RELATIONSHIP BETWEEN MAXIMAL VOLUNTARY VENTILATION AND DIAMETER OF AIRWAYS

PRELIMINARY REPORT

By

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Maximal Voluntary Ventilation (MVV) is a sensitive index of overall mechanical function of the lungs as it represents the final common pathway of ventilation. The MVV depends on factors like age and sex, breathing rate, pulmonary midposition at which breathing is performed, compliance of the lungs and thorax, muscular force, resistance of the airways which mainly depend on the diameter of the airways and on psychological factors like learning, motivation and endurance.

In this investigation the relationship of MVV to diameter of airways has been studied.

METHODS AND MATERIALS

Studies were conducted on 19 healthy male medical students between the ages of 19 and 22 years. All the subjects had performed the test previously and had understood the technique reasonably well.

All the determinations were done with the subject seated on a chair. The subject with the nose clipped was asked to breath as rapidly and as deeply as possible through a 2-way valve, the outflow limb of which was connected to a volume meter. The volume of air breathed in 15 sec. was directly read on the volume meter. In a few preliminary experiments MVV was also determined by collecting the air in a Douglas’s bag and measuring the volume. No significant differences were found in the MVV values between these two methods indicating that the frequency response of the volume meter was adequate for the purpose.

The subjects were allowed to choose their own rate and depth of respiration. The rates utilized varied from 50-100/min.

Obstruction to airflow was produced by introducing tubes of 7.5 cms. in length and of different diameters in the course of the airways. The diameters of the tubes used were 1.6, 1.2, 1.0, 0.6 and 0.5 cms. The diameter of the airways of rest of the equipment was also about 1.6 cms.

Depending on the position of the tubes in the course of the airways either common or inspiratory or expiratory obstruction was produced as shown in Fig. 1. Obstruction to airflow was present in common obstruction both during inspiration and expiration, in inspiratory obstruction only during inspiration and in expiratory obstruction only during expiration. The tubes were connected as near the mouth as possible.

Determinations were done in the three types of obstruction on different days and for any one set of determinations sufficient time was allowed in between the determinations to eliminate errors due to fatigue.
The MVV depends on the way in which breathing is performed, i.e., the process of airways which mainly affects like learning, motivation and the reformation of airways has been studied. Patients between the ages of 19 and had understood the technique and were seated on a chair. The subject with the equipment was also about a distance of 7.5 cms. in length and of 1.6 cm. of the tubes used was also about 9.5 cm. in length and of 1.2 cm. diameter. The airways either common or inspiratory in obstruction to air in and expiration, in inspiratory obstruction only during expiration. The MVV was observed in the series for each subject and the predicted values as reported by Bass B.H. (1) for each subject. The “Normal Values” of MVV were found to be lower than the MVV in slight degrees of obstruction. The mean “Normal” MVV was 60.5 L/Sq.M/Min.(BTPS) and the mean highest observed MVV was 69.4 L/Sq.M/Min.(BTPS). In a majority of subjects, the highest MVV was observed in common obstruction with tube diameters of 1.6 or 1.2 cms. The mean highest observed MVV is lower than the mean predicted value by 6.8 L/Sq.M/Min.(BTPS). Of the 19 subjects only 3 showed higher value than their predicted values. The highest MVV observed was 17.8 L/Sq.M/Min.(BPTS) higher than the corresponding predicted value and the lowest value was 17.6 L/Sq.M/Min.(BPTS) lower than the corresponding predicted value.

Table II shows the mean MVV and their ranges in the three types of obstructions. The MVV is seen to decrease at faster rate below a tube diameter of 1.2 cms. in common and inspiratory obstructions and below a tube diameters of 1.0 cm. in expiratory obstruction.

The MVV in any particular obstruction below a tube diameter of 1.2 cms. is highest in expiratory obstruction and lowest in inspiratory obstruction.
TABLE I

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>SURFACE AREA</th>
<th>&quot;NORMAL&quot; MVV In L/Sq.M./Min. (BTPS)</th>
<th>Highest MVV in L/Sq.M./Min. (BTPS)</th>
<th>Predicted value in L/Sq.M./Min.</th>
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</thead>
<tbody>
<tr>
<td>V.H.</td>
<td>1.58</td>
<td>86.4</td>
<td>94.5</td>
<td>76.58</td>
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<td>S.A.M.</td>
<td>1.58</td>
<td>52.2</td>
<td>68.7</td>
<td>77.21</td>
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<td>D.J.</td>
<td>1.52</td>
<td>61.8</td>
<td>73.0</td>
<td>76.31</td>
</tr>
<tr>
<td>D.</td>
<td>1.52</td>
<td>70.2</td>
<td>73.0</td>
<td>75.01</td>
</tr>
<tr>
<td>M.J.</td>
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<td>69.7</td>
<td>69.7</td>
<td>74.86</td>
</tr>
<tr>
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<td>51.4</td>
<td>77.1</td>
<td>76.16</td>
</tr>
<tr>
<td>N.S.H.</td>
<td>1.48</td>
<td>52.4</td>
<td>61.2</td>
<td>78.37</td>
</tr>
<tr>
<td>S.B.C.</td>
<td>1.49</td>
<td>68.3</td>
<td>74.0</td>
<td>75.83</td>
</tr>
<tr>
<td>V.C.</td>
<td>1.53</td>
<td>52.6</td>
<td>80.4</td>
<td>76.3</td>
</tr>
<tr>
<td>D.B.</td>
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<td>61.7</td>
<td>61.7</td>
<td>75.32</td>
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<td>R.V.N.</td>
<td>1.56</td>
<td>59.8</td>
<td>62.6</td>
<td>76.28</td>
</tr>
<tr>
<td>G.M.</td>
<td>1.6</td>
<td>56.0</td>
<td>58.7</td>
<td>76.28</td>
</tr>
<tr>
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<td>70.1</td>
<td>70.1</td>
<td>76.25</td>
</tr>
<tr>
<td>A.P.</td>
<td>1.62</td>
<td>61.2</td>
<td>69.2</td>
<td>76.54</td>
</tr>
<tr>
<td>S.G.</td>
<td>1.64</td>
<td>52.6</td>
<td>60.5</td>
<td>75.67</td>
</tr>
<tr>
<td>E.</td>
<td>1.68</td>
<td>71.1</td>
<td>73.7</td>
<td>76.26</td>
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<tr>
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<td>55.8</td>
<td>60.6</td>
<td>73.72</td>
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<td>B.S.</td>
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<td>65.9</td>
<td>76.46</td>
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<td>64.8</td>
<td>77.91</td>
</tr>
<tr>
<td>MEAN</td>
<td>1.53</td>
<td>60.5</td>
<td>69.4</td>
<td>76.17</td>
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</table>

DISCUSSION

The mean highest MVV observed in the present series is 69.4 L/Sq.M./Min. or 109.3 L/Min. The following are some of the values reported for Indian subjects quoted from M.N. Rao et al (4).

Lundgren et al (1953) age 25 years—110.5 L/Min.

Bhargava et al (1956) age 17—23 years—132.8 L/Min.


Rao et al (4) age 20—24 years—109.44 L/Min.
It is seen that the values obtained in the present investigation (age group of subjects 19—22 years) are comparable to those reported by Rao et al but lower than the values reported for Americans, which are given below quoted from Stuart and Collings (3).

Rasch and Brunt (Olympic Wrestlers) 86 L/Sq.M/Min.
Matheson (194 medical students) 88 L/Sq.M/Min.
Baldwin (18 hospital patients free from pulmonary disease) 71 L/Sq. M/Min.

(Age group of subjects in the above is not available)

The reasons for the low values in the present series are that determinations were done with subject seated on a chair. In a few preliminary experiments MVV was determined both in the standing and the sitting postures and that the MVV in the sitting posture was always lower by as much as 5—10 L/Min. Even otherwise the normal values obtained in different laboratories vary by as much as 30% according to the type of apparatus and the resistance it offers to breathing (2). Considering these facts the values obtained in this series are comparable to normal values reported by other workers.

It has been observed that in a majority of subjects the MVV increases with slight degrees of obstruction. Even though the increase is not statistically significant, it is very suggestive that the MVV does increase with slight degrees of obstruction. It is possible that with slight degrees of obstruction, the respiratory muscles might work at a better mechanical advantage resulting in higher MVV.

If the values of MVV in common and inspiratory obstructions are compared it is seen that the MVV in inspiratory obstruction is lower than the MVV in common obstruction. It is difficult to explain this fact because in both conditions the degree of limitation to air entry as well as other factors like muscular force and compliance are identical. It is likely that the altered and abnormal volume-tension relationship during inspiration and expiration may reduce the mechanical efficiency of the respiratory apparatus.
Fig. 2
Relationship between MVV and Radius in three types of obstruction. MVV values plotted are at ATPS. The vertical lines indicate the range of MVV.

The reduction of MVV in expiratory obstruction is less than in other types of obstructions. This suggests that the limitation to air entry into the lungs is a more important cause of decrease of MVV than the muscular force.

Fig. 2 shows the relationship of MVV to diameter of airways. It is seen that in common and inspiratory obstructions below a tube diameter 1.2 cms, the relationship is approximately linear. If it is assumed that the MVV at complete obstruction is zero, the relationship can be expressed in the form of a regression equation.

Such an equation for common obstruction is the following:

\[ Y = 0.0188 \times X \]

where \( Y \) = diameter of airways in cm.

and \( X \) = MVV in \( L/Sq.M/Min \) (BTPS)

The standard error of the estimate is \( \pm 0.12 \).

Similar equations can also be worked out for the relationship between the diameter and inspiratory and expiratory obstructions. However the relationship is not linear for expiratory obstruction.
SUMMARY

Relationship between Maximal Voluntary Ventilation (MVV) and diameter of airways was studied by introducing tubes of 7.5 cm in length and of varying diameters in the course of the airways of the equipment, among medical students between the ages of 19 and 22 years. Depending on the position of the tube, either common, only inspiratory or only expiratory obstruction was produced.

MVV increases slightly with slight degrees of obstruction.

MVV decreases at a rapid rate below a tube diameter of 1.2 cm in common and inspiratory obstruction and below a tube diameter of 1.0 cm in expiratory obstruction.

At any tube diameter below 1.2 cm, the MVV is lowest in inspiratory obstruction and highest in expiratory obstruction.

In common obstruction, the relationship between MVV and diameter of airways, below a tube diameter of 1.2 cm is given by the equation $Y=0.0188X$ (Standard error of estimate $\pm 0.12$), where $Y$=diameter of airways in cm. and $X$=MVV in $L/Sq.M/Min.(BTPS)$.

REFERENCES


