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Effectiveness of respiratory muscle training on pulmonary function and quality of life in cotton industry workers

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Abstract: Cotton sector workers are more likely to be exposed to the dust of cotton, leading to acute and chronic respiratory diseases, including chest tightness, bronchoconstriction, and occupational pulmonary disease. Physical exercise includes strengthening inspiratory muscles and training a larger muscle group, crucial to increase pulmonary function, exercise capacity, and cardiorespiratory endurance. To assess whether inspiratory muscle training (IMT) with aerobic exercise provides additional benefits in cotton workers to increase lung function and quality of life. A single-blinded interventional study performed at Angle Fibres Pvt. Ltd. cotton industry. One hundred (100) male workers based on enclosure criteria were randomly included and equally alienated into group A: Experimental (IMT + Aerobic Exercise) and group B: Control (Aerobic Exercise). Both groups received the supervised treatment four times each week for four weeks. Pulmonary function and excellence of life were measured at baseline, 4 weeks and 1 year follow-up. An Independent t-test was used for baseline comparisons. Repeated measures Multivariate ANOVA was applied for statistical analysis within and between group comparisons. No significant difference existed at the baseline. All the outcomes in each group demonstrated statistically significant differences. Among both groups, there was a statistically significance difference ($p<0.05$) in experimental group outcome measures FVC ($p=0.03$), FEV_1 ($p=0.02$), FEV_1/FVC ($p=0.04$) PEFR ($p=0.01$) and SGRQ score ($p=0.03$). In addition to aerobic exercise, respiratory muscle training is essential to pulmonary rehabilitation for improving lung function and quality of life for those employed in this cotton industry.

Introduction

After China, India is the second most prominent cotton-generating nation (Rao et al., 2013). Fine particulates of dust of cotton with diameters of ≤2.5 µm and ≥0.1 µm, which are collected in the lung's gas exchange region, where respiration is very slow. Cotton dust exposure for a short period can be illustrated with feelings of wheezing, chest tightness, coughing, sputum and breathlessness (Lestari et al., 2023). Long-term exposure can result in significant levels of persistent respiratory symptoms and an excess chronic yearly loss in forced expiratory volume per second (FEV1) (Wang et al., 2005).

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The concepts of respiratory muscle training are the same as other skeletal muscle training (Bhakta et al., 2023). The various physiological mechanisms have been elaborated to explain the effectiveness of the IMT, like optimisation of blood flow, decrease in central fatigue and decreased sense of respiratory and peripheral effort (Kaur et al., 2015; Goodall et al., 2014). Aerobic exercise is strongly suggested for maintaining physical, mental, and emotional health (Constant, 1982; Khant et al., 2017). Exercises on a bicycle ergometer and a treadmill have significant benefits in lowering ventilation demand and may limit the effects of respiratory limitations on exercise capability. Thus, a way to improve the function of inspiratory muscle. Still, limited evidence of respiratory muscle training in India and acceptance of the problems by cotton industry workers lead to low evidence-based practice (Mekonnen et al., 2021).

The analysis assesses whether inspiratory muscle training (IMT) with aerobic exercise provides additional benefits in cotton workers to increase lung function and quality of life.

Material and Methods

Study design and setting: A single-blinded interventional study was performed with cotton industry workers at Angel Fibers Private Limited, Rajkot.

Study population: Cotton industry workers

Inclusion criteria: 30 to 55 years male workers with at least one year of experience working in the cotton industry, smoker and non-smoker, all BMI types, $FEV_1/FVC > 70\%$.

Exclusion criteria: History of hospitalization in the last 6 months, unstable vital parameters and no interest in taking part in study.

Sample size: The sample size was estimated to be 16 for each outcome measure and 80 using the G-power software. Consequence level (α)-0.05, power (1-β)-0.9 and effect size-0.4 were selected. The overall sample size was computed to be 50 in each group using a drop-out rate of 25%.

Randomization: The principal investigator invited all the eligible workers to participate and randomized them equally into two groups based on computer-generated random numbers. The workers remained concealed from the treatment group. Control group B provided only aerobic exercise, and experimental group A provided inspiratory muscle training and aerobic exercise (Hoy et al., 2020; Saleem et al., 2021).

Study intervention

Aerobic exercise: The warm-up period includes overhead arm stretching, walking and static bicycling for 10 minutes. The main exercise session includes a static cycle ergometer for 20 minutes with a heart rate reserve (HRR) of 30 to 35% (Meek PM et al. 1999; Irwin S and Tecklin JS 2004)—continuous pulse recording by pulse oximeter is done during aerobic exercise. The cool-down period includes flat surface walking and overhead arm stretching for 5 minutes. Exercise progression after 2 weeks, a 5-minute increase in time and intensity, and a 5% increase in HRR was made. Supervised training sessions given to cotton industry workers 4 times per week (4 weeks).

Respiratory muscle training: It was executed with an inspiratory muscle trainer (Threshold; Philips; Respironics). The cotton workers were placed comfortably on chairs while wearing a nose clip. The cotton workers participated in supervised training sessions four times per week for four weeks. Inspiratory muscle training was provided in seven cycles. Each cycle lasts 21 minutes and consists of two minutes of breathing and one minute of rest. The training load explained to cotton workers as somewhat hard – between 12 to 14 on the Rated Perceived Exertion scale (RPE) (Borg G 1982; Hill K et al. 2010). The training load progression after two weeks was altered in the reverse direction by adding 4 cm H_2O to sustain previously.

Outcome measure

Pulmonary function test: According to the guidelines of the ATS, a computerized spirometry was performed on cotton workers (Pellegrino et al., 2005; Redlich et al., 2014). Initially, the procedure was explained to the workers. They were asked to take a few normal breaths, and later take a long deep breath (inspire rapidly and completely) and then to expire as hard and fast for as long as conceivable into the mouthpiece of the spirometer with lips closed tightly, then followed by deep inspiration to form flow volume loop on the computer screen. A nose clip was attached to the worker during the manoeuvre. Recording of best trail out of three of FVC, FEV_1, FEV_1/FVC, and PEFR on screen were noted down.

St. George's Respiratory Questionnaire (SGRQ): SGRQ is a scale used to estimate the excellence of life for persons with respiratory conditions like COPD and asthma (Jones, 2001). Written permission was obtained to use the copyrighted Gujarati version of the four-week SGRQ from St. George University, London (Jones et al., 1992). Several factors have been evaluated for calculating the score, such as age, gender, weight, duration of disease, worst and current pulmonary function test measurement. The SGRQ score is between 0 and 100; a

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high score suggests more disease severity and leads to more restrictions in daily living.

Data analysis: Using SPSS version 20, all statistical analysis was done.The Kolmogorov-Smirnov test was used to determine whether or not the data followed a normal distribution. An Independent t-test was applied for baseline comparisons. Repeated measures Multivariate ANOVA test was used to evaluate within and between groups. For all statistical analyses, the Alpha level was fixed at 0.05 and the 95% confidence interval to control type I error.

Ethical approval: Shree Giriraj Hospital Research Ethics Committee, Rajkot had accepted the research study and enrolled in the Clinical Trial Registry of India (CTRI).

Results

One hundred twelve workers were assessed for admissibility in the study, and one hundred met the eligible criteria. The workers were, at random, allocated into 2 different groups: A (n=50) and B (n=50). Mean + SD of age, BMI and duration of work of subjects were 41.55±6.35 years, 22.64±2.84 kg/m^2 and 87.59±46.52 months, respectively.

A baseline comparison of outcome measures between both groups (Table 1) was done using an independent t-test. No significant difference in FVC, FEV$_1$, FEV$_1$/FVC, PEFR and SGRQ was found between the groups.

Table 1. Baseline comparison of workers in groups A and B

Outcome	Experimental Group A [n=50] Mean ± SD	Control Group B [n=50] Mean ± SD	t-value	P-value
FVC (l)	2.97 ± 0.33	3.02 ± 0.34	-2.56	0.12
FEV$_1$ (l)	2.77 ± 0.34	2.84 ± 0.34	-1.25	0.21
FEV$_1$/FVC (%)	90.74 ± 8.17	90.89 ± 5.82	-0.04	0.97
PEFR (l/s)	5.77 ± 1.21	5.76 ± 1.43	0.03	0.98
SGRQ	12.46 ± 5.91	12.07 ± 6.00	0.38	0.71

Means and Standard Deviation (SD) of outcome measures at the end of the fourth week and one-year follow-up in both groups are represented in Table 2.

Repeated measure ANOVA test was used within the group comparison of FEV$_1$, FVC, FEV$_1$/FVC, PEFR and SGRQ and showed a significant difference (p<0.05). The effect size of FEV$_1$, FVC, FEV$_1$/FVC, PEFR and SGRQ was 0.163, 0.240, 0.109, 0.381 and 0.383 respectively in Table 3.

Table 2. Mean and SD of the outcome at the end of the fourth week and follow-up in groups A and B

Follow Up At	Outcome	Experimental Group A Mean ± SD	Control Group B Mean ± SD
Week 4 (N=50)	FVC (l)	3.20 ± 0.29	3.30 ± 0.32
	FEV$_1$ (l)	3.08 ± 0.25	3.07 ± 0.29
	FEV$_1$/FVC (%)	95.05 ± 5.70	93.29 ± 3.22
	PEFR (l/s)	7.40 ± 0.71	7.14 ± 1.25
	SGRQ	5.64 ± 4.02	7.17 ± 5.05
Follow up1 Year(N=50)	FVC (l)	3.14± 0.29	3.17 ± 0.24
	FEV$_1$ (l)	2.96 ± 0.28	2.92 ± 0.20
	FEV$_1$/FVC (%)	94.44 ± 4.70	92.26 ± 4.07
	PEFR (l/s)	7.22 ± 0.947	6.45 ± 1.16
	SGRQ	7.25 ± 3.49	10.89 ± 5.59

Table 3. Repeated measure multivariate ANOVA for within-group comparison of different outcomes for the experimental and control group

Outcome	F value	P value	Effect Size (Partial Eta Squared)
FVC (l)	25.27	0.000	0.163
FEV$_1$ (l)	41.04	0.000	0.240
FEV$_1$/FVC (%)	15.83	0.000	0.109
PEFR (l/s)	79.94	0.000	0.381
SGRQ	80.62	0.000	0.383

Repeated measure ANOVA test was used for between-group comparison of FEV$_1$, FVC, FEV$_1$/FVC, PEFR and SGRQ and showed a significant difference (p<0.05). The effect size of FEV$_1$, FVC, FEV$_1$/FVC, PEFR and SGRQ was 0.037, 0.000, 0.032, 0.045 and 0.036, respectively, in Table 4.

Table 4. Repeated measure multivariate ANOVA for between-group comparison of different outcomes for the experimental and control group

Outcome	F value	P value	Effect Size (Partial Eta Squared)
FVC (l)	5.06	0.03	0.04
FEV$_1$ (l)	0.05	0.02	0.00
FEV$_1$/FVC (%)	4.30	0.04	0.03
PEFR (l/s)	6.12	0.01	0.04
SGRQ	4.86	0.03	0.04

Discussion

Long-term inhalation of cotton dust leads to obstructive respiratory diseases such as pneumoconiosis.

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This study aimed to assess whether IMT with aerobic exercise provides additional benefits in cotton workers to increase lung function and excellence of life. Our study's results showed a statistical significance distinction ($p<0.05$) between groups. The control group also improved in FVC, FEV_1, FEV_1/FVC ratio, PEFR and SGRQ in the fourth week of treatment, but it was significantly less than the experimental group. Here, it is pertinent to note that IMT has an additional effect on strengthening inspiratory muscles, improving endurance level, increasing lung expansion and improving V/Q ratio to improve pulmonary function.

Wanke et al. (1994) suggested that inspiratory muscle training combined with cycle ergometer training increases the capacity of exercise, pulmonary function, and quality of life significantly more than cycle ergometer training alone. Ramírez-Sarmiento A et al. suggested that following the inspiratory muscle training, the proportion of type-I and diameter of type-II muscle fibres significantly increased in the intercostal muscles. It may be inferred from the current study that an increase in inspiratory muscle strength, neuromuscular adaptation and the rate of the depth of respiration indicates an improvement in pulmonary function and excellence of life during aerobic exercise and inspiratory muscle training (Ramírez-Sarmiento et al., 2002).

Various longitudinal studies were performed to assess the pulmonary functions in cotton workers and found statistically significant excessive annual decreases in FVC, FEV_1, FEV_1/FVC ratio, PEFR and quality of life (Ezema et al., 2022; Boaventura, 2022). The functional losses were considerably associated with collective endotoxin exposure. The cotton industry workers with a higher exposure level of collective endotoxin had considerably more significant pulmonary function losses than those with a low exposure level (Wanke et al., 1994; Wang et al., 2005; Christiani et al., 1996). In our study, there was a statistically significant difference ($p<0.05$) between the groups at 1-year follow-up and a decline in the FVC, FEV_1, FEV_1/FVC ratio, PEFR and SGRQ values in both groups. This indicates that pulmonary function and excellence of life decline slowly to baseline in both groups. However, compared to the control group, the decline ratio was lower in the experimental group. The decline of pulmonary function suggests that exposure to cotton dust and no training during the follow-up period leads to a deconditioning effect.

Conclusion

The present study demonstrates that respiratory muscle training and aerobic exercise lead to an improvement in cotton industry workers. Both groups showed improved lung function in FEV_1, FVC, FEV_1/FVC, and PEFR and quality of life in cotton industry workers. So, this study indicates that respiratory muscle training is an essential supplement to aerobic exercise for pulmonary rehabilitation to increase pulmonary function and quality of life in cotton industry workers. Considering the results of this study, it is recommended to include an inspiratory muscle trainer in the pulmonary rehabilitation program, which will increase pulmonary function by increasing inspiratory muscle strength and excellence of life. As female and elderly workers were not included in the sample, the results cannot be generalized.

Conflict of interest

None

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