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# STUDY ON MECHANICAL PROPERTIES OF LUNG BETWEEN SMOKERS AND NONSMOKERS*)

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## ABSTRACT

In this paper, the mechanical properties of the lungs were measured in 5 smokers and 5 nonsmokers. Detailed investigations were carried out on smokers during periods when they were smoking and when smoking was prohibited (3 months).

The results obtained were as follows:

1) The breathing work of smokers tends to be lower than that of nonsmokers.
2) The lung resistance of smokers tends to be higher than that of non-smokers.
3) The pressure-volume loops of smokers shift farther left than that of non-smokers.
4) The distubances in several mechanical properties observed during the period the smoking improved with the prohibition of smoking.

## INTRODUCTION

Many reports have been published in respect of pulmonary function impaired by smoking habits[1-5]. These reports describe distribution caused by smoking appears first in the peripheral bronchioles and then in various pulmonary functions.

The authors have studied the disturbance of mechanical properties out of disorders of the pulmonary function associated with smoking, the result of which is reported as follows.

## SUBJECTS AND METHODS

The subjects included 5 healthy smokers and 5 healthy nonsmokers. The lung work of breathing in these subjects was measured using Otis's method[6]; the dynamic lung compliance was measured using the method of mead et al.[7]; and the lung resistance (airway resistance plus lung tissue resistance) was also measured modifying the method of Smitt[8] as reference.

Subject A in the smokers group happened to discontinue smoking after the examination, so the same examinations were carried out 3 months after he had discontinued smoking to examine the improvement of the pulmonary functional disorders.

To measure the ventilatory volume and respiratory flow, Wedgetype spirometer (Model 170) of Custom Engineering & Development Co. was used. The transpulmonary pressure (the difference between the oral pressure and the intra-thoratic pressure) was measured with the

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differential manometer of Validyne Engineering Co., The 3 signals of the pressure, volume and flow was amplified with a Sanborn superimposed amplifier of Hewlett Packard Co., and fed to an on-line minicomputer (PDP-12) made by DEC, to measure the lung work of breathing, etc..

## RESULTS

Referring to results obtained by Cristie et al.[9] and Otis[10], the lung work of breathing was separated into work for the elastic resistance and that for the non-elastic resistance (herein after referred to as "work for viscous

**Table 1.** Pulmonary mecanical propertys' DATA of smokers and non-smokers

| SUBJECTS | SEX | AGE | Wins. | Wexp. | Wcd. | W | Wins.-cd. | Cd | Rins. | Rexp. | PK-YRS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | M | 35 | 4.98 | 1.21 | 3.77 | 7.9 | 0.71 | 0.26 | 1.36 | 2.90 | 23 |
| B | F | 51 | 4.65 | 2.93 | 2.95 | 7.58 | 1.69 | 0.11 | 8.10 | 20.18 | 55.5 |
| C | M | 59 | 8.58 | 2.46 | 8.01 | 11.04 | 0.57 | 0.24 | 1.60 | 7.48 | 41 |
| D | F | 67 | 3.12 | 1.40 | 2.12 | 4.52 | 0.99 | 0.10 | — | — | 24 |
| E | M | 68 | 5.92 | 3.69 | 4.45 | 9.61 | 1.53 | 0.16 | 4.79 | 11.20 | 49 |
| F | F | 25 | 7.72 | 0.88 | 6.06 | 8.6 | 1.65 | 0.17 | 2.19 | 1.66 | |
| G | M | 29 | 8.85 | 2.77 | 7.21 | 11.62 | 1.61 | 0.18 | 2.57 | 5.93 | |
| H | F | 55 | 5.29 | 1.54 | 5.34 | 6.88 | 0.05 | 0.41 | 0.06 | 3.33 | |
| I | M | 55 | 8.50 | 1.84 | 6.07 | 10.34 | 2.43 | 0.30 | 3.46 | 3.42 | |
| J | M | 57 | 9.20 | 1.55 | 7.65 | 10.75 | 1.55 | 0.25 | 2.69 | 4.13 | |

* W(kg.cm/L) Cd(L/cm$H_2O$) R(cm$H_2O$/L/sec.)
** A-E.....SMOKERS, F-J.....NON-SMOKERS

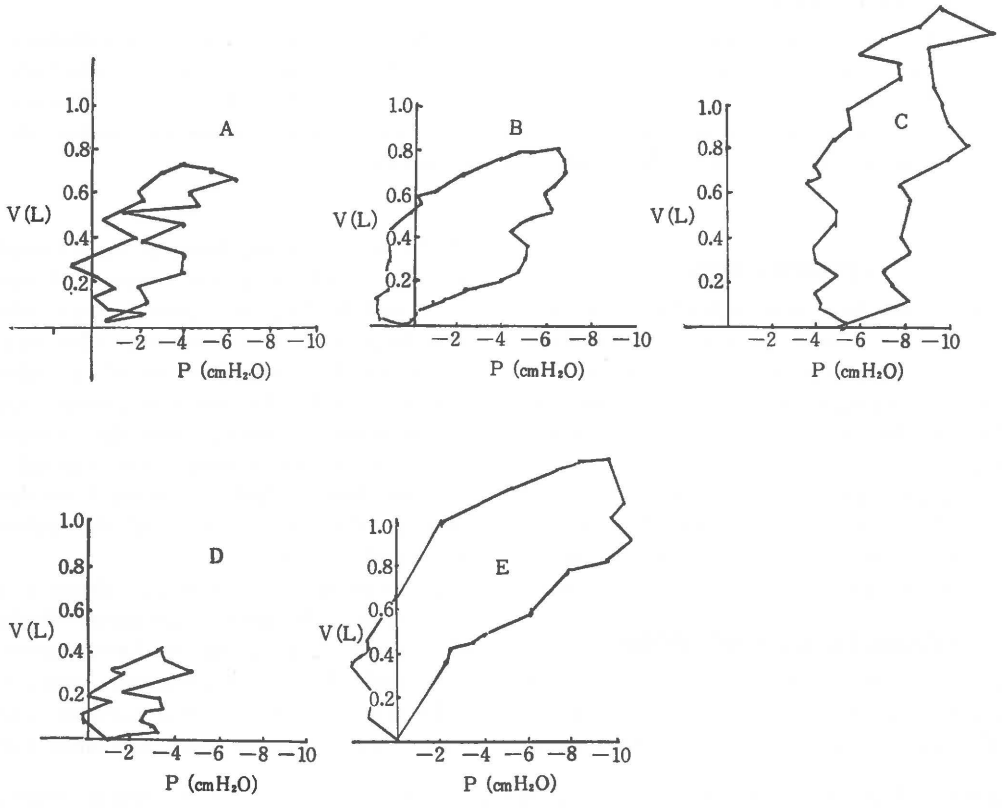


**Fig. 1.(A)** Pressure-volume hysteresis of smoking group

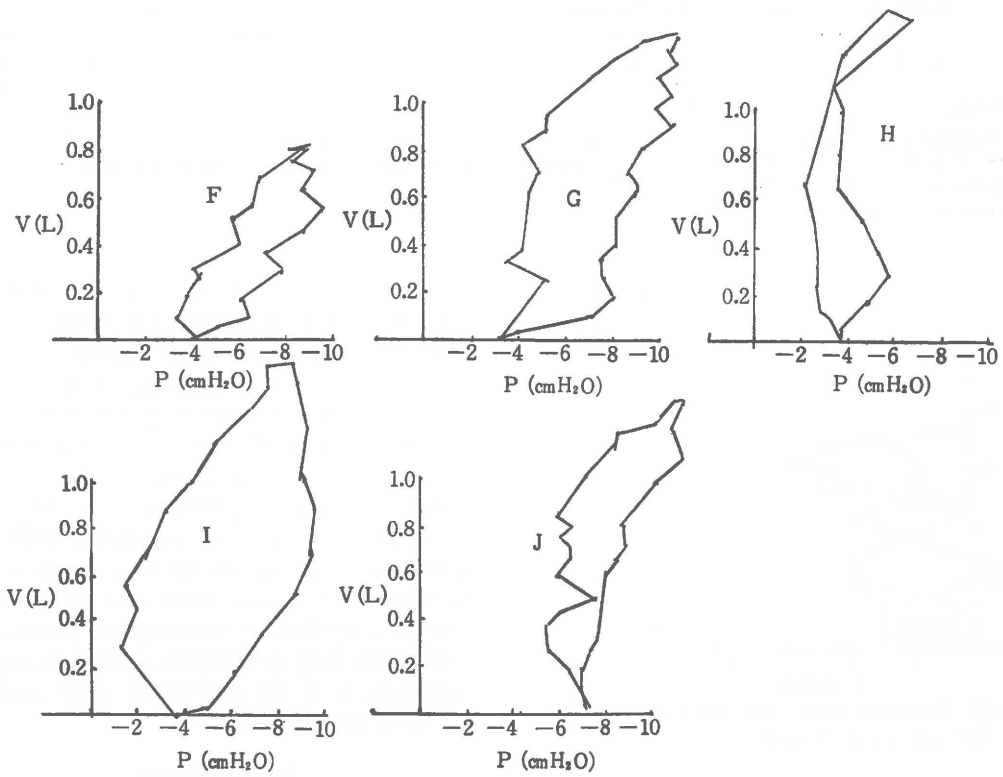


**Fig. 1.(B)** Pressure-volume hysteresis of non-smoking group

resistance" which is commonly called). These are shown in Table 1 together with dynamic lung compliance and lung resistance.

The total lung work of breathing in the case of smokers, was observed to be lower than that of nonsmokers. The work elastic resistance in smokers group (4.26±2.03 kg/cm) also showed a lower value in nonsmokers group (6.47±0.08 kg/cm). As demonstrated by Christie[9] and Slonim et al.[11], the work for elastic resistance should have been more than 60% of the total lung work. (In fact, the authors also observed to be more 60% in all cases of nonsmokers group.) But in most cases of smokers, this work was 59% or under. It indicated that the rate of work for viscous resistance increased in the total works.

In particular, when the work for viscous resistance is devided into expiration and inspiration, the work for viscous resistance was increased in the expiration of all cases as compared with that of insriration. This trend was more evident in smokers than in nonsmokers.

The lung resistance showed a significantly higher lung resistance in expiration in most cases of smokers and was thus similar to the work for viscous resistance as mentioned above. The dynamic lung compliance of smokers showed a lower rate compared with nonsmokers. Figure 1 shows the pressure-volume loops of smokers and nonsmokers in resting state (usual breathing). The pressure-volume loops of smokers shifted further to the left than that of nonsmokers.

In the case of smokers, the transpulmonary pressure in FRC level became close to atmospheric pressure in many cases, and the transpulmonary pressure on expiration became partly positive.

Figure 2 exhibits the pressure-volume loops of the subject A at the time of smoking and the time of 3 months after renuanciation of smoking. The pressure-volume loops at the time of smoking had shifted to the left, and the transpulmonary pressure on expiration may be observed to be partly positive. On the contrary, the pressure-volume loops of 3 months after stop of smoking, shifted to the right and

**Table 2.** Pulmonry mecanical propertys' DATA at smoking time and non-smoking time

| TIME | Wins. | Wexp. | Wcd. | W | Wins.-cd | Cd | Rins. | Rexp. |
|---|---|---|---|---|---|---|---|---|
| SMOKING | 4.98 | 1.21 | 3.77 | 7.9 | 0.71 | 0.26 | 1.36 | 2.90 |
| NON-SMOKING (3 months) | 8.12 | 2.78 | 7.49 | 10.9 | 1.04 | 0.19 | 1.22 | 2.85 |

* W(kg.cm/L) Cd(L/cm$H_2O$) R(cm$H_2O$/L/sec.)
** Subject is 35yrs and male.

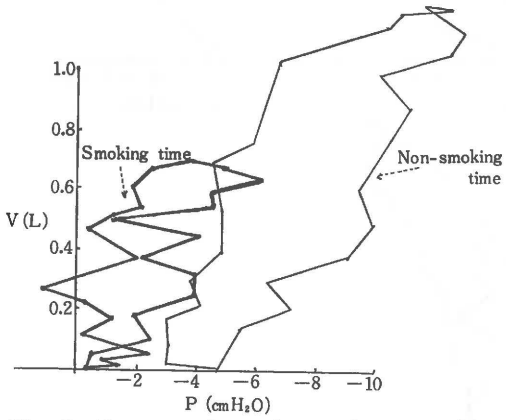


**Fig. 2.** Pressure-volume hysteresis at smoking time and non-smoking time

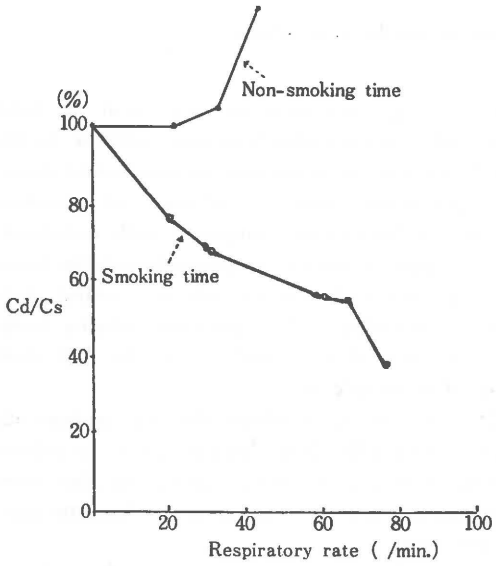


**Fig. 3.** Dbnamic compliance frequency dependency at smoking time and non-smoking time

the transpulmonary pressure on expiration was shown to be negative.

The lung work of breathing as seen in Table 2, shows a larger value of 3 months after smoking discontinued as compared with that at the time of smoking. In the case of 3 months after stop of smoking, however, the work for elastic resistance was determined to be 66.4% which was normal, against that was 47.7% in the case of smoking. This indicates that in case of 3 months after stop of smoking, the rate of the work for viscous resistance in the total lung work is decreased. But the pulmonary resistance on expiration as well as on inspiration, exhibited no significant difference between the case at the time of smoking and the time of 3 months after stop of smoking.

As seen in Figure 3, the frequency dependence of dynamic lung compliance showed significant improvement in the 3rd month after smoking had been discontinued.

## DISCUSSION

The effect of smoking is refrected by the frequency dependence of the dynamic lung compliance, in particular, among the mechanical properties on respiration[12,13].

As remarked by Hittleman et al.,[14] it is said that this may be due to an increase of uneven distribution of ventilation by smoking. In our study, the dynamic compliance of smokers on normal breathing is lower in its value than that of nonsmokers. Based on these reports[12-14] and our study on Subject A, as referred to Figure 3, it is presumed that such low dynamic compliance is due to the frequency dependence.

Generally, the lung work of breathing increases by the effect of various heart-lung diseases in many cases[15]. In most cases of our study, the lung work of smokers decreased, and it seemed as if the efficiency of breathing of smokers was better than that of nonsmokers.

However, it was determined that the lung work of breathing had decreased because the pressure-volume loops shifted to the left and the work for elastic resistance had decreased considerably. Hence the efficiency of breathing has not been improved. In other words, the transpulmonary pressure on expiration was posi-

tive in many cases. It is suggested, therefor, that the potential energy of elastic recoil pressure which has been deposited on inspiration was insufficient on expiration for smokers, thus the activity of the expiratory muscle was needed in many cases.

From these findings, the authors have considered that depiction of the pressure-volume loops would be an effective method to detect a disturbance of pulmonary function by smoking. In this case, however, a confidence in determination of the transpulmonary pressure must be important, and careful measurement is required. It is said that in the case of smokers, the airway resistance would not be increased[17]. However, it was reported by Nadel et al.[18] and Pelzer[19] that the resistance in female smokers increased. We have also confirmed an elevation in R value corresponding to the respiratory resistance which was measured by separating the respiratory inpiedance using the oscilation method[20].

In the present study, the rate of the work for viscous resistance of smokers was high against the total lung work of breathing as in patients with pulmonary emphysema, and an increase in lung resistance involving airway resistance was observed both during expiration and inspiration. Such lung resistance was not recoverd in those cases who had discontinued smoking for 3 months.

Buist et al.[21] confirmed the improvement of closing volume when smoking was discotinued. The disturbance of pulmonary function through smoking is reversible to some extent. How long time period is necessary to restore the pulmonary function after discontinuing? In our study we noted an improvement in the uneven distribution of breathing in the third month after smoking had been discontinued, and that the lung work of breathing had increased to the normal state.

Kato et al.[22] reported that from the 3rd to 7th day of offsmoking, the arterial $O_2$ differential pressure tended to decrease, but statistically, a significant difference was not confirmed.

The influence of smoking on the pulmonary function is said to be absent in young people, but is present in aged people. Amano et al.[23] reported that the disorders of pulmonary function by smoking would not be evident before the age of 60 years. Black et al.[24] also reported that the disorders in the flow-volume cure would appear at a fairly advanced age. Hence, restoration of disturbance in pulmonary function cannot be expected in those cases when smoking is discontinued at an advanced age.

Referring to the results obtained, it is presumed that reversibity of the disorders of pulmonary function cannot be expected, unless smoking is discontinued before the age of 40 years.

## CONCLUSION

We have studied the influence of smoking on the mechanical properties of the lung for ventilation. While the number of subjects were few, the influence of smoking on the lung work of breathing, pressure-volume loops, frequency dependence on the dynamic lung compliance, and lung resistance, has been confirmed. It was also suggested that the above mentioned mechanical properties except the lung resistance can be reserved by discontinuing smoking.

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