some of these barriers affect the efficiency of physiotherapy therapies in post-operative incisional pain care and how physiotherapists treat these cohorts.

CONCLUSION

The present comparative investigation found that all groups successfully reduced pulmonary dysfunction and pain following abdominal incisions. Rapid reduction of post-operative incision pain was shown to be much more pronounced in the high TENS group following abdominal surgery compared to the low TENS and control groups. Therefore, transcutaneous electrical nerve stimulation (TENS) is an effective method for reducing postoperative pain and enhancing pulmonary functions (i.e., forced expiratory volume in one second and forced vital capacity) in patients who have gone through abdominal surgery.

It has been proposed that transcutaneous electrical nerve stimulation (TENS) is a safe and potentially effective treatment for the adjunctive relief of postoperative pain since it does not have the same side effects or consequences as traditional opioids or non-opioid analgesics.

ACKNOWLEDGMENT

In particular, the authors would like to thank postgraduates in the Surgery Department, Government Medical College & Hospital, Cuddalore district, Tamil Nadu, for all of their assistance and cooperation during this project. In addition, the writers would like to express their appreciation to every physiotherapy postgraduate working on the general surgery wards.

Funding: No funding sources

Conflict of interest: None declared.

Ethical approval: The study was approved by the Institutional Ethics Committee, Government Medical College & Hospital, Cuddalore district, Tamil Nadu, INDIA.

REFERENCES:

1. *Weiser TG, Haynes AB, Molina G, Lipsitz SR, Esquivel MM, Uribe-Leitz T, Fu R, Azad T, Chao TE, Berry WR, Gawande AA. Estimate of the global volume of surgery in 2012: an assessment supporting improved health outcomes. Lancet. 2015 Apr 27;385 Suppl 2: S11. doi: 10.1016/S0140-6736(15)60806-6. Epub 2015 Apr 26. PMID: 26313057.*
2. *Crombie IK, Davies HT, Macrae WA. Cut and thrust antecedent surgery and trauma among patients attending a chronic pain clinic. Pain. 1998 May;76(1-2):167-71. PMID: 9696470.*
3. *Schug SA, Lavand'homme P, Barke A, Korwisi B, Rief W, Treede RD; IASP Taskforce for the Classification of Chronic Pain. The IASP classification of chronic pain for ICD-11: chronic postsurgical or posttraumatic pain. Pain. 2019 Jan;160(1):45-52. doi: 10.1097/j.pain.0000000000001413. PMID: 30586070.*
4. *Siafakas N, Stoubou A, Stathopoulou M, Haviaras V, Tzanakis N, Bouros D. Effect of aminophylline on respiratory muscle strength after upper abdominal surgery: a double-blind study. Thorax 1983 48:693–697.*
5. *Simonneau G, Vivien A, Sartene R, Kunstlinger F, Samii K, Noviant Y et al. Diaphragm dysfunction induced by upper abdominal surgery. Role of postoperative pain. Am Rev Respir Dis 1983 128:899–903.*
6. *Mankikian B, Cantineau J, Bertrand M, Kieffer E, Sartene R, Viars P. Improvement of diaphragmatic function by a thoracic extradural block after upper abdominal surgery. Anesthesiology 1988; 68: 379–386.*
7. *Rovina N, Bouros D, Tzanakis N, Velegrakis M, Kandilakis S, Vlasserou F et al. Effects of laparoscopic cholecystectomy on global respiratory muscle strength. Am. J. Respir. Crit. Care Med 1996; 153:458–461.*
8. *Huber JGillaspy M. Encyclopedic dictionary of AIDS-related terminology. New York: Haworth Information Press; 2000.*
9. *Wang B, Tang J, White PF, Naruse R, Sloninsky A, Kariger R, Gold J, Wender RH. Effect of the intensity of transcutaneous acupoint electrical stimulation on the postoperative analgesic requirement. Anesth Analg. 1997 Aug;85(2):406-13. doi: 10.1097/00000539-199708000-00029. PMID: 9249122.*
10. *Lin JG, Lo MW, Wen YR, Hsieh CL, Tsai SK, Sun WZ. The effect of high and low frequency electroacupuncture in pain after lower abdominal surgery. Pain. 2002 Oct;99(3):509-514. doi: 10.1016/S0304-3959(02)00261-0. PMID: 12406527.*
11. *Benedetti F, Amanzio M, Casadio C, Cavallo A, Cianci R, Giobbe R, Mancuso M, Ruffini E, Maggi G. Control of postoperative pain by transcutaneous electrical nerve stimulation after thoracic operations. Ann Thorac Surg. 1997 Mar;63(3):773-6. doi: 10.1016/s0003-4975(96)01249-0. PMID: 9066400.*
12. *Bjordal JM, Johnson MI, Ljunggreen AE. Transcutaneous electrical nerve stimulation (TENS) can reduce postoperative analgesic consumption. A meta-analysis with assessment of optimal treatment parameters for postoperative pain. Eur J Pain. 2003;7(2):181-8. doi: 10.1016/S1090-3801(02)00098-8. PMID: 12600800.*
13. *Sbruzzi G, Silveira SA, Silva DV, Coronel CC, Plentz RD. Transcutaneous electrical nerve stimulation after thoracic surgery: systematic review and meta-analysis of 11 randomized trials. Rev Bras Cir Cardiovasc. 2012 Jan-Mar;27(1):75-87. English, Portuguese. doi: 10.5935/1678-9741.20120012. PMID: 22729304.*
14. *Chow S-C, Shao J, Wang H. Sample size calculations in clinical research. 2nd ed. Boca Raton: Chapman & Hall/CRC; 2008. Section 3.1.1, page 50.*
15. *Rosner B. Fundamentals of Biostatistics. 4th ed. Duxbury Press; 1995. Page 221.*
16. *Johnson MI, Paley CA, Wittkopf PG, Mulvey MR, Jones G. Characterising the Features of 381 Clinical Studies Evaluating Transcutaneous Electrical Nerve Stimulation (TENS) for Pain Relief: A Secondary Analysis of the Meta-TENS Study to Improve Future Research. Medicina (Kaunas). 2022 Jun 14;58(6):803. doi:*

10.3390/medicina58060803. PMID: 35744066; PMCID: PMC9230499.

17. *Parseliunas A, Paskauskas S, Simatoniene V, Kubiliute E, Dainius E, Subocius A, Venclauskas L, Venskutonis D. Transcutaneous Electric Nerve Stimulation Reduces Pathological Sensation of Mesh One Week after Open Inguinal Hernia Surgery: Follow-Up Results from a Randomized, Double Blind and Placebo-Controlled Trial. Medicina (Kaunas). 2022 May 28;58(6):725. doi: 10.3390/medicina58060725. PMID: 35743988; PMCID: PMC9228604.*
18. *Vance CGT, Dailey DL, Chimenti RL, Van Gorp BJ, Crofford LJ, Sluka KA. Using TENS for Pain Control: Update on the State of the Evidence. Medicina (Kaunas). 2022 Sep 22;58(10):1332. doi: 10.3390/medicina58101332. PMID: 36295493; PMCID: PMC9611192.*
19. *Jensen MP, Karoly P, Braver S. The measurement of clinical pain intensity: a comparison of six methods. Pain 1986; 27:117–26.*
20. *Hjermstad MJ, Fayers PM, Haugen DF, Caraceni A, Hanks GW, Loge JH, Fainsinger R, Aass N, Kaasa S; European Palliative Care Research Collaborative (EPCRC). Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. J Pain Symptom Manage. 2011 Jun;41(6):1073-93. doi: 10.1016/j.jpainsymman.2010.08.016. PMID: 21621130.*
21. *Moore V. Spirometry: step by step. Breathe 2012; 8(3):232-240.*
22. *Finkelstein s, Lindgren B, Prasad B, Snyder M, Edin C, Wielinski C, Hertz M. Reliability and validity of spirometry measurements in a paperless home monitoring diary program for lung transplantation. Heart Lung 1993; 22(6):523-533.*
23. *IBM Corp. (2017). IBM SPSS Statistics for Windows. Armonk, NY: IBM Corp. Retrieved from https://hadoop.apache.org*
24. *Fiorelli A, Morgillo F, Milione R, Pace MC, Passavanti MB, Laperuta P et al (2012) Control of post-thoracotomy pain by transcutaneous electrical nerve stimulation: effect on serum cytokine levels, visual analogue scale, pulmonary function and medication. Eur J Cardiothorac Surg. 41(4):861–868; discussion*
25. *Liu YC, Liao WS, Lien IN (1985) Effect of transcutaneous electrical nerve stimulation for post-thoracotomy pain. Taiwan Yi XueHui Za Zhi J Formosan Med Assoc 84(7):801–809*
26. *Warfield CA, Stein JM, Frank HA (1985) The effect of transcutaneous electrical nerve stimulation on pain after thoracotomy. AnnThorac Surg 39(5):462–465*
27. *Erden S, Senol CS (2015) The effect of transcutaneous electrical nerve stimulation on post-thoracotomy pain. Contemp Nurse 51(2–3):163–170*
28. *Solak O, Turna A, Pekcolaklar A, Metin M, Sayar A, Solak O et al (2007) Transcutaneous electric nerve stimulation for the treatment of post-thoracotomy pain: a randomized prospective study. Thoracic Cardiovascular Surg 55(3):182–185*
29. *Chandra A, Banavaliker JN, Das PK, Hasti S (2010) Use of transcutaneous electrical nerve stimulation as an adjunctive to epidural analgesia in the management of acute thoracotomy pain. Indian JAnaesth 54(2):116–120*
30. *Cohen J. Statistical power analysis for the behavioral sciences. Routledge; 2013 May 13.*
31. *Noteboom JT, Allison SC, Cleland JA, Whitman JM. A primer on selected aspects of evidence-based practice to questions of treatment. Part 2: interpreting results, application to clinical practice, and self-evaluation. J Orthop Sports Phys Ther. 2008 Aug;38(8):485-501. doi: 10.2519/jospt.2008.2725. Epub 2008 Aug 1. PMID: 18678961.*
32. *Borges MR, de Oliveira NML, Antonelli IBS, Silva MB, Crema E, Fernandes LFRM. Transcutaneous electrical nerve stimulation is superior than placebo and control for postoperative pain relief. Pain Manag. 2020 Jul;10(4):235-246. doi: 10.2217/pmt-2019-0063. Epub 2020 Jun 22. PMID: 32564661.*
33. *Kurata NB, Ghatnekar RJ, Mercer E, Chin JM, Kaneshiro B, Yamasato KS. Transcutaneous Electrical Nerve Stimulation for Post-Cesarean Birth Pain Control: A Randomized Controlled Trial. Obstet Gynecol. 2022 Aug 1;140(2):174-180. doi: 10.1097/AOG.0000000000004798. Epub 2022 Jul 6. PMID: 35852266.*
34. *Karaman S, Karaman T, Deveci H, Ozsoy AZ, Delibas IB. Effect of transcutaneous electrical nerve stimulation on quality of recovery and pain after abdominal hysterectomy. J Anaesthesiol Clin Pharmacol. 2021 Jan-Mar;37(1):85-89. doi: 10.4103/joacp.JOACP_207_19. Epub 2021 Apr 10. PMID: 34103829; PMCID: PMC8174447.*
35. *Rakel B, Frantz R. Effectiveness of transcutaneous electrical nerve stimulation on postoperative pain with movement. J Pain. 2003 Oct;4(8):455-64. doi: 10.1067/s1526-5900(03)00780-6. PMID: 14622666.*
36. *Özsoy, Ismail & Ozyurek, Seher & Senduran Yıldırım, Meric & Avci, Ersin & Karadibak, Didem. (2015). Movement-evoked pain and fear of dehiscence but not rest pain are related with cough strength after open abdominal surgery. European Respiratory Journal. 46. PA2796. 10.1183/13993003.congress-2015.PA2796.*
37. *Rakel B, Frantz R. Effectiveness of transcutaneous electrical nerve stimulation on postoperative pain with movement. J Pain. 2003 Oct;4(8):455-64. doi: 10.1067/s1526-5900(03)00780-6. PMID: 14622666.*
38. *Melzack R & Wall P.D. Pain mechanisms: A new theory. Science 1965; 150:971–978.*
39. *Wall P.D & Sweet W.H. Temporary abolition of pain in man. Science 1967; 155:108–109.*
40. *Walsh D. Clinical applications and related theory of pain. New York: Churchill Livingstone; 1997*
41. *Ali J, Yaffe C, Serrette C. The effect of transcutaneous electric nerve stimulation on postoperative pain and pulmonary function. Surgery 1981; 89(4):507-12.*
42. *Taura P, Planella V, Balust J, Beltran J, Anglada T, Carrero E, Burgues S. Epidural somatostatin as an analgesic in upper abdominal surgery. Pain 1994; 59:135-140.*
43. *Reeve EB, Nanson EM, Rundle F. Observation on inhibitory reflexes during abdominal surgery. Clinical Science 1951; 10: 65-87.*

44. *Garcia-Valdecasas J, Almenara R, Cabrer C, De-Lacy A, Sust M, Taura P, Fuster J, Grande L, Pera M, Sentis J. Subcostal incision versus midline laparotomy in gallstone surgery: a prospective and randomized trial. British Journal of Surgery 1988; 75: 473-475. 146.*
45. *Sharp JT, Goldberg NB, Druz WS, Danon J. Relative contributions of rib cage and abdomen to breathing in normal subjects. Journal of Applied Physiology 1975; 39: 608-618*
46. *Koumantakis GA, Watson PJ, Oldham JA. Trunk muscle stabilization training plus general exercise versus general exercise only: randomized controlled trial of patients with recurrent low back pain. Physical therapy 2005; 85(3):209-25*
47. *Boden I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, Denehy L. The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. Trials. 2015 Dec 15; 16:573. doi: 10.1186/s13063-015-1090-6. PMID: 26666321; PMCID: PMC4678689.*

****