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Original Article

Effect of Respiratory Muscle Training on Lung Function on Quarry Workers in Minia Governorate Egypt

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Abstract:
Objective: To find the effect of aerobic exercises versus respiratory muscle training on lung function among quarry workers [Randomized controlled trial]. Forty quarry workers participated in the study. **Methods:** Patients were randomly allocated to two groups. Group A was given aerobic exercises by engaging in a 30 minute session of walking on a treadmill for eight weeks, three times a week [control group]. Group B was given a respiratory muscle training program using an incentive spirometer, diaphragmatic breathing exercises, lateral costal breathing exercises, and pursed lip breathing exercises in addition to aerobic exercise for eight weeks [study group]. A spirometer was used for a pulmonary function test, which evaluated lung function by measuring Forced Vital Capacity [FVC], Forced Expiratory Volume in one second [FEV1], and the ratio of FEV1 to FVC. **Results:** Findings of this study indicated substantial improvements of FVC, FEV1, and FEV1/FVC after treatment in both groups values [P value < 0.00001]. There were significant differences between both groups after treatment regarding FVC, FEV1, and FEV1/FVC, with favored results in Group B. **Conclusion:** Both groups showed a significant improvement in lung function in favor of group B. So, this study proves that respiratory muscle training is an essential supplement to aerobic exercise for pulmonary rehabilitation to improve pulmonary functions in quarry workers.
Keywords: Quarry workers, Aerobic exercises, Incentive spirometer, pulmonary functions.
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1. Introduction

Quarrying art is a longstanding commercial practice in regions rich in natural resources like marble, limestone, and gypsum. An individual employed in a quarry is exposed to numerous risks arising from the inhalation of airborne particulates, which significantly affects their health and safety. Airborne particles are the most hazardous chemical that may be inhaled, and they can potentially cause health problems for quarry workers such as respiratory, dermal, along with optical irritation as well as damage [1].

Extended inhalation of particulate matter generated from the crushing of granite rocks harms lung function and leads to various respiratory symptoms and other health issues in quarry workers [2]. One specific issue in certain quarries is the inhalation of dust that contains silica. This can cause silicosis, a permanent lung disease characterized by lung inflammation and breathing problems. The condition continues to worsen long after exposure to silica dust has stopped. Reports from both the United States as well as China have indicated that a significant number of individuals are exposed to silica dust, leading to the development of silicosis. This condition has proven to be fatal, particularly among older workers [3]. Developing nations, particularly those in Africa, often lack well-established health and safety policies, which are a methodical approach to controlling all potential dangers that could cause harmful working conditions for industry employees [4].

Studies show that silica in stone composition is a key factor in respiratory diseases like obstructive and restrictive lung conditions. Prolonged dust exposure leads to decreased pulmonary function in various occupations [5], causing lung irritation, inflammation, and fibrosis, which impair oxygen diffusion and lung function [6]. Altered mucus properties form plugs, obstructing airflow and reducing FVC, FEV1, and the FEV1/FVC ratio [7]. Lower lung function values indicate a higher risk of chronic respiratory and lung diseases [8]. The diagnosis of lung disease involves assessing the efficiency as well as the functional capacity of the lungs by measuring various lung volumes, known as ventilator function. The key factors in ventilatory function are FEV1 and FVC [9].

Smoking cessation, medication treatment, long-term oxygen therapy, surgery, rehabilitation, and physical therapy, particularly chest physical therapy [CPT], are all components of an exercise program whose intensity is mostly determined by the severity of the condition [10].The enhancement in pulmonary function may be attributed to the enhanced strength of respiratory muscles, enhanced thoracic movement, and the establishment of balance among the lungs along with chest elasticity through regular exercise. The beneficial impact of aerobics on enhancing respiratory functions in individuals without health issues demonstrates that exercise can be regarded as a crucial element of pulmonary rehabilitation among patients suffering from lung disorders [11].

2. Materials and Methods

Study Setting and Population:

This study was conducted in Minia, a governorate in Egypt located 234 km south of Cairo. Due to the proximity of Deraya University to numerous quarries, the study was carried out as a community service by the university. The area is rich in rocks and minerals, making it an ideal location for quarrying and mining activities. The quarries covered a large portion of the community, with workers involved in various roles, both in the factories and offices. The factory work includes tasks such as mining, milling, blasting, breaking, bagging, and loading stones, while office work involves administrative tasks.

Subjects:

The study included 40 male quarry workers, aged between 35 and 55 years, with BMI values ranging from 25 to 34.9 kg/m^2, classifying them as overweight or class 1 obese. These participants were randomly selected from the Deraya University Outpatients Clinic and Minia University's Cardiothoracic Hospital during the period from October 2023 to April 2024. Ethical approval was obtained from the Cairo University Physical Therapy Faculty's Ethical Committee [No: P.T. REC/012/004295], and the trial was registered at ClinicalTrials.gov [NCT06070584] on September 24, 2023. Each participant signed a written informed consent form before joining the study. The study was randomized, with participants assigned to one of two groups: Group A received moderate-intensity aerobic exercises, which involved 30-minute sessions of walking on a treadmill, performed three times a week for eight weeks. Group B underwent aerobic exercises as group A in addition to respiratory muscle training using an incentive spirometer and performed breathing exercises, including diaphragmatic, lateral costal, and pursed-lip breathing exercises, three times weekly for eight weeks. Pulmonary function was assessed using a spirometer before and after the intervention

Inclusion criteria: Participants included in the study were male quarry workers who had been employed in the quarries for at least five years and exhibited chest manifestations. The age range was between 35 and 55 years, with BMI values from 25 to 34.9 kg/m².

Exclusion criteria: Patients with acute chest infections, mental instability, chest cancer, musculoskeletal diseases, and other disorders that could potentially impact the study's findings were excluded from the trial.

Instrumentation

- A weight and height scale [Model MC. Health Scale, RTZ-120A, China] was used to calculate BMI before starting the intervention.
- Lung function was assessed using a Geratherm Respiratory Blue Cherry spirometer.
- A Kettler treadmill [UK] was used for aerobic exercise, with participants from both groups walking continuously for 30 minutes, three times a week, for eight weeks.
- The incentive spirometer device is extensively utilized in physical, speech, as well as respiratory therapy to motivate the patient to engage in slow and deep inhalation by providing visual feedback. It is crucial to inhale gently when using a spirometer, as this enables the lungs to expand and the airways to open. The incentive spirometer is cost-effective and easily manageable equipment that can be utilized in rehabilitation without any reported adverse effects. Once a patient learns how to use it correctly, it is easy to train, and they won't need assistance anymore. Further, patients are more likely to comply with treatment plans when they receive visual feedback [12].

The procedure of exercises for group A:

Participants followed an 8-week treadmill walking regimen with the following parameters:

[1] **Mode:** Aerobic exercise

[2] **Intensity:** Moderate [60-75% of maximum heart rate]

[3] **Duration:** 30 minutes per session [5-minute warm-up, 20-minute conditioning, 5-minute cool-down]

[4] **Frequency:** Three times per week

[5] The Karvonen method was used to calculate target heart rates:

HR Max = 220 - age

Target HR = 60-75% [HR Max – HR Rest] + HR Rest [13].

The procedure of exercises for Group [B]:

Participants in Group B performed a combination of aerobic exercise [moderate intensity as group A] and respiratory muscle training. The respiratory training consisted of the following:

Incentive spirometer training: Participants were instructed to take deep breaths to raise the spirometer's indicator balls, hold their breath for one second, and then exhale slowly. This was repeated five times, followed by a rest before repeating the process for three sets, with a total training of 15 minutes.

Diaphragmatic breathing: Participants placed one hand on their abdomen and the other on their sternum, breathing deeply to move the hand on their abdomen upward while keeping the hand on their sternum still. This was repeated five times, for three sets with rest intervals.

Lateral costal breathing: To improve lateral chest expansion and strengthen external intercostal muscles, participants performed deep breaths while the therapist applied gentle outward pressure on both sides of their chest. This was repeated five times, for three sets with rest.

Pursed-lip breathing: Participants took deep breaths through their nose [count of two] and exhaled slowly through pursed lips [count of five]. This was repeated five times per set, for three sets [14]. The exercises for Group B followed a structured order: aerobic exercise, incentive spirometer training, diaphragmatic breathing, lateral costal breathing, and pursed-lip breathing.

Evaluation procedures:

Participants' weight and height were measured to calculate BMI, using the formula: BMI = weight [kg]/height [m²] [15 -16]. All methods were performed in accordance with the relevant guidelines and regulations. Each participant in both groups passed through the following evaluation procedures conducted by their respective physicians and physiotherapist. The participant stood in an upright position, wore nasal clips, and held a mouthpiece to measure lung capacity. Instructions such as tidal inspiration, deep inspiration, and forced expiration were displayed on the spirometer screen. The results, including forced vital capacity [FVC] and forced expiratory volume in one second [FEV1], were recorded and stored. The highest FVC and FEV1 values from three spirometry attempts were selected for analysis [17]. Compare the parameters recorded before and following eight weeks [**Figure 1**].

Figure 1: Geratherm Spirometer

Statistical analysis

To contrast the subject characteristics between the groups, an unpaired t-test was used. The Shapiro-Wilk test was used to ensure that the data followed a normal distribution. A Levene's test was conducted to assess the homogeneity of variances among the different groups. A Mixed MANOVA was conducted to investigate the impact of the treatment on FVC and FEV1, in addition to the ratio of FVC to FEV1. To conduct multiple comparisons, post hoc tests have been carried out utilizing the Bonferroni correction. The significance level for all statistical tests was set at $p < 0.05$. For this study, we used SPSS 25 for Windows [IBM SPSS, Chicago, IL, USA] to carry out all of our statistical analysis.

3. Results

- Subject characteristics:

Table [1] shows the subject characteristics of groups A and B. There was no substantial difference among groups regarding age as well as BMI [$p > 0.05$].

Table 1. Comparison of subject characteristics among the groups A & B:

	Group A	Group B			
	Mean ±SD*	**Mean ±SD**	**MD***	**t- value**	**p-value***

Age [years]	4.75 ±44.35	5.49±43.70	0.65	0.33	0.74
BMI [kg/m²]	2.51±29.25	2.36±28.38	0.87	1.13	0.27

*SD, Standard deviation; MD, mean difference; p-value, Probability value.

Mixed MANOVA revealed a substantial interaction effect of treatment as well as time [F = 849.87, p = 0.001, Partial eta squared = 0.98]. There was a substantial main effect of treatment [F = 7.45, p = 0.001, Partial eta squared = 0.38]. There was a substantial main effect time [F = 10306.82, p = 0.001, Partial eta squared = 0.99].

Within-group comparison

There was a substantial improvement in FVC, FEV1, as well as FVC/FEV1 post-treatment in comparison to pretreatment in both groups [p > 0.001]. The percentage of change of FVC, FEV1, as well as FVC/FEV1 of group A, was 8.68, 10.86, and 2.53%, and that in group B was 12.20, 19.48, and 5.99%. [**Table 2**].

Between-group comparison

Following treatment, group B's FVC, FEV1, as well as FVC/FEV1 improved substantially when compared to group A. [p < 0.05] **[Table 2] & [Figure 2].**

Table 2. Mean FVC, FEV1, and FVC/FEV1 pre and post-treatment of groups A and B:

	Pre treatment	**Post treatment**			
	Mean ±SD	**Mean ±SD**	**MD [95% CI]**	**of change %**	**p-value**
FVC [L]					
Group A	0.14 ± 4.03	4.38 ± 0.15	-0.35 [-0.37, -0.32]	8.68	0.001
Group B	0.17 ± 4.10	4.60 ± 0.18	-0.5 [-0.53, -0.48]	12.20	0.001
MD **[95% CI]**	-0.07 [-0.16, 0.03] p = 0.19	-0.22 [-0.33, -0.12] p = 0.001			
FEV1 **L]]**					
Group A	3.04 ± 0.14	3.37 ± 0.14	-0.33 [-0.34, -0.33]	10.86	0.001
Group B	3.08 ± 0.12	3.68 ± 0.13	-0.6 [-0.61, -0.59]	19.48	0.001
M**D [95% CI]**	-0.04 [-0.13, 0.05] p = 0.35	-0.31[-0.40, -0.22] p = 0.001			
FVC/FEV1 %]]					
Group A	75.18 ± 4.07	77.08 ± 3.57	-1.9 [-2.68, -1.13]	2.53	0.001
Group B	75.32 ± 4.34	79.83 ± 3.82	-4.51 [-5.29, -3.74]	5.99	0.001
M**D [95% CI]**	-0.14 [-2.84, 2.55] p = 0.91	-2.75 [-5.12, -0.38] p = o.o2			

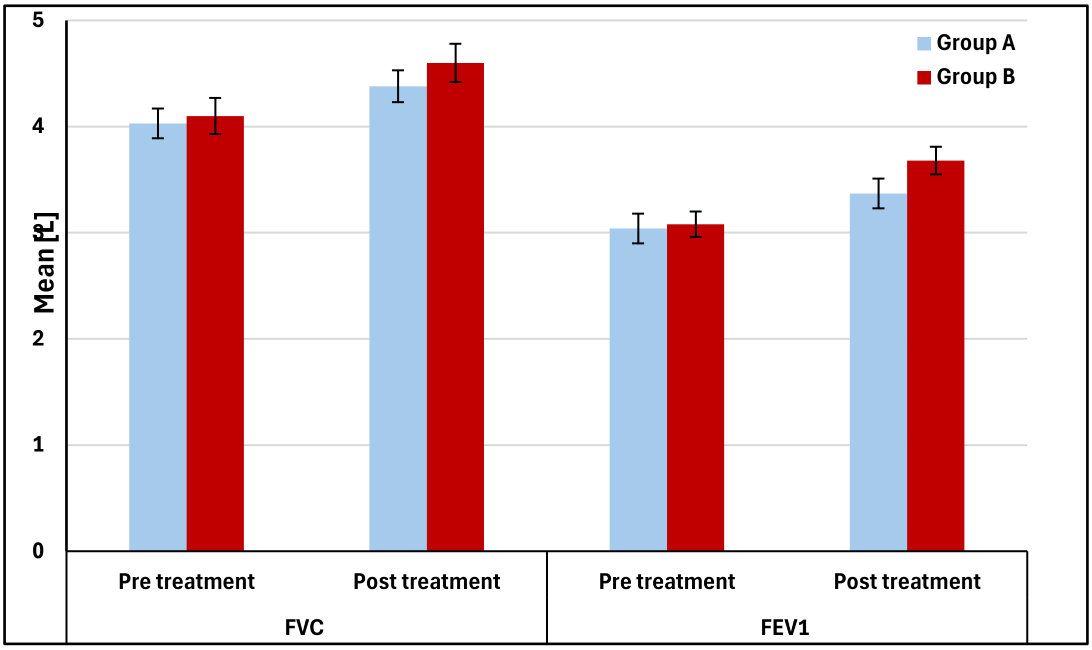
SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Probability value

4. Discussion

This study showed that the incidence of respiratory diseases was higher among quarry workers; this may be due to high exposure to quarry dust.

The study's main objective was to assess whether IMT and/or aerobic exercise provide additional benefits in quarry workers to improve lung function.

Workers with greater than 5 years of work experience exhibited a higher prevalence of respiratory symptoms compared to the reference group. This is corroborated by additional research, which demonstrates that an extended period of work experience is linked to a greater proportion of respiratory symptoms related to one's occupation [18, 19, 20]. This could be attributed to the fact that as the duration of working experience increases, the amount of time exposed to dust also increases. Prolonged exposure to particles of dust or chemicals results in an increased accumulation of dust in the respiratory system and chronic inflammation, which exacerbates breathing difficulties and is characterized by various respiratory symptoms [21].



[Figure 2] Mean FVC and FEV1 pre and post-treatment of groups A and B

The findings of our study indicated a statistical significance distinction [$p<0.05$] between groups. Group A also improved in FVC and FEV1, in addition to the FEV1/FVC ratio in the eight weeks of treatment, but it was significantly less than group B.

The study demonstrated that the use of an incentive spirometer [IS] significantly improved both respiratory muscle strength as well as pulmonary functions, specifically in terms of FVC and FEV1. The findings align with a prior investigation carried out by Amal et al. 2023, that analyzed the influence of IS on ABG, spirometry, and diaphragmatic function among COPD patients. This study further demonstrated that IS had a stronger impact on improving ABG, certain pulmonary function parameters [FEV1/FVC], as well as diaphragmatic function in individuals with COPD [22].

Also, Arwa and Nedal,2018 found that aerobic exercise had significant improvement in FEV1, MVV, and FEV1/FVC. After engaging in high-intensity aerobic exercise, there was a substantial improvement in FEV1 and MVV. However, changes in FVC were not statistically significant. The increase in FEV1 indicates that engaging in high-intensity aerobic exercise enhances the flow of air in the respiratory tract. The findings indicate that engaging in aerobic exercise on the treadmill has a beneficial impact on the respiratory function of sedentary individuals [23].

Kumar et al. 2016 investigated incentive spirometry to determine its effectiveness in inducing sighing or yawning and promoting deep breaths in patients with inactive atelectasis and a tendency for shallow breathing. Additionally, the study examined the impact of inspiratory incentive spirometry on the recovery of pulmonary function as well as diaphragm movement in patients who had undergone laparoscopic abdominal surgery. The results showed that the technique led to early recovery in both aspects [24]. Also, our result matched with Qaseem et al. 2011, who found pulmonary rehabilitation programs could improve FEV1, FVC, and FEV1/FVC, which leads to reduced air entrapment, enhanced respiratory function, and increased survival rates among those with COPD. Updated guidelines and research indicate that pulmonary rehabilitation is the most effective non-pharmacological treatment for COPD [25].

Limitations of the study:

This study investigated a small sample size; so, future investigations will necessitate a larger sample size.

5. Conclusion:

The current study investigates that respiratory muscle training and aerobic exercise lead to an improvement in lung function in quarry workers. Both groups showed a significant improvement in lung function in FEV1, FVC, and FEV1/FVC in quarry workers in favor of group B. So, this study investigates that respiratory muscle training is an essential supplement to aerobic exercise for pulmonary rehabilitation to increase pulmonary function in quarry workers.

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Authors' contribution:

THM, MAS, HAA, and WEH prepared the protocol for registration; conceptualized the study; and were involved in database searching, data abstraction, statistical analysis, report writing, and manuscript draftin **THM**, **WEH, and HAA** were involved in the screening of primary studies, resolution of conflicts during data extraction, statistical analysis, and manuscript write-up. All authors read and approved the final manuscript before submission. All authors reviewed and approved the final manuscript.

Ethical approval:

The study was approved by the ethical committee of Cairo University, Egypt, with the following reference number: P.T.REC/012/004295.

Trial details: This clinical trial was registered at ClinicalTrials.gov [NCT06070584].

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