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Comparative Evaluation of Incentive Spirometer and Diaphragmatic Breathing Exercise on Pulmonary Function and Functional Capacity in Drivers Exposed to Air-Conditioned and Non-Air-Conditioned Environments

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ABSTRACT

Background: Incentive spirometer (IS) and diaphragmatic breathing exercise (DBE) are simple, non-invasive interventions known to improve lung expansion, enhance ventilation, and strengthen respiratory muscles. To evaluate the effect of the Incentive spirometer and Diaphragmatic breathing exercise on pulmonary function, functional capacity, and perceived exertion in AC and non-AC drivers.

Methods: A pre- and post-experimental study was conducted in Urban and rural areas of Tirupati over 12 weeks. This study was conducted with 30 male drivers aged 20–50 years, divided into AC (n = 15) and Non-AC (n = 15) groups using convenience sampling. Anthropometric data (baseline measures such as age, height, weight, and BMI) were collected from all subjects. Pulmonary function (Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), FEV_1/FVC ratio was assessed using a portable spirometer. In contrast, functional capacity was evaluated through the Six-Minute Walk Test (6MWT) distance, and Borg Rate of Perceived Exertion (RPE) was noted. All participants performed the Incentive spirometer and Diaphragmatic breathing exercise for 12 weeks under supervision.

Results: Both groups showed significant improvement in pulmonary function and functional capacity ($p < 0.05$). Non-AC drivers demonstrated greater gains in pulmonary function and walking distance, whereas AC drivers showed a greater reduction in RPE scores.

Conclusion: This study on male drivers showed that the incentive spirometer and diaphragmatic breathing exercises significantly improved lung function and 6MWT distance and reduced exertion. Non-AC drivers had greater improvements, highlighting the role of the environment in respiratory adaptation. These findings support the addition of breathing exercises to occupational health programs for drivers.

Keywords: Incentive spirometer, diaphragmatic breathing, pulmonary function, functional capacity, AC and Non-AC drivers, occupational health.

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INTRODUCTION

Drivers frequently face issues such as prolonged sitting, limited chest expansion, exposure to vehicle pollution, and sedentary lifestyles, all of which can impair physical performance, cause muscle fatigue, and reduce lung capacity [1]. These elements may eventually raise the chance of cardiovascular and pulmonary issues as well. For those who drive for extended periods, pulmonary function is crucial because adequate lung ventilation and oxygen exchange are required to sustain physical well-being, alertness, and endurance [2].

Epidemiological studies among professional drivers report a high burden of respiratory morbidity. The reported prevalence of respiratory symptoms ranges from ~40% to 67%, depending on the occupational setting and assessment criteria. In Paris, taxi drivers working predominantly in air-conditioned vehicles reported that 40% had chronic respiratory or allergic disease, including allergic rhinitis (29%) and asthma (16%) [3]. Similarly, in an Indian cohort of state transport bus drivers, 67.1% reported respiratory symptoms in the past year, compared to 21.2% of controls, though HVAC type was not stratified [4].

In India, a cross-sectional study of state transport bus drivers documented chronic respiratory disease prevalence of 9.97% (95% CI: 7.34–14.66%) and chronic respiratory symptoms in 19.2% [5] Additionally, a Malaysian study on long-distance express bus drivers reported abnormal pulmonary function (FVC% and $FEV_1\% < 80\%$) in 50% of participants and abnormal FEV_1/FVC ratios in 46.7%, with common symptoms including phlegm (23.3%), cough (20%), wheeze (13.3%), and chest tightness (10%) [6].

Specific AC-related disease entities, such as hypersensitivity pneumonitis ("air-conditioner lung"), have been described in occupational settings, with outbreak prevalence as high as 15% when forced-air systems are contaminated. Though rare, these conditions highlight the potential for improperly maintained AC systems to disseminate fungal spores or bacteria, exacerbating respiratory morbidity [7].

Respiratory therapies such as IS and DBE have been used in the study to enhance ventilation and promote diaphragmatic activity. Breathing exercises like the Incentive Spirometer (IS) and Diaphragmatic Breathing Exercises (DBE) are non-pharmacological interventions shown to improve pulmonary function in individuals with sedentary occupations, including drivers. Incorporating these exercises into professional drivers' daily routines can be very effective in counteracting the harmful effects of extended sitting, minimizing the risk of atelectasis, and enhancing endurance, attention, and tolerance to long working hours [8].

The study objective aimed to determine the effects of the Incentive spirometer and Diaphragmatic breathing exercise on Pulmonary function, as measured by FVC, FEV1, and FEV1/FVC, using a Portable spirometer in drivers exposed to AC and Non-AC. To know the effect of the Incentive Spirometer and Diaphragmatic Breathing exercise on Functional capacity with the Six-minute walk test through Distance covered and Borg RPE in drivers exposed to AC and Non-AC.

METHODOLOGY

The study was conducted in both urban and rural areas of Tirupati. An experimental study design with a pre- and post-intervention approach was employed. A total of 30 participants were selected through convenience sampling, with a 12-week duration.

Participants who met the inclusion criteria were recruited, and informed consent was obtained before enrollment. Baseline measurements were recorded before the intervention, and post-intervention outcomes were assessed at the end of the study period to evaluate the intervention's effectiveness.

Male Drivers were included. Individuals used AC [drivers] regularly for at least 6 hours daily for the past 6 months, with no history of respiratory or cardiovascular disease: Non-AC users [drivers], Age group: 20 to 50 years. Subjects who are willing to participate in the study were included. Unstable angina, recent myocardial infarction within the previous months, COPD, tuberculosis, asthma, and subjects who are not willing to participate in the study were excluded.

Outcome Measures

Pulmonary function was measured using a Portable spirometer, and Functional capacity was measured through the 6 Minute walk test and the Borg RPE scale.

A conventional spirometer was used to measure changes in lung volume. The spirometer used in this study was the Contec SP80B Portable spirometer.

Study Procedure

The study commenced after obtaining Institutional Ethics Committee approval reference no. IEC NO: 1849). The study procedure was explained to the subjects who fulfilled the inclusion criteria, and after obtaining informed consent, demographic data were collected. Anthropometric data (baseline measures such as age, height, weight, and BMI) were collected from all subjects. Pulmonary function was assessed with a portable spirometer, and functional capacity was evaluated using the Six Minute Walk Test (6MWT). Subjects were divided into two groups: Drivers who used AC (AC users) and Drivers who did not use AC (NON-AC users). Both groups received the Diaphragmatic Breathing exercise along with the Incentive Spirometer. Reassessment of pulmonary function and functional capacity was performed at the end of 12 weeks.

Pulmonary function tests were measured using a Portable spirometer. A conventional spirometer was used to measure changes in lung volume. The spirometer used in this study was a Contec SP80B Portable spirometer. Data were acquired from different subjects, where each time, the change in lung volume during the respiration protocol was recorded. Simultaneously capture thermal images and respiratory volume data using a Contec SP80B spirometer, and measure spirometric parameters such as FEV1, FVC, and FEV1/FVC ratio. Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), Ratio of FEV1to

FVC(FEV1/FVC).

PFT measurements were performed using the equipment, with a minimum of 3 readings per occasion at 15-minute intervals, and the maximum values were recorded. Spirometry parameters such as FVC, FEV1, and FEV1/FVC ratio were recorded in the sitting position. Three recordings were taken, and the best effort was recorded at 15-minute intervals, with the maximum value recorded. All recordings were done between 9 AM and 11 AM to eliminate the effect of diurnal variation.

Functional capacity was evaluated using the Six-Minute Walk Test (6MWT) [9]. During the test, the subject stood and rated their baseline dyspnea and overall fatigue using the Borg RPE [Rate of perceived exertion] scale [10]. The lap counter was set to zero, and the timer was set to 6 minutes. The subject then walked at a comfortable pace, and every lap was marked on the sheet. The distance walked was calculated.

Study Protocol

Both groups received incentive spirometer (IS) training combined with diaphragmatic breathing exercise (DBE). The Incentive spirometer used in this study was a Romsons Respirometer (SH-6082). Subjects were instructed to perform slow, deep inhalations to reach maximum inspiratory volume, maintain target flow, and avoid rapid exhalation. Diaphragmatic breathing emphasized engaging the diaphragm, relaxing neck and shoulder muscles, and promoting slow, deep breaths to improve lung expansion, respiratory muscle strength, and oxygenation. The treatment protocol was conducted over 12 weeks, starting with 5 sessions/week (weeks 1–4), progressing to 6 sessions/week (weeks 5–8), and then to 7 sessions/week (weeks 9–12), with each session lasting 10 minutes and including 2 repetitions. Before the treatment, anthropometric data were recorded, pre-test values were obtained, and post-test values were obtained after 12 weeks.

The Physiotherapy treatment aimed to improve lung volumes, strengthen respiratory muscles, and prevent airway collapse or air trapping by using an incentive spirometer properly and combining it with diaphragmatic breathing.

Figure 1: FVC, FEV1 measuring by Contec SP80B Spirometer

Figure 2: Subject performing IS exercise

Figure 3: Subject performing DBE

Figure 4: Measuring 6MWT (Distance covered)

Statistical Analysis

The data were analyzed using SPSS software version 22. Individual data were analyzed by intention-to-treat; all continuous data were assessed for normality. Data following normal distribution were expressed as mean and standard deviation and analyzed using parametric tests (paired t-test for within-group comparisons and independent t-test for between-group comparisons). Data that did not follow a normal distribution were analyzed using nonparametric tests (the Wilcoxon test for within-group comparisons and the Mann–Whitney test for between-group comparisons). A "p" value of <0.05 was considered statistically significant. Within-group differences were assessed to determine changes from baseline to post-intervention for each group (AC users and non-AC users). Between-group differences were analyzed using change scores (delta values).

RESULTS

The results were analyzed using SPSS 22, the statistical analysis software used for the study. Outcome measures were taken before and at the end of the 12th week, and the values were tabulated using MS Excel.

Table 1: Demographic Data

Variable	AC Users (Mean ± Sd)	Non-Ac Users (Mean ± Sd)	p -Value
Age	35.33 ± 7.76	37.06 ± 9.46	0.588
Height	174.93 ± 5.89	175.73 ± 5.25	0.698
Weight	68.47 ± 3.20	73.6 ± 7.88	0.027
BMI	22.33 ± 1.35	23.82 ± 2.22	0.036

Table 1 compares the baseline characteristics of individuals who use air conditioning (AC users) and those who don't (non-AC users). Non-AC users were slightly older (37.06 ± 9.46 vs. 35.33 ± 7.76 years), heavier (73.6 ± 7.88 vs. 68.47 ± 3.20 kg), and had a higher BMI (23.82 ± 2.22 vs. 22.33 ± 1.35) compared to AC users, while height was similar between groups (175.73 ± 5.25 vs. 174.93 ± 5.89 cm).

Table 2: Pre-Treatment Data of Pulmonary Function Test And 6MWT

Variable	AC Users (Mean ± Sd)	Non-AC Users (Mean ± Sd)
PRE FVC	3.20 ± 0.39	3.94 ± 0.23
PRE FEV1	2.51 ± 0.40	3.29 ± 0.25
PRE FEV1/FVC	78.33 ± 6.28	83.23 ± 3.62
PRE WALK RPE	8.20 ± 1.78	7.53 ± 0.91
6MWT (DISTANCE)	409.733 ± 38.95	417.00 ± 21.82
Post Walk RPE	13.53 ± 1.50	11.93 ± 1.03

Table 2 shows that AC users had lower pre-FVC (3.20 ± 0.39 vs. 3.94 ± 0.23 L), pre-FEV_1 (2.51 ± 0.40 vs. 3.29 ± 0.25 L), and FEV_1/FVC ratio (78.33 ± 6.28 vs. 83.23 ± 3.62) than non-AC users. Pre-walk RPE was slightly higher in AC users (8.20 ± 1.78 vs. 7.53 ± 0.91). The 6MWT distance was similar (409.73 ± 38.95 vs. 417.00 ± 21.82 m), while post-walk RPE remained higher in AC users (13.53 ± 1.50 vs. 11.93 ± 1.03).

Table 3: Post-Treatment Data of Pulmonary Function Test And 6MWT

Variable	AC Users (Mean ± SD)	Non-AC Users (Mean ± SD)
POST FVC	3.86 ± 0.266	4.47 ± 0.34
POST FEV1	3.28 ± 0.31	3.89 ± 0.27
POST FEV1/FVC	84.86 ± 3.93	87.12 ± 3.71
PRE WALK RPE	7.4 ± 0.73	6.8 ± 0.77
6MWT (DISTANCE)	434.8 ± 48.91	616.0 ± 45.90
POST WALK RPE	12.53 ± 0.99	10.33 ± 1.23

Table 3 describes that Post-intervention, AC users showed lower FVC (3.86 ± 0.27 vs. 4.47 ± 0.34 L), FEV_1 (3.28 ± 0.31 vs. 3.89 ± 0.27 L), and FEV_1/FVC ratio (84.86 ± 3.93 vs. 87.12 ± 3.71)

compared to non-AC users. Pre-walk RPE was higher in AC users (7.4 ± 0.73 vs. 6.8 ± 0.77). The 6MWT distance was markedly shorter (434.8 ± 48.91 vs. 616.0 ± 45.90 m), and post-walk RPE remained higher (12.53 ± 0.99 vs. 10.33 ± 1.23).

For both AC and non-AC users, most lung function measurements (like FVC, FEV1, and FEV1/FVC) followed a regular pattern, and the tests used were similar to the t-test. This means their lung function values were evenly distributed. However, some measurements, such as perceived exertion (RPE) and walking distance, did not follow a normal distribution, especially among AC users, so non-parametric tests such as the Wilcoxon or Mann-Whitney test were used.

Table 4: Within-Group Comparisons (Paired t-test)

Variable		Mean (Before)	Mean (After)	Mean Difference	t-Value	p-Value
AC USERS	FVC	3.20	3.86	0.66	9.05	0.00
	FEV1/FVC	78.33	84.86	6.53	6.62	0.00
NON-AC USERS	FVC	3.94	4.313	0.373	4.09	0.00
	FEV1/FVC	82.293	87.12	4.82	7.486	0.00

Table 4 describes lung capacity (FVC) in AC users, which improved from 3.20 to 3.86, and their FEV1/FVC ratio increased from 78.33% to 84.86%. These changes were statistically significant.

Similarly, non-AC users also improved their FVC, which increased from 3.94 to 4.31, and their FEV1/FVC ratio rose from 82.29% to 87.12%. However, the amount of improvement was greater in non-AC users, especially in FVC.

Table 5: Within-Group Comparisons (Wilcoxon Test)

Variable		Positive Ranks	Negative Ranks	Z value	p- value
AC USERS	POST FEV1 VS PRE FEV1	15	0	3.41	0.00
	PRE WALK RPE VS POST WALK RPE	4	6	1.4	0.13
	6MWT VS 6MWT	10	4	0.787	0.04
	POST WALK RPE VS PRE WALK RPE	3	10	2.1	0.03
NON AC USERS	POST FEV1 VS PRE FEV1	15	0	3.306	0.00
	PRE WALK RPE VS POST WALK RPE	2	9	1.87	0.06
	POST 6MWT VS PRE 6MWT RPE	15	0	3.416	0.01
	POST WALK RPE VS POST WALK RPE	5	8	0.411	0.41

Table 5 shows a within-groups comparison of changes in non-normal data. The Wilcoxon signed-rank test showed significant improvements in FEV_1 and 6MWT in both groups. AC users also reported reduced post-walk RPE, indicating less exertion, while non-AC users improved in lung function and walking distance, but perceived effort remained unchanged.

Table 6: Group Comparisons (Independent t Test)

Variable	AC Users Mean	Non-AC Users Mean	Mean Difference	t Value	p-value
DELTA FVC	0.373	0.660	0.28	2.454	0.02
DELTA FEV 1/FVC	3.88	6.52	2.64	2.379	0.02

Table 6: Compare the extent of improvement between the two groups, changes (deltas) in FVC and FEV1/FVC were analyzed using an independent t-test, showing greater improvements in non-AC users for FVC (0.66 vs. 0.37) and FEV_1/FVC (6.52 vs. 3.88), both statistically significant ($p = 0.021$), indicating they benefited more due to lower baseline values.

Table 7: Group Comparisons (Mann-Whitney Test)

Variable		Mean Rank	U Value	Z Value	P -Value
DELTA FEV1	AC Users	15.50	112.50	0.00	1.08
	Non-AC Users	15.50			
DELTA 6MWT	AC Users	14.97	0.500	4.655	0.00
	Non-AC Users	16.03			
DELTA PRE RPE	AC Users	22.97	104.50	0.33	0.73
	Non-AC Users	8.03			
DELTA POST RPE	AC Users	17.97	75.50	1.56	0.118
	Non-AC Users	13.03			

Table 7 presents the results of the Mann-Whitney U test comparing the change (delta) between AC and non-AC users for variables that were not normally distributed. Mann-Whitney U test showed no group differences in FEV_1, pre-walk RPE, or post-walk RPE. However, delta 6MWT was significantly greater in non-AC users ($U = 0.50$, $p < 0.001$), indicating superior improvement in walking distance.

DISCUSSION

This study was conducted on 30 subjects, divided into two groups: AC drivers and Non-AC drivers. They were trained to use an incentive spirometer and to perform diaphragmatic breathing exercise. The findings of this study indicate that both groups showed significant improvement in pulmonary function parameters and 6-minute walk distance, and a reduction in dyspnea, indicating that the intervention was effective regardless of AC exposure. However, non-AC drivers showed greater improvement in pulmonary function parameters and functional capacity than AC drivers.

This study investigated the comparative effects of incentive spirometer (IS) and diaphragmatic breathing exercise (DBE) on pulmonary function and functional capacity among drivers working in air-conditioned (AC) and non-air-conditioned (non-AC) environments. Both groups demonstrated significant improvement in FVC, FEV_1, FEV_1/FVC ratio, 6MWT distance, and reduction in Borg RPE scores after 12 weeks of intervention, confirming the efficacy of IS and DBE as low-cost, non-invasive respiratory rehabilitation tools.

Non-AC drivers showed greater improvements in FVC and FEV_1 compared to AC drivers. This finding can be explained by their higher baseline exposure to heat, dust, and traffic-related pollutants, which have been shown to reduce lung volumes and airflow. Lai et al. (2005) [11] reported that non-AC bus drivers in Hong Kong had lower FVC and FEV_1 and more respiratory symptoms than AC drivers, findings that support the present study's baseline results. Similarly, Bener et al. (1997) [12] found that taxi drivers, mostly driving non-AC vehicles, had lower lung function than manual laborers due to chronic exposure to exhaust. These studies indicate that pollutant exposure leads to airway obstruction and reduced lung compliance, leaving more room for improvement when respiratory training is introduced.

AC drivers, on the other hand, also improved in PFT parameters, but to a lesser extent. This aligns with the findings of Badaam et al. (2015) [5], who observed that prolonged exposure to cold, dry air from air conditioners can increase airway resistance and reduce diaphragmatic excursion. Thus, although AC protects drivers from external pollutants, it still poses respiratory challenges that can be partially mitigated through IS and DBE.

The Six-Minute Walk Test (6MWT) was used to measure functional endurance, which depends on both cardiopulmonary efficiency and muscular oxygen delivery. Non-AC drivers showed greater improvement in walking distance than AC drivers. This may be because their baseline functional capacity was more affected by heat stress and polluted environments, leading to greater measurable benefits when trained. Roy et al. (2024) [13] found that rural, non-AC drivers had lower baseline 6MWT performance but responded well to breathing interventions, findings that parallel those of the current study.

AC drivers also improved in 6MWD, but their most notable gain was a reduction in perceived exertion (RPE). This suggests that IS, which provides visual feedback for sustained inspiration, was especially helpful for AC drivers, who often adopt shallow breathing patterns in cooled environments. These results are consistent with Sharma & Shweta (2019) [14], who found that IS and DBE improved breathing comfort in individuals working long hours in AC settings.

In non-AC drivers, IS reopens under-ventilated alveoli that may be partially obstructed by pollutant exposure, thereby improving pulmonary function and functional endurance as reflected in higher FVC, FEV_1, and six-minute walk distance (6MWD) [15] in AC drivers, IS counteracts the airway resistance and small airway closure associated with cold, dry air inhalation, leading to improvements in inspiratory capacity and greater ease of breathing[16] This contributes to reduced dyspnea and lower ratings of perceived exertion.

Taken together, the physiological changes produced by DBE and IS explain the improvements observed in both pulmonary function tests and functional capacity. While non-AC drivers showed greater objective improvements in lung volumes and walking distance, AC drivers reported greater subjective relief in breathing comfort and reduced exertion. These differences highlight the influence of environmental exposure on respiratory adaptations and underscore the relevance of incorporating both techniques in occupational health programs for professional drivers.

The results also reinforce the role of environmental factors in influencing respiratory adaptation. While AC reduces exposure to pollutants, it introduces cold, dry air, which can increase airway resistance. Non-AC environments expose drivers to unfiltered dust and pollutants, leading to chronic respiratory strain. Therefore, tailored respiratory training (IS for AC drivers, DBE for Non-AC drivers) could be an effective occupational health strategy.

CONCLUSION

The findings of this study indicate that the intervention significantly improved lung volumes, 6-minute walk distance, and perceived exertion in both groups. Non-AC drivers achieved greater objective improvements in pulmonary function and walking distance, and a reduction in perceived exertion, than AC drivers. These results highlight the role of environmental exposure in influencing respiratory adaptations. Therefore, it is recommended that occupational health programs for drivers incorporate an incentive spirometer and diaphragmatic breathing exercise to enhance respiratory health and functional capacity.

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