# LUNG VOLUMES IN TEMPORARY RESIDENTS AT HIGH ALTITUDES

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Before the mechanisms of adaptation and acclimatization of temporary and permanent residents of high-altitude districts can be understood, a detailed study must be made of the changes arising in these conditions in the apparatus of external respiration.

Many investigators have observed an increase in the size of the chest in the indigenous population of localities situated at high altitudes and in temporary residents staying there for long periods.

A decrease in the vital capacity of the lungs (VCL) at a lowered labometric pressure was first reported by Bert [8]. In a pressure chamber in conditions equivalent to an altitude of 4-6 km, the VCL of the subject fell on the average by 8%. When they breathed oxygen, their VCL showed a tendency to return to normal [11]. On Pike's Peak (4300 m) and on the Eastern Pamir (3600 m) the VCL of unacclimatized persons diminished during the first days of the ascent and increased after acclimatization [4, 6, 11]. Several investigators observed only a decrease in the VCL of subjects at high altitudes [2, 5, 9].

However, no information is available concerning changes in all the lung volumes, especially the residual volume, of temporary residents in high altitude areas.

The author investigated the lung volumes in the summer months of 1962 and 1963 in the Mugab district of the Eastern Pamir, situated at an altitude of 3600 m (mean barometric pressure 485 mm Hg). People live here and work on farms and in industry at altitudes of up to 4600 m.

## EXPERIMENTAL METHOD

The lung volumes were measured by the method of helium dilution in a closed system [11] by an apparatus for determining residual volume consisting of a spirograph a helium gas-analyzer. The resistance to respiration in the apparatus did not exceed 4-5 mm water with a ventilation of 8 liters/min. The error of determination was within ±5% of the measured value. A constant concentration of oxygen in the system was maintained automatically. The limits of measurement of the helium concentration were 0-7 vols.%. The error of determination of the residual volume of the lungs was less than ±10%.

The summer inhabitants of the Murgab, who had lived there for 1-3 years (21 males) and members of the expedition (9 males) were investigated. The latter group was investigated in Dushanbe before the ascent to high altitudes, in the Murgab (3 times during a stay lasting 45 days), and after the descent (3 times in the course of 3 months in Dushanbe).

The temporary residents were aged between 22 and 26 years, and the members of the expedition between 19 and 27 years, except for one who was 45 years old. The investigations were carried out during the first half of the day before lunch, after a preliminary rest when the subject was in a sitting position in a comfortable chair.

The results of all the measurements were reduced to the conditions of air in the lungs on the BTPS system (i.e., the volume occupied by the air at a body temperature of 37°, at the given atmospheric pressure, and with full saturation with water vapor).

The expected VCL of the subjects was determined from a nonogram [3], plotted from the formula of Baldwin and co-workers [7].

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TABLE 1. Lung Volumes of Healthy Young Male Residents of Dushanbe and of Temporary (1-3 years) Residents of Murgab (Altitude 3600 m)

| | Residents of Dushanbe | | | Residents of Murgab | | |
|---|---|---|---|---|---|---|
| | Mean value (M) | Mean deviation ($\sigma \pm$) | Mean error (m ±) | Mean value (M) | Mean deviation ($\sigma \pm$) | Mean error (m ±) |
| Age, in years | 21.0 | 2.2 | 0.3 | 22.0 | 1.3 | 0.3 |
| Height (in cm) | 167.3 | 6.0 | 0.9 | 169.0 | 3.7 | 0.8 |
| Weight (in kg) | 59.0 | 7.5 | 1.2 | 60.0 | 3.5 | 0.8 |
| VCL (in liters) | 4.28 | 0.57 | 0.09 | 5.00 | 0.49 | 0.10 |
| VCL (expected, in liters) | 4.04 | 0.32 | 0.05 | 4.20 | 0.17 | 0.04 |
| VCL (in percent of expected) | 105.0 | 10.0 | 2.6 | 119.0 | 9.0 | 2.0 |
| IV (in liters) | 2.74 | 0.56 | 0.09 | 3.37 | 0.49 | 0.10 |
| ERV (in liters) | 1.47 | 0.28 | 0.04 | 1.63 | 0.25 | 0.05 |
| RV (in liters) | 1.24 | 0.20 | 0.03 | 1.92 | 0.32 | 0.07 |
| FRC (in liters) | 2.71 | 0.36 | 0.06 | 3.55 | 0.38 | 0.04 |
| TLC (in liters) | 5.52 | 0.64 | 0.10 | 6.92 | 0.67 | 0.15 |
| Ratio RV/TLC × 100 (in %) | 22.7 | 3.4 | 0.5 | 27.4 | 3.2 | 0.7 |

Note: Here and in Table 2: VCL—vital capacity of lungs; IV—inspiratory volume; ERV—expiratory reserve volume; RV—residual volume; FRC—functional reserve capacity; TLC—total lung capacity.

TABLE 2. Changes in Lung Volume at Intervals in Male Members of the 1962 Expedition (Mean Data)*

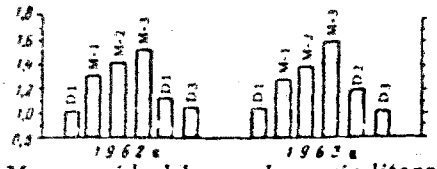
| Place and date of examination | Vital capacity of lungs | | | IV (in liters) | ERV (in liters) | RV (in liters) | FRC (in liters) | TLC (in liters) | Ratio RV/TLC (in %) |
|---|---|---|---|---|---|---|---|---|---|
| | expected (in liters) | actual (in liters) | percent of expected | | | | | | |
| Dushanbe, 1. July 1-5, before leaving for the mountains | 4.16 | 4.53 | 108 | 2.94 | 1.59 | 1.11 | 2.70 | 5.64 | 19.4 |
| Murgab, 1. July 10-15—first week of stay at high altitude | 4.16 | 4.48 | 107 | 3.11 | 1.38 | 1.38 | 2.76 | 5.82 | 23.0 |
| Murgab, 2. August 3-8—second week of stay at high altitude | 4.16 | 4.51 | 108 | 3.23 | 1.27 | 1.50 | 2.77 | 6.00 | 24.5 |
| Murgab, 3. August 18-23—sixth week of stay at high altitude | 4.16 | 4.56 | 109 | 3.26 | 1.30 | 1.57 | 2.86 | 6.13 | 25.3 |
| Dushanbe, 2. August 26-30—first week after descent | 4.16 | 4.61 | 110 | 3.11 | 1.50 | 1.24 | 2.74 | 5.88 | 20.7 |
| Dushanbe, 3. September 20-25—fourth week after descent | 4.16 | 4.52 | 108 | 3.02 | 1.48 | 1.16 | 2.64 | 5.68 | 20.2 |

* Average age 25.2 years, average height 168 cm, and average weight 62 kg.

To compare the lung volume of the residents of Dushanbe and Murgab, 40 young healthy male students (control) and 21 healthy males living temporarily (1-3 years) at a high altitude were investigated respectively (Table 1).

The mean values obtained for the residents of Dushanbe (Table 1) were close to those in the literature [10] and can be taken as normal for young healthy persons living on the plains, and examined in a sitting position (in the lying position the inspiratory volume is 300 ml greater than in the sitting position, and all the other lung volumes in the lying position are somewhat smaller than in the sitting position).

By comparison with the control data, the lung volumes of the temporary residents of Murgab showed an increase, which was statistically significant ($P < 0.01$), in the residual volume (RV) on account of which the functional reserve capacity (FRC) and the total lung capacity (TLV) also were increased. The ratio of



Mean residual lung volume (in liters) of members of the expedition before the ascent (D1, at the high altitude (M-1, -2, -3) and after the descent (D2, 3), from the results of examination of members of a high-altitude expedition in 1962-63. The times of the investigation correspond to those given in Table 2. D—Dushanbe; M—Murgab.

RV to TLC was also increased over the control level. These results show that at a high altitude the volume of the chest is increased both during maximal expiration and maximal inspiration.

The VCL, IV, and ERV of the temporary residents of the high altitude region were the same or slightly greater than in the controls, suggesting a good excursion of the chest wall.

The results of the examination of members of the expedition at intervals (before the ascent, at the high altitude, and after the descent) revealed characteristic changes in the lung volumes depending on the length of stay at the high altitude (Table 2).

As Table 2 shows, after the ascent, the VLC of persons climbing to high altitudes for the first time remained substantially unchanged. The significant increase in the residual volume by an average of 0.5 liter over its initial value, on the 40th-50th day of the stay at a high altitude ($P < 0.05$), was associated with the increase in the TLC, maintenance of the VLC, and some redistribution of volumes between the IV and ERV. The ratio of RV to TLC was appreciably increased.

The increase in the residual volume and the FRC was thus a regular feature both of the members of the expedition and of the persons living at a high altitude for 1-3 years.

When the members of the expedition made a second ascent to the same high-altitude district next year, it was found that the VLC remained unchanged, the residual volume increased at the same times (see figure), and in some subjects this actually happened slightly earlier.

To summarize the facts described above, the increase in the residual volume and the functional residual capacity of the lungs during an ascent to a high altitude, leading to an increase in the respiratory surface, is one of the mechanisms of adaptation of the body to the conditions of chronic exposure to a reduced partial pressure of oxygen. The fact discovered in this investigation, that the residual volume rises comparatively quickly (after the first week of the ascent) at a high altitude and is restored after the return to the plains, deserves attention.

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