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Effect Of Inspiratory Muscle Training Combined with Low-Level Light Therapy on Pulmonary Function and Pain on Neck Pain Post Thyroidectomy Scar Wound in Premenopausal Females

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ABSTRACT:

Background: About 80% of patients experience neck pain and stiffness after having an open thyroidectomy, which is one of the most common endocrine surgical procedures. This procedure is typically done as a result of thyroid cancer. Purpose: The goal of the study was to examine the efficacy of a combination of inspiratory muscle training along with low-level light therapy for post-thyroidectomy neck pain among premenopausal women in terms of pulmonary function and pain, as well as wound healing.

Methods: 60 female patients diagnosed to get open surgery of thyroidectomy, their ages between 35 and 45 years, and their Body Mass Index (BMI) ranged between 25 and 29.9

kg/m². They were randomized into three groups. Group (A) consisted of 20 female patients who received only traditional medical treatment daily at first week, then three sessions per week for an additional three weeks, while Group (B) consisted of 20 female patients who received traditional medical treatment and inspiratory muscle training daily at first week, then three sessions per week for an additional three weeks. Group (C) consisted of 20 female patients who received traditional medical treatment, inspiratory muscle training, and low-level light therapy daily for the first week, then three sessions per week, day after day, for an additional three weeks. FVC, FEV1, PEF, and MVV, as well as PImax during the spirometry test, visual analog scale, and photographic wound assessment, were assessed pre- and post-study.

Results: Group A showed non-significant improvement pre our post-treatment in all outcome measurements, but both groups A and B showed significant improvement in all outcome measurements (pulmonary function, pain (VAS score), and wound healing) from pre-treatment to post-treatment measurements (P value < 0.001).

Conclusion: Both inspiratory muscle training alone and inspiratory muscle training combined with low-level light therapy have a beneficial effect on improving pulmonary function, pain (VAS score), and wound healing in favor of the combination of inspiratory muscle training with low-level light therapy.

1. INTRODUCTION

Among the most common endocrine surgeries is an open thyroidectomy. Most of the time, this is done to treat thyroid cancer, and afterward, about 80% of patients have neck pain as well as stiffness [1]. Patients may experience pain due to the scars that form on the exposed region of a thyroidectomy. Mechanical strain on the borders of the wound, infiltration of inflammatory cells, the development of new blood vessels, the proliferation of fibroblasts, and the production of cytokines like transforming growth factor (TGF)-β1 are the key processes that contribute to scar formation. There are now anti-scar techniques that aim to address various causes of scarring. Various methods include lasers and phototherapies, skin tension-bearing modalities, and local injections of botulinum toxin, in addition to topical anti-scar medicines. However, a thorough assessment of the effects of various anti-scar techniques on treating thyroidectomy scars is lacking, and present research is fragmented. [2]. The aesthetic impact of the scar following a thyroidectomy has piqued the curiosity of many thyroid surgeons [3], leading to several efforts to reduce the visibility of these scars. By using video-assisted thyroidectomy, the incision length for the procedure has been reduced from the 10-cm-long Kocher's incision to just 15 mm long [4]. Furthermore, there is no visible scar on the neck after a thyroidectomy performed using endoscopic surgery using a postauricular route or robotic surgery using an intraoral technique [5]. Specific physiotherapy focused on targeted stretching and strengthening of the neck muscles in conjunction with breathing exercises has been developed at Cristo Re Hospital in Rome for improved management in a public health context [6].

A low-level light therapy device that utilizes 830/590 nm light-emitting diodes is used to alleviate pain and speed wound healing without creating heat. What makes this method therapeutically useful are the photochemical mechanisms that increase mRNA synthesis, improve cell proliferation, and alter cell membrane permeability [7]. LED-LLLT is a form of low-level light treatment that uses light-emitting diodes to photoactivate specific cells in the body without generating heat or damaging surrounding tissues. There are a number of processes that take place following photoactivation that allow LED-LLLT to alleviate inflammation and discomfort, improve tissue healing, stimulate the regeneration of various tissues and neurones, and avoid tissue damage [8]. Within the near-infrared spectrum, that LED-LLLT emits at a wavelength of 830 nanometers; wound healing may be accelerated via the regulation of fibroblast proliferation along with attachment and collagen production [9].

Rehabilitation, which might consist of chest physical therapy (CPT), medication treatment, long-term oxygen therapy, and smoking cessation, in addition to surgical treatment, are all components of an exercise program whose intensity is mostly determined by the severity of the condition. The goal of pulmonary rehabilitation programs is to help patients regain their independence and functional status via a combination of physical exercise, education, dietary counselling, and smoking cessation support. The following parameters, including pulmonary function, visual analog scale, and photographic method for wound assessment, were

measured before and after the treatment course. There is no significant effect of the combination of inspiratory muscle training (IMT) in addition to LLLT 830/590 nm light-emitting diode-based devices on pulmonary function, pain, and wound healing in neck pain post-thyroidectomy in premenopausal females [10].
Treatments such as topical medications, tension-bearing devices, local injections, lasers, and low-level light treatment have recently evolved as anti-scar techniques by addressing the underlying causes of scar development. But so far, studies on treatments to help heal scars from thyroid surgeries are still fragmented. Our research was to examine the effects of a combination of IMT and LLLT on pulmonary function, pain, and wound healing, as well as neck pain in premenopausal women after a thyroidectomy.

2. MATERIALS AND METHODS

Design and participants

A randomized controlled trial was performed in the outpatient clinics of the Faculty of Physical Therapy and the inpatient surgery department of Suez Canal University Hospital between February and June 2026 among post-thyroidectomy premenopausal females.

Participants and recruitment:

Sixty premenopausal female patients aged between 35 and 45 years, whose body mass index (BMI) ranged from 25 to 29.9 kg/m², underwent open thyroidectomy and have neck pain and scar wounds, were included in the study.

Sample Size Calculation

According to NPRS data, the necessary sample size for this study was determined to be twenty individuals per group utilizing G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany). This was done to avoid type II errors. A power of 80% along with an effect size of 0.8 was used in the calculation, with $\alpha = 0.05$ [11].

Ethical consideration:

All patients were informed about the research's objective, nature, and any risks involved, and they were requested to sign a written permission form prior to the commencement of the trial. Furthermore, the research was approved by the Ethical Committee of Scientific Research at the Physical Therapy Faculty's Institutional Review Board at Cairo University (No. P.T. REC / 012 / 006429). Any woman clinically diagnosed to get open surgery of thyroidectomy, aged between 35 and 45 years, with a BMI of 25-29.9 kg/m², and also medically stable and under medical control, was included in the study. While any woman was excluded from the study if she had neurological conditions (convulsions, involuntary movement), a BMI (below 25 & above 30 kg/m²), diabetic disease, cardiac diseases, and respiratory diseases.

Randomization Procedure

60 premenopausal female patients diagnosed with open surgery for thyroidectomy were randomized into three groups. **Group (A)** consisted of 20 female patients who received only traditional medical treatment daily for the first week, then three sessions per week for an additional three weeks in the form of continued care for the wound (wash the area gently with saline solution and also apply an antibiotic spray). **Group (B)** consisted of 20 female patients who received traditional medical treatment and inspiratory muscle training, daily for the first week, then three sessions per week for an additional three weeks. **Group (C):** consisted of 20 female patients who received traditional medical treatment, IMT, and LLLT utilizing an 830/590 light-emitting diode (LED)-based device daily for the first week, then three sessions per week, day after day, for an additional three weeks. **(Figure 1).**

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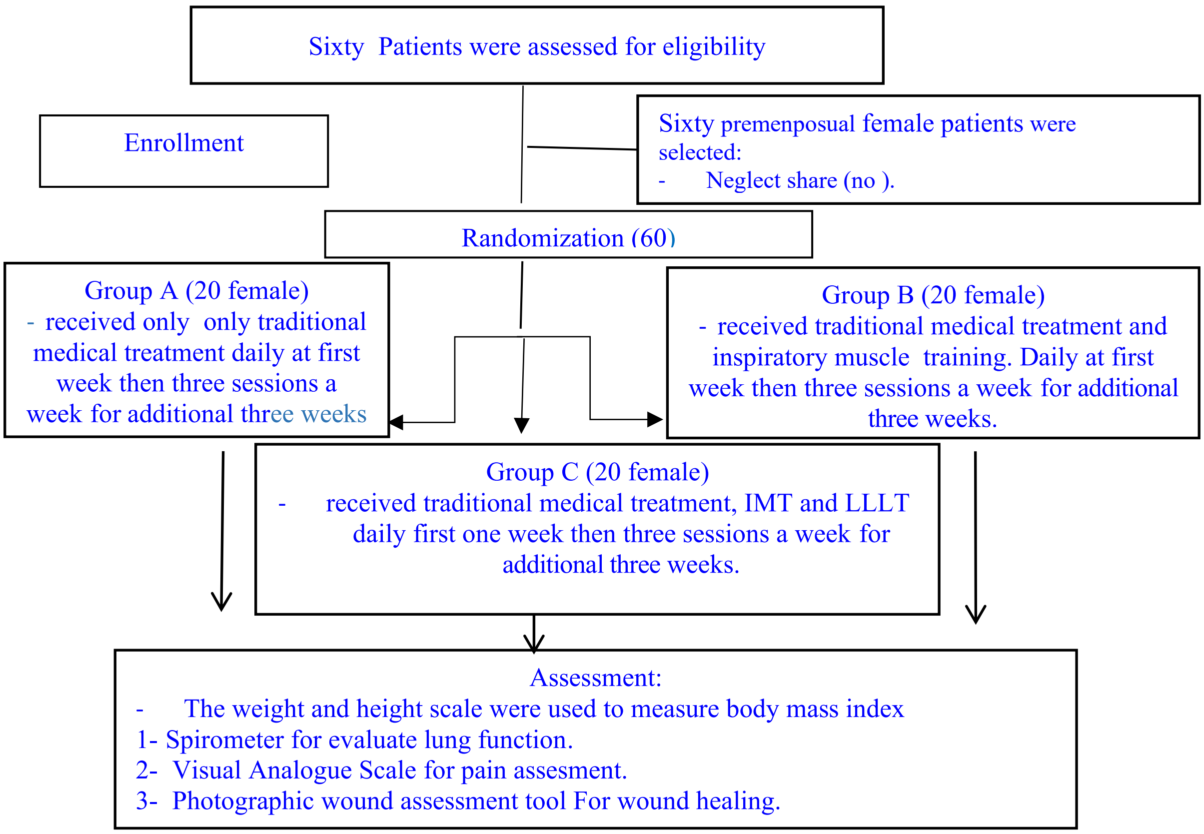

Figure (1): Consort flow chart.

I- <u>Evaluation Instruments</u>:

1. Weight and Height Scale:

Utilized to determine each participant's height and weight in order to evaluate their expected lung function.

2. Spirometer for evaluating lung function:

A spirometer, used by a skilled researcher, measured lung function. The American Thoracic Society (ATS) established standard protocols for all measurements. The participants were given enough time to comprehend the test protocol and provide the necessary flows. Participants were seated and used a nasal clip and disposable mouthpieces to firmly apply their lips during the exam. Each participant was given three opportunities to replicate their flow, and the spirometer automatically chose the best one. Applied on the first day after surgery and again four weeks after finishing the course of therapy. As part of the spirometry procedure, the patient's FVC, FEV1, PEF, MVV, and PI max were measured using a spirometer. Both groups took it before the research began and again at the end of the eight weeks.

- **Spirometry test:**

Preparation of the pulmonary function tests: Before conducting testing of ventilatory function, a physician calibrated the device.

Predicted values shown on the flow screen by the spirometer are based on the subject's data, which includes their name, age, gender, height, and weight in kilograms. Subject preparation: All patients had their weight and height measured prospectively as part of the pre-procedure package. The patient was given each of these instructions clearly before receiving it. Before you start the exam, be sure you know what the various instructions mean, such as "hold your breath," "breathe naturally," "breathe in deeply," and then "expire the air out."

Each patient had a simplified version of the test that they were presented with before the trial began. A nose clip was used to prevent air from leaking out of the nostrils, and after that, a new mouth piece was put into the patient's mouth very securely.

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The patient was instructed to breathe a few times to get used to the device prior to the test, and all measurements were conducted in an upright position according to prescribed standards. Each test was done three times, and the optimal result for each parameter was chosen.

There are a minimum of three manoeuvre [17]. The percentages of the expected normal values were used for determining all of the ventilatory function test results. Forced vital capacity (FVC) and forced expiratory volume in one second (FEVI) are the spirometric measurements that were evaluated. With three tries and measurements recorded every three minutes, it's clear that the third try is superior. All measured variables' predicted values were transformed into percentages. From the FEV1/FVC ratios (derived from FEVI and FVC)

- **Respiratory muscle endurance measurement.**

As part of ventilatory endurance testing, the goal was to find the maximal sustainable ventilation (MSV), which is usually given as a percentage of the maximal voluntary ventilation (MVV)18. To perform the MVV test, you had to take deep, fast breaths for ten to fifteen seconds. When you do this, your breath should be greater than your tidal volume but less than your tidal capacity.

- **Measure respiratory muscle force:**

Mouth: Maximum airway pressures achieved voluntarily. The maximal inspiratory force, often known as MIP, is a non-invasive measure of inspiratory muscle force. Position: All patients were measured while sitting if feasible. A leak should be provided with the equipment in order to avoid pressure from the cheek and buccal muscles. The patients' nostrils were sealed with a nasal clip to keep air from escaping. Mouthpiece: A flanged mouthpiece, similar to the ones often used for assessing lung function. In order to prepare for the MIP measurement, patients must first practice inhaling using a mouthpiece up to residual volume, and then they must perform their maximum inspiratory effort while breathing in through a closed airway. **(Figure 2).**

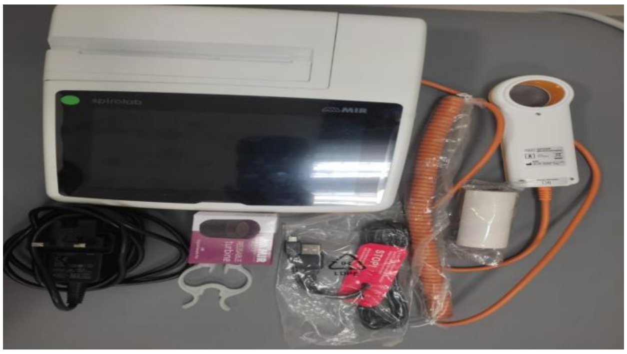

Figure 2. Spirometry

3. Visual Analogue Scale:

It was utilized for measuring the amount of pain, as shown in the part on evaluation methods. A 10-centimeter horizontal line with the values 0 for no pain and 10 for severe pain is shown. The VAS is a reliable tool for measuring pain because it provides both visual and numerical representations of the data. It was applied on the first postoperative day and 4 weeks later after completing the treatment protocol **(Figure 3).**

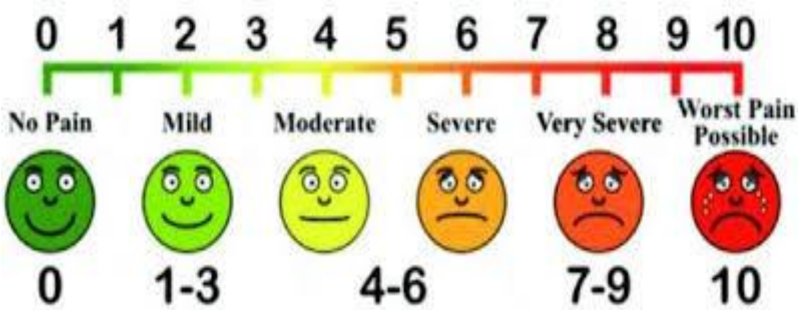

Figure 3: Visual Analog Scale

4. Photographic wound assessment tool for wound healing:

A photographic picture that was part of the study was captured with an Olympus OM-2 camera. Optimal lighting was used to minimize shadows and glare and enhance picture contrast when photographs were shot in a range of healthcare environments. Prior to capturing photographs, a 15-centimeter ruler with readable millimeter divisions, the identification number of the patient, and the assessment date were placed next to the wound. The camera was positioned at a right angle to the wound bed, with varying distances between the wound and the camera for capturing the whole wound, the ruler, the identification number of the patient, the assessment date, and the surrounding skin sample. Photographic images were taken upon obtaining written informed consents. Patients were made aware that their identity would be kept secret throughout. Photographic images were taken on the first postoperative day and 4 weeks later after completing the treatment protocol **(Figure 4).** Frequency: All evaluation instruments were conducted before treatment (day one post-operative) and following four weeks (at the end of treatment).

Photographic Wound Assessment Tool
PWAT – Revised

Item	Assessment			Score
1. Size	0 = wound is closed (skin intact) or nearly closed (<0.3cm^2) 1 = 0.5 – 2.0 cm^2 2 = 2.0 - 10.0 cm^2 3 = 10.0 – 20.0 cm^2 4 > 20.0 cm^2			
2. Depth	0. wound is healed (skin intact) or nearly closed (<0.3cm^2) 1. full thickness 2. unable to judge because majority of wound base is covered by yellow/black eschar 3. full thickness involving underlying tissue layers 4. tendon, joint capsule, bone, visible/ present in wound base			
3. Necrotic Tissue Type	0 – None visible or wound is closed (skin intact) or nearly closed (<0. 3cm^2) 1 = majority of necrotic tissue is thin White/grey or yellow slough 2 = majority of necrotic tissue is thick, adherent white yellow slough or fibrin 3 – majority of necrotic tissue is white/grey devitalized tissue or eschar 4 = majority of necrotic tissue is hard grey to black eschar			
4. Total Amount of Necrotic Tissue	0 = None visible in open wound or wound is closed (skin intact) or nearly closed(0.3cm^2) 1 = < 25% of wound bed covered 2 = 25% to 50% of wound covered 3 = > 50% and < 75% of wound covered 4 = 75% to 100% of wound covered			
5. Granulation Tissue type	0 = Wound is closed (skin intact) or nearly closed (<0.3cm^2) 1 = majority (>50%) of granulation tissue is healthy looking (even bright red appearance) 2 = majority of granulation tissue is unhealthy (eg. pale, dull, dusky, hypergranulation) 3 = majority of granulation tissue is damaged, friable, degrading 4 = there is no granulation tissue present in the base of the open wound (all necrotic)			
6. Total Amount of Granulation Tissue	0 = Wound is closed (skin intact) or nearly closed (<0.3cm^2) 1 =75% to 100% of open wound is covered with granulation tissue 2 = >50% and <75% of open wound is covered with granulation tissue 3 = 25% to 50% of wound bed is covered with granulation tissue 4 = <25% of wound bed is covered with granulation tissue			
7. Edges (directly touching and within 0.5cm of wound edge)	0 = Wound is closed (skin intact) or nearly closed (<0.3cm^2) or edges are indistinct, diffuse, not clearly visible because of re-epithelialization 1 = majority (>50%) of edges are attached with an advancing border of epithelium 2 = majority of edges are attached even with wound base (not advancing) 3 = majority of edges are unattached and/or undermined 4 = majority of edges are rolled, thickened or fibrotic (do not include callus formation)			
8. Periulcer Skin Viability (consider skin visible in photo or within 10 cm of wound edge)	Number of factors affected 0 = None 1 = One only 2 = Two or Three 3 = Four or Five 4 = six or more	- callus - dermatitis - maceration - desiccation or cracking - bright red, erythemic	- edema - excoriation - skin tearing/irritation r/t wound dressing or tape - hypo/hyper pigmentation - other: ______________	
TOTAL SCORE				

Figure 4: Photographic wound assessment tool (PWAT)

<u>II- Treatment Instruments</u>:

1. Hand-held threshold inspiratory muscle training device to strengthen inspiratory muscle training.

Treatment procedures:

1- Group (A): consisted of 20 females who received only traditional medical treatment daily at first week and then day after day for an additional three weeks in the form of continued care to the wound (the 1st in the hospital on the 1st post-surgery day, washing the area gently with saline and applying an antibiotic spray).

2- Group (B): consisted of 20 females who received traditional medical treatment and IMT daily at the first week and then three sessions a week, day after day, for an additional three weeks.

3-Group (C): consisted of 20 females who received traditional medical treatment, IMT, and LLLT 830/590 nm light-emitting diode (LED)-based device daily at the first week post-operative, then three sessions a week, day after day for an additional three weeks. **Frequency**: Daily during the first week post-operative, then three sessions a week, day after day, for an additional 3 weeks (total treatment duration: 4 weeks).

DATA ANALYSIS AND STATISTICAL DESIGN

To determine whether the data were normally distributed, we used the Shapiro-Wilk normality test in conjunction with Q-Q plots. Means and standard deviations were utilized in descriptive statistics to represent regularly distributed data, whereas medians and first and third quartiles were utilized for abnormally distributed parameters. For outcome measures with normally distributed data (FEV1/FVC, PI max, PWAT), a mixed ANOVA was utilized to analyze whether the changes over time differ depending on groups (the interaction effect). When the interaction effect in the mixed ANOVA was significant, the simple main effect of the within-groups factor was analyzed to identify changes over time. A post-hoc Tukey HSD test was performed for pairwise comparison after a significant interaction effect was reported in the mixed ANOVA to identify which groups differed. For MVV, a one-way ANCOVA was utilized to compare groups post-treatment while controlling for a significant baseline difference, and a dependent t-test was employed to compare means before and after intervention. For outcome measures with abnormally distributed data, the Wilcoxon Signed-Rank test was employed to compare before-and-after medians, and the Kruskal-Wallis test was used for comparison of medians between groups. Post-hoc Dunn's test with Bonferroni correction was conducted for pairwise comparison when the p-value from the Kruskal-Wallis test was significant.

The magnitude of change in means and medians from baseline was determined by percent change score, determined as [post-value − pre-value / pre-value] × 100. Effect size was determined for pairwise comparisons following ANOVA and ANCOVA as mean difference (MD) and 95% confidence interval (CI). Also, effect size was determined for pairwise comparisons following the Kruskal-Wallis test using rank-biserial correlation (r), calculated as r = the z-score from Dunn's test/square root of N, where N is the total number of samples (in the two groups being compared). The significance level for data analysis was set at 0.05. However, for both the Wilcoxon-Signed Rank test and dependent t-test, the alpha level was adjusted to a new significance threshold of 0.017 using the Bonferroni correction method to avoid Type I error, calculated by dividing the 0.05 standard level by 3 (number of tests). Data analysis was conducted utilizing the Statistical Package for the Social Sciences (SPSS) software version 24 for Windows (SPSS, Inc., Chicago, IL) [12].

3. RESULTS

3.1. Baseline data

The mean value of patients' ages was 41.35±2.23, 40.4±2.3, and 40.3±2.2 years in groups A, B, and C, respectively, with no significant difference among groups (p=0.270) (Table 1). The BMI was 27.56±1.21, 27.48±1.03, and 27.55±1.08 kg/m² in groups A, B, and C, respectively, with no significant difference between groups (p=.967) (Table 1). No significant differences were detected in body weight and height among groups at baseline (p > 0.05) (Table 1). Also, no significant differences were found among groups in FEV_1/FVC, Pimax, and PWAT (p > 0.05) (Table 1).

Table 1 baseline data

Variable	**Group A (n=20)**	**Group B (n=20)**	**Group C (n=20)**	**p-value**
Age (yrs)	41.35 ± 2.23	40.4 ± 2.3	40.3 ± 2.2	.270
Body weight (kg)	70.12 ± 5.18	68.0 ± 6.12	67.6 ± 7.68	.414
Height (meters)	1.6 ± .05	1.57 ± .05	1.56 ± .07	.239
BMI (kg/m²)	27.56 ± 1.21	27.48 ± 1.03	27.55 ± 1.08	.967
FEV1/FVC (%)	74.92 ± .35	74.99 ± .286	75.13 ± .244	.078
Pimax (cmH_2O)	62.2 ± 5.77	59.8 ± .71	61.79 ± 3.83	.137
PWAT total score	16.2 ± 2.26	16.55 ± 2.012	16.75 ± 1.8	.689

Data are presented as means and standard deviations. * Significant p-value based on one-way ANOVA.

BMI, body mass index. FEV1/FVC, forced expiratory volume in the 1st second/forced vital capacity. Pimax, maximal inspiratory pressure. MVV, maximal voluntary ventilation. PWAT, Photographic Wound Assessment Tool.

Outcome measures

3.2.1. Within groups

The median values of VAS were reduced significantly (p < .001) in groups A, B, and C by 25%, 43.75%, and 75%, respectively (Table 2). The median values of FEV_1 were increased significantly (p < .05) by 5%, 5%, and 8.8% in groups A, B, and C, respectively (Table 2). The median values of FVC were increased significantly (p=0.001) only in groups B along with C by 3.7% and 1.5%, respectively (Table 2). For the VAS score, no significant difference was detected in median values among groups at baseline (p=0.941) (Table 2). After interventions, a significant difference was observed among groups ($p < 0.001$) (Table 2). For FEV1, FVC, and FEV1/FVC, no significant difference was detected in median values among groups at baseline (p=0.929), (p=0.843), and (p=0.078), respectively (Table 2). After interventions, a significant difference was observed for FEV1, FVC, and FEV_1/FVC among groups (p=0.010), (p=0.625), and (p<0.001) (Tables 2, 4).

Table 2. Results for the outcome measures with abnormally distributed data

Outcome measures		Group A (n=20)	Group B (n=20)	Group C (n=20)	P-value
VAS score	**Pre**	8.0 (7.0, 9.0)	8.0 (7.0, 9.0)	8.0 (7.0, 9.0)	0.941
	Post	6.0(5.0, 7.0)	4.5 (4.0, 5.0)	2.0(2.0, 3.0)	<.001¶
	p-value	<.001ǂ	<.001ǂ	<.001ǂ	
	% median change	↓25%	43.75%	75%	
FEV_1 (Liters)	**Pre**	3.06 (3, 3.14)	3.05 (2.99, 3.12)	3.07(2.99, 3.10)	0.929
	Post	3.21 (3.1, 3.36)	3.20 (3.13, 3.25)	3.34(3.21, 3.4)	0.010¶
	p-value	0.006ǂ	<.001ǂ	<.001ǂ	
	% median change	↑5%	↑5%	↑8.8%	
FVC (Liters)	**pre**	4.09 (4, 4.2)	4.04 (4, 4.18)	4.09(4, 4.15)	0.843
	post	4.16 (4, 4.34)	4.19 (4.09, 4.24)	4.15(4.05, 4.22)	0.625
	p-value	0.205	0.001ǂ	0.001ǂ	
	% median change	↑1.7%	↑3.7%	↑4.5%	

Data are presented as medians and 1st and 3rd quartiles. ¶ Significant p-value from Kruskal-Wallis test ($p < 0.05$). ǂ Significant p-value from Wilcoxon signed rank test (< adjusted p-value of 0.017). VAS, Visual Analog Scale. FEV_1, forced expiratory volume in one second. FVC, Forced vital capacity

3.2.3 Pairwise comparisons following significant Kruskal-Wallis test (post-intervention).

Post-hoc analysis showed that the median values of VAS were significantly different between groups A and B [p = 0.017; effect size (r) = 0.44] in favor of group B, between groups A and C [p < .001; effect size (r) = 1], and between groups B and C [p < .001; effect size (r) = 0.64], favoring group C (Table 3). Post hoc analysis showed that the median values of FEV1 were significantly different only between groups B and C in favor of group C [p = 0.014; effect size (r) = 0.45] (Table 3). There was a difference with a medium effect size (r=0.37) between groups A and C with a tendency towards statistical significance (p=0.057) (Table 3).

Table 3. Pairwise comparisons following a significant Kruskal-Wallis test (post-intervention).

Outcome measure	Pairwise comparisons [a]								
	Group A versus group B			Group A versus group C			Group B versus group C		
	Adj. p-value	Z	Effect size (r)	Adj. p-value	Z	Effect size (r)	Adj. p-value	Z	Effect size (r)
VAS	0.017*	2.770	0.44	<0.001*	6.806	1	<0.001*	4.036	0.64

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FEV_1	0.999	0.485	0.08	0.057	-2.346	-0.37	0.014*	-2.831	-0.45

Adj.: Adjusted. [a] pairwise comparison that was performed using the post-hoc Dunn's test with Bonferroni correction adjustments. *Significant p-value. VAS, Visual Analog Scale. FEV_1, forced expiratory volume in one second. r: Rank Biserial Correlation [0.10 small effect, 0.30 medium effect, and 0.50 large effect].

Note: Multiple comparisons for FVC were not performed as the p-value from the Kruskal- Wallis test was not significant post-intervention.

3.2.4 Results for the outcome measures with normally distributed data

The mean values of FEV_1/FVC increased significantly ($p < .05$) in groups A, B, and C by 3.3%, 2.25%, and 7% (Table 4). The mean values of PI max increased significantly ($p < 0.001$) in groups A, B, and C by 4.2%, 14.4%, and 18%, respectively (Table 4). The mean values of MVV increased significantly ($p < 0.001$) in groups A, B, and C by 9.8%, 10.4%, and 12.7%, respectively (Table 4). The mean values of the PWAT total score decreased significantly ($p < .001$) in groups A, B, and C by 7.1%, 17.5%, and 26.9%, respectively (Table 4). For PWAT total score, no significant difference was found in mean values between groups at baseline ($p = .689$) (Table 1). After interventions, a significant interaction impact was found ($p < 0.001$) (Table 4).

Table 4. Results for the outcome measures with normally distributed data

Outcome measures		**Group A (n=20)**	**Group B (n=20)**	**Group C (n=20)**	Interaction effect p-value	Between-groups effect p-value
FEV_1/FVC (%)	**pre**	74.92 ± .35	74.99 ± .286	75.13 ± .244	<0.001*	<0.001‡
	post	77.38 ± 3.649	76.68 ± 1.505	80.37 ± 1.98		
	p-value	<0.001§	0.005§	<0.001§		
	% Mean change	↑3.3%	↑2.25%	↑7%		
Pimax (cmH_2O)	**pre**	62.2 ± 5.77	59.8 ± .71	61.8 ± 3.83	<0.001*	0.008‡
	post	64.8 ± 5.68	68.4 ± 3.04	72.9 ± 3.46		
	p-value	<0.001§	<0.001§	<0.001§		
	% Mean change	↑4.2%	↑14.4%	↑18%		
PWAT	**pre**	16.2 ± 2.26	16.55 ± 2.012	16.75 ± 1.8	<0.001*	0.181
	post	15.05 ± 2.06	13.65 ± 1.81	12.25 ± 1.48		
	p-value	<0.001§	<0.001§	<0.001§		

	% Mean change	↓7.1%	↓17.5%	↓26.9%	
MVV (L/min)					p-value
	pre	75.9 ± 0.46	78.6 ± 2.4	80.1 ± 0.53	< .001¶
	post	83.35 ± 2.10	86.77 ± 2.35	90.27 ± 2.32	0.001†
	p-value	<.001ǂ	<.001ǂ	<.001ǂ	
	% Mean change	↑9.8%	↑10.4%	↑12.7%	

* Significant p-value (<0.05) for the main interaction effect, ‡ significant p-value (<0.05) for the main between-groups effect, and § significant p-value (<0.05) for the main simple effect (within-groups) based on mixed ANOVA test. ¶ Significant p-value from one-way ANOVA. † Significant p-value from one-way ANCOVA. ǂ Significant p-value from the paired t test (< adjusted p-value of 0.017).

FEV_1/FVC, forced expiratory volume in one second/forced vital capacity. Pimax, maximal inspiratory pressure. PWAT, Photographic Wound Assessment Tool. MVV, maximal voluntary ventilation.

3.2.5 Pairwise comparisons following mixed ANOVA and one-way ANCOVA (post-intervention)

Post-hoc analysis showed that the mean values of FEV_1/FVC were significantly different only between groups A and C [p = .001, MD = -1.60, 95% CI = -2.58 to -.63] and between groups B and C [p < .001, MD = -1.91, 95% CI = -2.88 to -.94] in favor of group C. Post-hoc analysis showed that the mean values of Pimax were significantly different only between groups A and C [p = 0.011, MD = -3.83, 95% CI = -6.9 to -.75] and between groups B and C [p = .035, MD = -3.26, 95% CI = -6.3 to -.18] in favor of group C (Table 5). Post-hoc analysis showed that the mean values of MVV were significantly different only among groups A and C [p = 0.002, MD = -3.5, 95% CI = -5.85 to -1.15] and among groups B and C [p = .003, MD = -2.30, 95% CI = -3.93 to -0.66] in favor of group C (Table 5). For the PWAT total score, no significant difference was found in mean values between groups pre-treatment (p=.689) (Table 1). A significant interaction impact (p < 0.001) was seen after the therapies (Table 4). No significant differences were found between the groups (p > 0.05) according to the post-hoc analysis (Table 5).

Table 5. Pairwise comparisons following mixed ANOVA and one-way ANCOVA (post-intervention)

Outcome measure	Pairwise comparison								
	Group A versus group B			Group A versus group C			Group B versus group C		
	p-value	MD	95% CI	p-value	MD	95% CI	p-value	MD	95% CI
FEV_1/FVC[a]	.730	.31	-.66 to 1.28	.001*	-1.60	-2.58 to -.63	<.001*	-1.91	-2.88 to -.94
Pimax[a]	.897	-.57	-3.64 to 2.50	.011*	-3.83	-6.9 to -.75	.035*	-3.26	-6.3 to -.18
MVV[b]	.376	-1.20	-3.11 to .71	.002*	-3.5	-5.85 to -1.15	.003*	-2.30	-3.93 to -.66
PWAT[a]	.658	.525	-.91 to 1.96	.155	1.12	-.32 to 2.6	.580	.60	-.84 to 2.0

a: Pairwise comparison performed using the Tukey HSD post-hoc test

b: Pairwise comparison with adjustments using the Bonferroni correction

* Significant p-value (< 0.05). FEV_1/FVC, forced expiratory volume in one second/forced vital capacity. Pimax, maximal inspiratory pressure. MVV, maximal voluntary ventilation. PWAT, Photographic Wound Assessment Tool.

4.DISCUSSION

Patients may experience discomfort due to the exposed location of thyroidectomy scars [2]. The purpose of this research is to examine the efficacy of a combination of IMT and LLLT for post-thyroidectomy neck pain among premenopausal women in terms of pulmonary function and pain, as well as wound healing.

Our findings showed significant improvement in pulmonary function, pain (VAS score), and wound healing for both groups B, who received traditional medical treatment and IMT, daily at the first week, then three sessions a week for an additional three weeks; and group C, who received traditional medical treatment, IMT, and LLLT using an 830/590 light-emitting diode-based device daily for the first week, then three sessions a week, day after day, for an additional three weeks, from pre-treatment to post-treatment measurements (P value <0.001) favoring group C.

Pulmonary Function

Our result agree with Desai et al.[13], who discovered that beginning structured exercise immediately following surgery may accelerate healing, lessen the likelihood of pulmonary problems, and prevent muscular atrophy. By strengthening the abdominal wall along with diaphragmatic function, targeted breathing exercises may reduce the risk of postoperative pulmonary complications (such as atelectasis) in addition to incisional hernias.

The findings are in line with those of Nunes et al.[14], who noted that there is still inconsistency regarding the impact of IMT on FEV1 and FVC in both healthy individuals and patients, with some studies reporting improvements in these parameters after IMT and others failing to do so. Patients who did not participate in respiratory exercises during the first five days after hospitalization had a significantly lower MIP, which is in line with our findings Suesada et al. [15]. As previously stated by Paiva et al. [16], our results, an improvement in respiratory muscle strength (RMS) along with endurance, may be the result of more motor unit activation in a chest physical therapy (CPT) program, according to the report. Incentive spirometry (IS) enhances ventilation efficiency, provides visual feedback for diaphragmatic training, and keeps positive pressure within the airways, as well as improves perfused alveoli, according to the report. To enhance muscular strength via a higher inspiration/expiration ratio, the patient should mobilize a large tidal volume while completing IS breathing exercises at a modest respiratory rate. In a patient utilizing IS, the maximal inspiration may raise the transpulmonary pressure and pulmonary volume; moreover, the residual inspiration maintains this rise and ensures alveolar stability.

However, Ramos et al. [17] disagreed with our findings, which showed that roller hockey players did not significantly improve their FEV1 and FVC after twelve sessions of IMT. Another systematic study HajGhanbari et al. [18] that did not find a significant rise in FEV1 following IMT in the athletes did not match our findings.

Wound Size, Scar Healing, and Pain (VAS):

Our results are in line with those of Barreto et al. [19], who showed that all patients got the standard treatment—consisting of sterile gauze and simple saline dressings—which may have been helpful in reducing the size of the ulcers on their own. In a study conducted by Kasymov et al. [20], it was discovered that the proposed technique has both a good hemostatic and anti-inflammatory impact. This anti-inflammatory impact was observed in a decline in a total complication rate from 29.5% to 10.2% ($p < 0.001$), a reduction in the proportion of surgical lympho-hemorrhagic side effects from 11.5% to 3.1% ($p = 0.019$), and a reduction in the postoperative observation time from 6.0 ± 1.1 to 4.9 ± 0.8 days ($p < 0.05$).

We found that the mechanisms linked to photobiomodulation are thought to be mitochondrial in nature, leading to increased ATP synthesis and the induction of signaling compounds for calcium ions (Ca^{2+}) and proton ions (H^+). This is supported by the work of Karu [21] and Kim et al. [22]. The primary chromophore of red as well as yellow visible light is cytochrome c oxidase (CCO), an end-terminal enzyme of the mitochondrial respiratory chain. CCO possesses an absorption peak at 633 nm, but 590 nm is also effective in activating the components of the mitochondrial respiratory chain, leading to the start of a series of intracellular reactions mediated by photochemistry. Angiogenesis activation, enhanced blood flow, reduced and prevented apoptosis, modulation of low concentrations of reactive oxygen species, higher ATP production, and transcription factor induction are among these. Proliferation as well as migration of fibroblasts, modification of cytokines, growth factors, and inflammatory mediators, and an upregulation of antiapoptotic proteins are all possible outcomes of these pathways.

Research that supports the findings of Taha et al. [23], indicates that LLLT may promote wound healing and alleviate pain in the body. Its effectiveness in treating chronic or slow-healing wounds, including DFUs, has been further shown. Optimizing the LLLT's therapy benefits may be achieved by adjusting its parameters, such as wavelength and output power, as well as energy density. Our findings are in line with those of the study by Nasi et al. [24], which found that 6 patients had thyroid lobectomy while 6 others received complete thyroidectomy. At 1, 7, and 30 days post-op, patients underwent follow-up examinations. Results showed that patients who participated in ten therapy sessions—one in the hospital on the day following surgery and nine more in telerehabilitation three times weekly for three weeks—had less neck pain and an improved quality of life. This therapy has the potential to be recommended as an option for patients undergoing thyroidectomy due to the significant decrease in cost and morbidity associated with it, as well as the fact that patients can be treated remotely through telerehabilitation.

Consistent with previous research Desai et al., [25], early rehabilitation has the potential to enhance mental health by alleviating anxiety and depression caused by prolonged immobility and pain .

In contrast, our results were contradicted by Alvarenga et al. [26], who discovered that the treatment group had a greater mean pain score than the control group post-LLLT. This suggests that the treatment didn't provide any significant benefit, as the scores were both lower and under 1.5.

Limitations of the study:

The study was limited by the lack of consensus regarding the most relevant measure for evaluating the efficacy of IMT. Prior research has also used MIP, transdiaphragmatic pressure, maximum expiratory pressure, and diaphragm muscle thickness, as well as respiratory muscle power output, to evaluate responses to IMT.

CONCLUSION

This study provides strong evidence supporting that both inspiratory muscle training exercise alone and combined with LLLT have a beneficial effect on improvement in pulmonary function, pain (VAS score), and wound healing. In favor of the combination of IMT exercise with combined LLLT.

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Conflict of interest

The authors have no conflict of interest to declare.

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