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SPIROMETRIC EVALUATION OF LUNG FUNCTION IN AGRICULTURAL WORKERS COMPARED WITH HEALTHY CONTROLS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Agricultural workers are exposed to organic and inorganic dusts, endotoxins, pesticides and fertilisers that can impair respiratory health. Field-based spirometric data from Indian farm workers remain limited. **Objective:** To compare forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, forced expiratory flow between 25% and 75% of FVC ($FEF_{25–75}$) and peak expiratory flow (PEF) between agricultural workers and healthy controls with sedentary occupations.

Materials and Methods: In this cross-sectional study, 250 male agricultural workers and 250 healthy male controls were enrolled at chittor district between 8am to 12pm. Anthropometric and cardiovascular parameters were recorded and spirometry was performed using a computerised spirometer (RMS Medspiror). Groups were compared using Welch's t-test; $p < 0.05$ was considered significant.

Results: Farm workers were older than controls (57.9 ± 8.3 vs 29.8 ± 7.6 years) and had higher body mass index and blood pressure (all $p < 0.001$). All spirometric indices were significantly lower in farm workers: FVC 1.55 ± 0.39 vs 4.22 ± 0.55 L, FEV_1 1.07 ± 0.38 vs 4.27 ± 0.52 L, $FEF_{25–75}$ 0.92 ± 0.62 vs 6.82 ± 1.03 L/s and PEF 3.00 ± 1.10 vs 8.33 ± 1.17 L/s (all $p < 0.001$). The mean FEV_1/FVC ratio in farm workers was 0.685 ± 0.127.

Conclusion: Agricultural workers had markedly lower lung function than controls, with a pattern suggestive of airflow obstruction. Because the groups differed substantially in age, the findings should be confirmed using age-, height- and smoking-adjusted reference values. Periodic spirometric screening of farm workers is recommended.

Keywords: Agricultural workers' diseases; Occupational exposure; Organic dust; Respiratory function tests; Spirometry; India.

INTRODUCTION

Agriculture remains the largest source of employment in India and is recognised as one of the most hazardous occupations worldwide.[1,2] Respiratory disease was among the first occupational hazards of farming to be described: Olaus Magnus warned of the dangers of inhaling grain dust in 1555, and Ramazzini again noted the risk in *De Morbis Artificum* in 1700.[2] Farm workers are exposed to a complex mixture of respiratory hazards, including organic dusts from grain, hay and animal housing; microorganisms and their products such as endotoxins, glucans and fungal spores; pesticides, fertilisers, solvents and fuels; toxic gases from silos and animal waste, such as ammonia, hydrogen sulphide and oxides of nitrogen; and inorganic dusts such as silica.[1-3]

These exposures produce a spectrum of disease that involves the whole respiratory tract, including rhinitis, asthma and asthma-like syndrome, chronic bronchitis, chronic obstructive pulmonary disease (COPD), organic dust toxic syndrome and hypersensitivity pneumonitis (farmer's lung).[1,2] Pesticide use has been associated with wheeze, chronic bronchitis and adult-onset asthma among farmers,[4-6] and a history of pesticide poisoning with lower FVC and FEV_1.[7] Farmers exposed to high dust concentrations have a higher prevalence of

asthma symptoms and chronic respiratory disease [8–10], and longitudinal studies in dairy farmers have linked traditional farming practices with poorer and more rapidly declining lung function.[11,12]

In India, many farm workers handle fertilisers and pesticides with few protective measures, and limited access to health care in rural areas means that respiratory disease often presents late. Indian data on lung function in this population, particularly from field-based testing, remain limited.[13] Spirometry is simple, non-invasive and portable, which makes it well suited to screening in field settings.[14,15]

We therefore aimed to measure FVC, FEV_1, the FEV_1/FVC ratio, $FEF_{25–75}$ and PEF in agricultural workers and to compare them with those of healthy controls engaged in sedentary occupations.

MATERIALS AND METHODS

Study design and setting

This cross-sectional comparative study was conducted at chittor district, Andhra Pradesh and the Department of Physiology, SVIMS, University between 2020 to 2021.

Ethical considerations

The study was approved by the Institutional Ethics Committee of SVIMS, University. The purpose of the study was explained to each participant in the local language, and written informed consent was obtained. Participants were assured that their information and test results would remain confidential and would not be shared with any agency or employer. The study was conducted in accordance with the Declaration of Helsinki.

Participants

Group I comprised 250 male agricultural workers recruited from Chittor. Their work included mixing organic manure with chemical fertilisers, harvesting, dusting and spraying insecticides, for approximately 10 hours a day. Group II comprised 250 healthy males engaged in sedentary occupations, recruited from the staff of SVIMS University, with no history of occupational exposure to dust or chemicals.

Inclusion Criteria: Were male sex, age 30 to 56 years, at least 10 to 20 years of farm work (Group I), and willingness to participate with written informed consent.

Exclusion Criteria: Were current or past tuberculosis, pneumonia, COPD or other known chronic respiratory disease, other exclusions, e.g., recent thoracic/abdominal surgery, cardiac disease, inability to perform spirometry, and unwillingness to participate.

Clinical and anthropometric assessment

Each participant was evaluated with a standardised proforma that recorded personal, occupational, smoking and family history, followed by a physical examination. Measurements were taken in the fasting state, with participants in light clothing and without shoes. Weight (kg) was measured with a Karada Scan body composition analyser and height (cm) with wall-mounted stadiometer. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Heart rate (HR) and blood pressure were recorded. Mean arterial pressure (MAP) was calculated as DBP + (SBP − DBP)/3 and the rate–pressure product (RPP) as HR × SBP/100.

Spirometry

Spirometry was performed on the day after the clinical assessment, with 5–10 participants tested per day in the field, using a PC-based computerised spirometer (RMS Medspiror; Recorders and Medicare Systems, Chandigarh, India). Participants were asked to avoid a heavy meal, smoking and hot drinks for 4–6 hours before testing, and those using bronchodilators withheld them for 48 hours. The procedure was explained and demonstrated beforehand. With the participant seated and wearing a nose clip, a disposable mouthpiece was placed in the mouth; after a few tidal breaths, the participant inhaled maximally and then exhaled as forcefully, rapidly and completely as possible. Three acceptable manoeuvres were obtained, and the mean of the three values was used for analysis.[14] Testing was stopped if the participant developed significant headache or chest or abdominal pain. The parameters recorded were FVC, FEV_1, FEV_1/FVC, $FEF_{25–75}$ and PEF.

Statistical analysis

Data were entered in Microsoft Excel and analysed using SPSS 26.0. Continuous variables are presented as mean ± standard deviation (SD). Normality was assessed using the Shapiro–Wilk test. Groups were compared using Welch's unequal-variance t-test, and results are reported as mean differences with 95% confidence intervals (CIs). Effect sizes were expressed as Hedges' g. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

Participant characteristics

A total of 500 men were studied, 250 in each group. Their characteristics are summarised in Table 1. Farm workers were significantly older than controls (mean difference 28.1 years; 95% CI 26.7–29.5; $p < 0.001$). They also had higher weight, BMI, heart rate, systolic, diastolic and mean arterial pressure and rate–pressure product (all $p < 0.001$), whereas height differed only marginally (mean difference 1.6 cm; $p = 0.020$).

Spirometric parameters

All spirometric indices were significantly lower in farm workers than in controls (Table 2, Figure 1). Mean FVC was 2.67 L lower (95% CI 2.59–2.75), FEV_1 3.20 L lower (95% CI 3.12–3.28), $FEF_{25–75}$ 5.89 L/s lower (95% CI 5.74–6.04) and PEF 5.32 L/s lower (95% CI 5.12–5.52) in farm workers (all $p < 0.001$). The mean FEV_1/FVC ratio in farm workers was 0.685 ± 0.127, below the conventional fixed threshold of 0.70. The standardised mean differences for all measured variables are shown in Figure 2; the

spirometric differences were large, with effect sizes ranging from −4.7 for PEF to −7.0 for FEV_1

Table 1: Demographic, anthropometric and cardiovascular characteristics of the study participants

Characteristic	Farm workers (n = 250)	Controls (n = 250)	Mean difference (95% CI)	p-value
Age (years)	57.93 ± 8.31	29.83 ± 7.62	28.10 (26.70 to 29.50)	< 0.001
Height (cm)	158.70 ± 8.70	157.10 ± 6.52	1.60 (0.25 to 2.95)	0.020
Weight (kg)	69.01 ± 9.11	59.81 ± 7.02	9.20 (7.77 to 10.63)	< 0.001
BMI (kg/m^2)	27.55 ± 3.04	23.62 ± 2.04	3.93 (3.48 to 4.39)	< 0.001
Heart rate (beats/min)	77.35 ± 3.26	74.79 ± 2.49	2.56 (2.05 to 3.07)	< 0.001
SBP (mmHg)	129.90 ± 3.57	124.40 ± 5.25	5.50 (4.71 to 6.29)	< 0.001
DBP (mmHg)	84.52 ± 2.44	81.87 ± 2.82	2.65 (2.19 to 3.11)	< 0.001
MAP (mmHg)	99.65 ± 2.09	96.09 ± 2.58	3.56 (3.15 to 3.97)	< 0.001
RPP (beats·mmHg/min × 10^{-2})	100.50 ± 5.30	93.08 ± 5.14	7.42 (6.50 to 8.34)	< 0.001

Values are mean ± SD. All participants were male. p-values from Welch's t-test. BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; RPP, rate–pressure product; CI, confidence interval.

Table 2: Comparison of spirometric parameters between farm workers and controls

Parameter	Farm workers (n = 250)	Controls (n = 250)	Mean difference (95% CI)	Hedges' g	p-value
FVC (L)	1.55 ± 0.39	4.22 ± 0.55	−2.67 (−2.75 to −2.59)	−5.62	< 0.001
FEV1 (L)	1.07 ± 0.38	4.27 ± 0.52*	−3.20 (−3.28 to −3.12)	−6.98	< 0.001
FEV1/FVC	0.685 ± 0.127	1.00 ± 0.00*	—	—	—
FEF25–75 (L/s)	0.92 ± 0.62	6.82 ± 1.03	−5.89 (−6.04 to −5.74)	−6.92	< 0.001
PEF (L/s)	3.00 ± 1.10	8.33 ± 1.17	−5.32 (−5.52 to −5.12)	−4.69	< 0.001

Values are mean ± SD. p-values from Welch's t-test. FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEF25–75, forced expiratory flow between 25% and 75% of FVC; PEF, peak expiratory flow; CI, confidence interval.

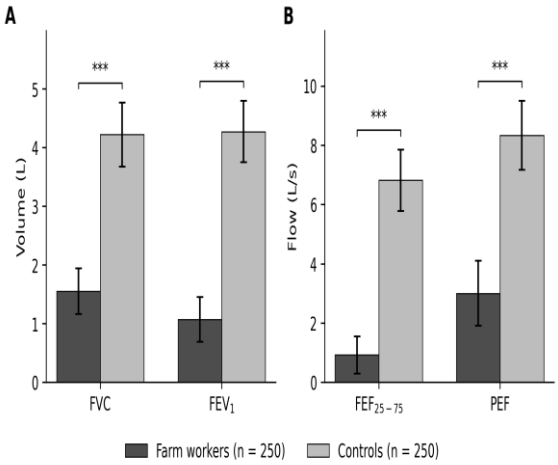


Figure 1: Spirometric volumes (A) and flows (B) in farm workers and controls. Bars show mean and error bars show SD. ***p < 0.001 (Welch's t-test). FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEF25–75, forced expiratory flow between 25% and 75% of FVC; PEF, peak expiratory flow.

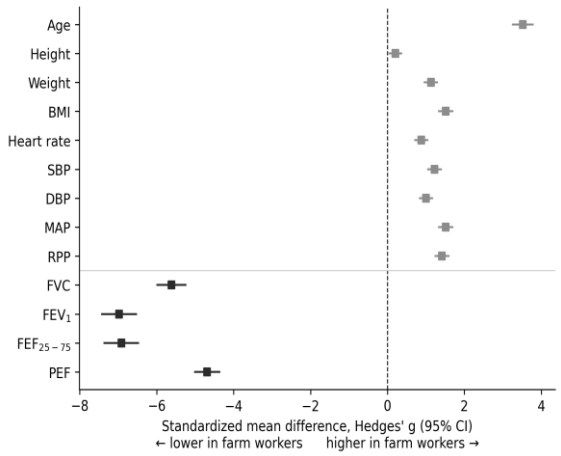


Figure 2: Standardised mean differences (Hedges' g, with 95% CI) between farm workers and controls for demographic, anthropometric, cardiovascular (grey) and spirometric (black) variables. Negative values indicate lower values in farm workers. BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; RPP, rate–pressure product.

DISCUSSION

In this cross-sectional study, agricultural workers had substantially lower FVC, FEV_1, $FEF_{25–75}$ and PEF than healthy sedentary controls, and their mean FEV_1/FVC ratio fell below 0.70. Taken together, these findings suggest predominantly obstructive impairment, involving both the larger airways

(reduced FEV_1 and PEF) and the small airways (reduced $FEF_{25–75}$).

Our findings are consistent with earlier reports. Khatib et al. found significantly lower FVC, FEV_1 and FEV_1% in grain workers than in sedentary workers in Wardha district.[13] Dalphin et al. reported poorer lung function among dairy farmers using traditional fodder storage than among those using barn drying,[11] and Beseler and Stallones showed that pesticide poisoning was associated with lower FVC and FEV_1.[7] In a review of farming populations from temperate zones, Omland noted that FEV_1 and FEV_1/FVC appear to be reduced in farmers and that longitudinal studies indicate an accelerated annual decline in FEV_1.[3] Gainet et al., in a 12-year follow-up, found that accelerated decline in vital capacity and FEV_1 was associated with age, smoking and male sex, and that decline in vital capacity was faster in dairy farmers working on traditional farms,[12] while modernisation of the farm environment has been associated with better lung function.[23]

Several mechanisms may explain these findings. Organic dusts contain biologically active compounds that, together with co-existing toxic gases, may have additive or synergistic effects on the airways.[1,2] Bacterial endotoxins, heat-stable lipopolysaccharides whose biological activity resides in lipid A, provoke neutrophilic airway inflammation.[17,18] Grain dusts and animal danders contain allergenic proteins, and more than 250 agents have been identified as causes of immunological occupational asthma,[19] irritant exposures can also induce asthma through epithelial injury and neurogenic inflammation.[20,21] Pesticide exposure has independently been associated with wheeze, chronic bronchitis and asthma.[4-6] The reduction in FVC observed here may reflect air trapping secondary to obstruction, but a restrictive component cannot be excluded, since hypersensitivity pneumonitis commonly produces a restrictive defect,[22] spirometry alone cannot distinguish between these possibilities.

The magnitude of the differences observed in this study is considerably larger than in most previous reports.[3,11,13] This is at least partly explained by the large difference in age between the groups, because lung function declines with age, and possibly by differences in smoking habits.

Strengths and limitations

The strengths of this study include a relatively large sample, the use of a standardised protocol in a field setting and the measurement of several complementary spirometric indices. It also has important limitations. First, the groups were not matched for age; farm workers were on average 28 years older than controls, so part of the observed difference reflects normal ageing. Second, lung function was compared as absolute values rather than as percentage of predicted values or z-scores derived from appropriate reference equations,[15,16] such adjustment for age and height would allow a more valid comparison. Third, smoking status, which is a major determinant of lung function, was not adjusted for. Fourth, the mean of three manoeuvres was used rather than the largest value recommended by current standards,[14] and post-bronchodilator testing was not performed, so reversibility could not be assessed. Fifth, occupational exposure was not quantified, and the cross-sectional design precludes causal inference. Finally, only men from a single site were studied, which limits generalisability.

Implications

Agricultural workers in this setting showed evidence of considerable respiratory impairment. Portable spirometry is a practical tool for periodic screening in rural areas, allowing early detection and referral of affected workers to a pulmonologist. Education about the hazards of agricultural dusts and chemicals, together with the use of personal protective equipment, should be promoted. Future studies should use age-matched controls, reference-equation-based interpretation, post-bronchodilator testing and multivariable analysis adjusting for smoking and exposure.

CONCLUSION

Agricultural workers had significantly lower FVC, FEV_1, FEV_1/FVC, $FEF_{25–75}$ and PEF than healthy sedentary controls, consistent with airflow obstruction. Because the groups differed markedly in age, these findings should be confirmed using predicted values and adjustment for confounders. Regular spirometric screening, awareness programmes and respiratory protection are recommended for farm workers.

Declarations

Ethics approval and consent to participate: Approved by the Institutional Ethics Committee of SVIMS University. Written informed consent was obtained from all participants.

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Conflict of interest: The authors declare no conflict of interest.

Data availability: The data supporting the findings of this study are available from the corresponding author on reasonable request.

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