CHANGES OF VENTILATORY FUNCTION AMONGST SMOKERS AND NON-SMOKERS*

By

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Tobacco smoke contains a number of substances which may exert some effects upon the body. They include particles of the smoke dust which disturb the function of the respiratory airways, tar which exerts an irritant effect upon the bronchial epithelium and nicotine which increases the heart rate and elevates the systolic blood pressure (17, 19, 20). The inhalation of tobacco smoke causes an immediate rise in the airway resistance, which persists for at least an hour. Nadel and Widdicombe (14) have shown that this change is a reflex response to the deposition of particles of dust upon the epithelial lining of the airway passage, but is not specific to tobacco smoke alone. The intensity of the response varies from smoker to smoker. Medermot (10) has shown that it is maximum in those who bring up sputum.

The notoriety of the effect of tobacco smoke is well publicised and sometimes in exaggeration of its actual harmful effect. The enormous literature on the subject has proved it beyond doubt that the tobacco smoke has definite ill effect on the ventilatory function. As already pointed out, there are reports that the effect of tobacco smoking is more prominent in subjects, who produce sputum, or who have asthmatic tendency, or who are exposed to other hazardous conditions. In this regard, Hong et al. (9) have commented that the lungs may tolerate one irritant reasonably well but react adversely when exposed to two or more. Now, it poses a problem, whether the tobacco smoke alone is pathogenic or it only aggravates the pathogenicity of the other hazards. To look deep into this problem, it is desirable to study the effect of smoking in various climatic and atmospheric conditions. If the reported effects are specific for tobacco smoke, then the changes should move in the similar direction, but if not, then the changes may be varied in nature. Edelman et al. (6) have reported that the mean values of VC, FEV₁, and MVV, adjusted to 50 years of age and a height of 176 cm. are significantly lower both in cigarette smokers and ex-smokers than in non-smokers, but pipe and cigar smokers showed the same values as non-smokers. This study indicates that some harmful substances are present in cigarettes, but not in the tobacco. On the other hand, Wilhelmensen and Tibblin (21) have reported that they have found no significant difference in frequency of symptoms between smokers of cigarettes and smokers of pipes or cigars or both, with the same daily tobacco consumption and that the lung function tests show uniform tendency of deterioration with increasing tobacco consumption. These two last mentioned studies are

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apparently contradictory, one reporting a difference between the cigarette, pipe and cigar smokers, but the other reporting no such difference. This gives a clear indication of some unknown parameters which might have influenced the conditions. There is another conflicting report by Payne and Kjelsberg (16). They have reported that the cigarette smokers in the age group of 16-19, show a higher mean value of ventilatory capacity than non-smokers and there is no marked difference between cigarette smokers and non-smokers amongst women. These anomalies might be due to either varied climatic and atmospheric conditions or defective sampling of the population and the results being obtained by chance.

Almost the entire literature on this subject is of Western origin based on the studies carried out in those countries. The climatic conditions are naturally different in those countries from that of India. So, it has been thought worthwhile to undertake a study, which might help to know the effects of tobacco smoke on ventilatory function of Indian subjects in comparison to the already available results from other countries. It is also expected that this knowledge will help in forming the ‘norms’ of ventilatory function of Indian subjects by giving due weightage to the interfering effect of smoking, if there is any.

MATERIALS AND METHODS

Experimental subjects were selected from the administrative and laboratory staff members of Central Mining Research Station and all of them were males. The subjects were in the age range of 25—40 years, height 150—178 cms and weight 37—69 kg. The subjects did not give any history of frank complaint of cardio-respiratory origin, except three subjects who had mentioned about their proneness to common cold. But all the subjects were free from any respiratory complaint during the time of study. In the smokers group were taken 18 subjects and in the non-smokers group 14 subjects. For all the subjects the forced vital capacity (FVC) and forced expiratory volume for one second (FEV1.0) were determined by using the Jones Air-Basal Metabolism unit following the method reported earlier from this laboratory (4). These determinations were made once during the year 1963-64 and again during early part of 1969. This was done to observe the long term effect of cigarette smoking on the ventilatory function in comparison to changes in non-smokers. In order to find out the diurnal variation in ventilatory function, 6 subjects were selected from each group and FVC, FEV1.0 and Mean Maximal Expiratory Flow between 50—75% of FVC (MMEF50-75%) were recorded once between 9-30 a.m. to 10-00 a.m. and again between 4-30 p.m. to 5-00 p.m. The smokers were requested not to smoke for one and a half hour prior to these determinations. Both in the forenoon and afternoon, three to four recordings were made for each subject and the best one analysed for final results. MMEF50-75% was expressed as lit/sec.

For the determination of immediate effect of smoking on ventilatory function another group of eight subjects was selected from the subjects mentioned above. To avoid reflex broncho-constriction these subjects were also not allowed to smoke for about one and a half hour prior to these determinations. The determinations of lung function were made one
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group were taken 18 subjects the forced vital capacity (FVC) examined during the year of 1963-64 and the other during the early part of 1969, for

both the smokers and non-smokers. This table also showed the percentage reduction of FVC

and FEV$_1$ during the period of interval between the two experiments. The results showed that while there was reduction in both the cases and in both the items, the reduction in FVC was more than FEV$_1$ amongst the smokers, whereas the reduction of FEV$_1$ was more than the FVC amongst the non-smokers.

**Table I**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>No. of subjects</th>
<th>Year of determination</th>
<th>FVC in lit. Mean ± SD</th>
<th>FEV$_1$ in lit. Mean ± SD</th>
<th>Percent change of FVC</th>
<th>Percent change of FEV$_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokers</td>
<td>18</td>
<td>1963-64</td>
<td>3.757 ± 0.403</td>
<td>2.903 ± 0.474</td>
<td>-10.2</td>
<td>-6.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1969</td>
<td>3.374 ± 0.449</td>
<td>2.723 ± 0.462</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Smokers</td>
<td>14</td>
<td>1963-64</td>
<td>3.718 ± 0.475</td>
<td>3.048 ± 0.469</td>
<td>-8.4</td>
<td>-12.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1969</td>
<td>3.403 ± 0.432</td>
<td>2.663 ± 0.397</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The same thing was also shown graphically in Fig. 1.

*Fig 1* Change of forced vital capacity and forced expiratory volume for 1.0 second over the period of five years among smokers and non-smokers.
In Table 2, the mean values with ± S.D. of FVC, FEV\textsubscript{1.0} and MMEF \textsubscript{50-75\%} for smokers and non-smokers, measured in the forenoon and afternoon were given.

### Table II

Diurnal variation of FVC, FEV\textsubscript{1.0} and MMEF \textsubscript{50-75\%} amongst smokers and non-smokers.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>No of subjects</th>
<th>Time of determination</th>
<th>FVC in lit.</th>
<th>FEV\textsubscript{1.0} in lit.</th>
<th>MMEF \textsubscript{50-75%} in lit/sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean ± S.D.</td>
<td>Mean ± S.D.</td>
<td>Mean ± S.D.</td>
</tr>
<tr>
<td>Smokers</td>
<td>6</td>
<td>Forenoon</td>
<td>4.096 0.425</td>
<td>3.167 0.499</td>
<td>2.438 0.397</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Afternoon</td>
<td>3.904 0.470</td>
<td>3.038 0.510</td>
<td>2.223 0.677</td>
</tr>
<tr>
<td>Non-Smokers</td>
<td>6</td>
<td>Forenoon</td>
<td>3.654 0.482</td>
<td>2.829 0.364</td>
<td>2.294 0.677</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Afternoon</td>
<td>3.571 0.586</td>
<td>2.708 0.461</td>
<td>2.267 0.462</td>
</tr>
</tbody>
</table>

Fig. II presented the same results graphically along with the percentage variations. The declines of FVC, FEV\textsubscript{1.0} and MMEF \textsubscript{50-75\%} were definitely more in the smoker group than those in the non-smoker group. This might be the effect of cigarette smoking. The declines of FEV\textsubscript{1.0} and MMEF \textsubscript{50-75\%} were more in comparison to FVC in the smoker group.

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**Fig 2**

Diurnal variation of ventilatory capacity amongst smokers and non-smokers.
Table 3 presented the mean values with ± S.D. of the same lung function tests for 8 subjects, determined before and at certain intervals after smoking a cigarette.

**Table III**

<table>
<thead>
<tr>
<th>No. of condition at the time of determination</th>
<th>FVC in lit. Mean ± S.D.</th>
<th>FEV₁₀₀ in lit. Mean ± S.D.</th>
<th>MMEF 50-75% in lit/sec Mean ± S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before smoking</td>
<td>3.500 0.236</td>
<td>2.947 0.357</td>
<td>3.894 1.962</td>
</tr>
<tr>
<td>Immediately after smoking</td>
<td>3.469 0.255</td>
<td>2.641 0.351</td>
<td>3.293 2.563</td>
</tr>
<tr>
<td>10 minutes after smoking</td>
<td>3.497 0.296</td>
<td>2.828 0.551</td>
<td>3.708 1.898</td>
</tr>
<tr>
<td>20 minutes after smoking</td>
<td>3.434 0.334</td>
<td>2.681 0.291</td>
<td>3.608 1.840</td>
</tr>
<tr>
<td>30 minutes after smoking</td>
<td>3.506 0.269</td>
<td>2.819 0.330</td>
<td>3.430 1.566</td>
</tr>
</tbody>
</table>

Graphical presentation of the same was given in Fig. 3.
The subjects with smoking habit included in this study could not be considered as heavy smokers. No subject consumed more than ten cigarettes a day. In the study of diurnal variations, the subjects reported that they smoked about 6 cigarettes in between two determinations, once in the morning and again in the afternoon. None of the subjects, this study had reported any production of sputum or any susceptibility to cough and cold. All the subjects with or without smoking habits were from the same socio-economic status. The micro-environments (residential and daily living condition) to which they were exposed were also of the similar type. Therefore, any difference in the functional status of the ventilatory capacities between the two groups, might be attributed mainly to smoking habits.

The results of FVC and FEV$_{1.0}$ for the subjects with and without smoking habits over an interval of five years did not support the view of Hong et al. (9) that the mean age standardized FEV$_{1.0}$ for the smokers was significantly lower than that for the non-smokers. It was, however, not proper to conclude anything in this respect without considering the same subjects as their own control because in their study, the smoker group might have inherent lower ventilatory capacities than those of non-smoker group. Higgings and Oldham (8) reported the change in IMBC (Indirect maximum breathing capacity) amongst smokers and non-smokers over the period of five years in a group of miners and ex-miners. The results showed that the changes in IMBC in smokers and non-smokers were not much different. Edelman et al. (6) and Olsen and Gilson (15) also reported lower values of VC, FEV$_{1.0}$, and MVV in smokers but they also did not mention if the study was made on the same subjects on both the occasions. Table 1 of the present study clearly showed that the initial values of FVC were of the same order in both the groups, but the fall in FVC amongst the smokers was slightly more than the non-smokers, whereas the initial FEV$_{1.0}$ for the non-smokers was little higher than the smokers, but the fall in FEV$_{1.0}$ amongst the non-smokers was more prominent than that of the smoker group.

This discrepancy of greater fall in FVC than FEV$_{1.0}$ amongst the smokers and reverse in the case of the non-smokers might be explained perhaps as due to the long term effect of smoking on the lung compliance rather than the airway-resistance. Attinger and Segal (2) reported that other than in emphysema the measure of vital capacity was a rough estimate of pulmonary compliance. And it was mentioned by Cotes (5) that the loss of elastic recoil that occurred with increasing age weakened the forces which prevented the closure of the respiratory bronchioles during expiration; closure therefore, occurred at progressively larger lung volumes as age advanced. Loss of vital capacity was the result of reduction in the distensibility of the lung as well as a diminution of the compliance. The higher decrease in lung compliance amongst smokers might have played a prominent part in FEV$_{1.0}$ by preventing the closure of the respiratory bronchioles and thus

DISCUSSION

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could not be considered as heavy is a day. In the study of the 6 cigarettes in between the
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susceptibility to cough and cold. None of the subjects in
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smoker group. Higgings and
breathing capacity) amongst
of miners and ex-miners.
and non-smokers were not much
for the non-smokers was little
amongst the smokers and
probably, due to greater flow resistive force particularly at this later portion of FVC. The
smokedust might have induced the broncho-constriction and increased the flow resistive force.
Nadel and Widdicombe (14) reported that the cigarette smoke induced the reflex broncho-
constriction, that persisted for about an hour. But we did not allow our subjects to smoke
one and a half hour prior to the determination, still the results suggested the presence of flow resistive force. It might be that the smoke induced broncho-constriction which persisted for longer period than one hour.

Table 3 and Fig. III showed the immediate effect of smoking on FVC, FEV$_{1.0}$ and
MMEF$_{50-75\%}$. The results on FVC supported the view of Motley and Kuzman (11) that there
was no significant change in the mean values of vital capacity after smoking. Our results on
FEV$_{1.0}$ supported the findings of Simonsson (18), who found a small change in FEV$_{1.0}$ after
smoking like that of the present study. There is very little reference about the effect of smok-
ing on MMEF$_{50-75\%}$. The study of Nadel and Comroe (12) showed that the airway-resistance
produced due to smoking could be prevented through inhalation of Isuprel aerosol before
smoking. The decrease of the value of MMEF$_{50-75\%}$ immediately after smoking in this study
indicated the increase of flow resistive force. Both the FEV$_{1.0}$ and MMEF$_{50-75\%}$ tended to
return towards the pre-smoking values after 10 minutes of smoking and almost returned to that
level in another 20 minutes. Our previous remark that the effect of smoking might persist even
more than one hour when compared to this observation might create some confusion. The
report of Nadel and Tierney (13) might help in clarifying this contradiction. They stated that
a single deep inspiration was followed by a marked temporary decrease in induced mild to
severe broncho-constriction which may continue for about 30 min. So, perhaps the obligatory manoeuvre of deep inspiration prior to FEV$_{1.0}$ and MMEF$_{50-75\%}$ determination might have increased these values towards the normal levels in those subsequent determinations.

**SUMMARY**

This study comprised of the observation of the effects of cigarette smoking on lung func-
tions on 18 smokers in comparison to 14 non-smokers. Observations were made on the same
subjects once in 1963-64 and then again in 1969 and the relative deterioration in lung function
of the two groups during this period is compared. The lung function tests included in this
The investigation were FVV, FEV 1.0 sec. and MMEF 50-75%. The observations were made for:

(i) immediate effects of smoking, (ii) diurnal variation and (iii) the effects of long term smoking on lung function.

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