Blood Volume and Body Haematocrit of Rats Native to a Simulated Altitude of 3500 m

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Abstract. Circulating blood volume (BV) as the sum of circulating red cell volume (RCV) and plasma volume (PV) was estimated in rats native to a simulated altitude of 3500 m (“natives”), in rats born at sea level and later in life transferred to the simulated high altitude (“newcomers”), and in control sea-level rats. RCV per kg body weight (b.w.) was significantly larger in both “newcomers” and “natives” than in controls. PV per kg b.w. was in the “newcomers” insignificantly and in the “natives” significantly smaller than in the controls. BV per kg b.w. in both high altitude groups tended to be larger than in controls but the difference was not significant. Arterial haematocrit (Ahct) in the “newcomers” was significantly higher than in the controls, and in the “natives” significantly higher than in both other groups. Body haematocrit (the ratio of RCV and BV in per cent) was smaller than Ahct in all groups; this was more pronounced in the “newcomers” than in the controls and even more so in the “natives”. Apparently the haematocrit in the minute vessels of the organs of animals exposed to chronic hypoxic hypoxia increases much less than might be expected from changes of the Ahct.

An attempt was made to evaluate the possible error of the more commonly used method of estimating BV, when only RCV, or only PV, is measured, and BV and its complementary fraction are calculated from arterial or venous haematocrit. When, in our results, BV was calculated from RCV and Ahct in the “newcomers” was significantly higher than in the controls, and in the “natives” significantly higher than in both other groups. Body haematocrit (the ratio of RCV and BV in per cent) was smaller than Ahct in all groups; this was more pronounced in the “newcomers” than in the controls and even more so in the “natives”. Apparently the haematocrit in the minute vessels of the organs of animals exposed to chronic hypoxic hypoxia increases much less than might be expected from changes of the Ahct.

Key words: High altitude — Blood volume — Red cell volume — Plasma volume — Body haematocrit — Rat.

Introduction

Several studies dealing with the effect of exposure to natural or simulated high altitude on blood volume were performed in rats (Fryers, 1952; Anthony and Kreidler, 1961; Tribukait, 1963; Feigen and Johnson, 1964; Johnson and LaRoche, 1968; Pepelko, 1971; Wolfe and Horvath, 1975; Kasalický et al., 1977). All these papers reported a larger circulating red cell volume per unit of body weight in rats exposed to high altitude. Plasma volume has been found to be decreased, not changed or increased. Consequently, the total circulating blood volume per unit of body weight must have been either the same or larger in rats exposed to high altitude, when compared with control sea-level animals. It has been suggested that variations in plasma volume probably are due to varying experimental conditions, particularly due to a different degree of hypoxia and variation in the duration of exposure (Wolfe and Horvath, 1975). To our knowledge, only rats born at sea level and exposed to high altitude later in their life were studied, but never animals born at altitude. The primary purpose of this study was to estimate the circulating red cell volume (RCV), the plasma volume (PV), and the total circulating blood volume (BV) in rats that spent their entire (also prenatal) life in conditions of chronic hypobaric hypoxia, and to compare them with control sea-level animals and with rats born at sea level and later exposed to simulated high altitude.

A common method of estimating blood volume is that either RCV or PV is measured, and BV and its complementary fraction are calculated from arterial or venous haematocrit. When, in our results, BV was calculated from RCV and Ahct, the absolute values and also the differences between groups were somewhat underestimated. When BV was calculated from PV and Ahct, the BV itself, and particularly the differences between groups, were overestimated quite considerably. It is suggested that the only safe way to estimate BV is to measure RCV and PV separately.
body haematocrit. An additional purpose of this study was to check the validity of this assumption. Therefore, RCV and PV were estimated separately and BV was calculated as their sum.

### Methods

Rats of Wistar strain were used. A group of female and male rats mated in the low pressure chamber were kept at a reduced pressure corresponding to an altitude of 3500 ± 200 m, the animals of another group were mated outside the chamber. Male animals born in the low pressure chamber stayed there until the day of the measurements; this group is called "natives". Male rats born outside the chamber were mated in the low pressure chamber was kept at a reduced pressure ("natives") at a simulated altitude of 3500 m (mean ± S.D.; n = number of animals) and later in life exposed to simulated altitude ("newcomers"), and in rats born and spending their entire life in a low pressure chamber ("natives") at a simulated altitude of 3500 m (mean ± S.D.; n = number of animals)

Table 1

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Controls (n = 8)</th>
<th>&quot;Newcomers&quot; (n = 7)</th>
<th>&quot;Natives&quot; (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 ± 4</td>
<td>84 ± 2</td>
<td>86 ± 5</td>
<td></td>
</tr>
<tr>
<td>316 ± 23</td>
<td>283 ± 16</td>
<td>242 ± 20</td>
<td></td>
</tr>
<tr>
<td>45.9 ± 2.2</td>
<td>54.7 ± 1.4</td>
<td>64.4 ± 5.2</td>
<td></td>
</tr>
<tr>
<td>RCV per kg b.w. (ml/kg) 23.5 ± 3.8</td>
<td>28.7 ± 1.2</td>
<td>32.8 ± 6.0</td>
<td></td>
</tr>
<tr>
<td>PV per kg b.w. (ml/kg) 30.8 ± 2.2</td>
<td>29.6 ± 1.1</td>
<td>25.9 ± 2.2</td>
<td></td>
</tr>
<tr>
<td>BV per kg b.w. (ml/kg) 54.2 ± 5.1</td>
<td>58.3 ± 1.7</td>
<td>58.7 ± 6.0</td>
<td></td>
</tr>
<tr>
<td>Ahct-Bhct 43.1 ± 3.3</td>
<td>49.2 ± 1.3</td>
<td>55.6 ± 5.2</td>
<td></td>
</tr>
<tr>
<td>Ahct 2.8 ± 2.1</td>
<td>5.5 ± 1.8</td>
<td>8.8 ± 2.0</td>
<td></td>
</tr>
<tr>
<td>Ahct/Bhct 0.938 ± 0.044</td>
<td>0.900 ± 0.030</td>
<td>0.863 ± 0.031</td>
<td></td>
</tr>
</tbody>
</table>

Values are given in the table as mean ± S.D.; values are corrected for plasma trapping by multiplying by a factor of 0.967, the mean value obtained from 10 measurements in preliminary experiments. Blood (0.3 ml) for the measurements of the radioactivity was digested in 4.7 ml 6 N KOH for 24 h and the activity of 51Cr and 125I was determined in a well scintillation counter (Philips). From the administered activity, the activity in the blood of 51Cr and 125I was determined in a well scintillation counter (Philips). From the administered activity, the activity in the blood of 51Cr and 125I was determined in a well scintillation counter (Philips).

Ten minutes after the injection of labelled erythrocytes and plasma, 0.3 ml arterial blood was sampled; this equilibration time is sufficient according to Rakušan and Rajhathy (1972), and to our own preliminary experiments.

At the same time blood for the estimation of the haematocrit in a microcentrifuge was taken from the arterial cannula. Haematocrit values were corrected for plasma trapping by multiplying by a factor of 0.967, the mean value obtained from 10 measurements in preliminary experiments. Blood (0.3 ml) for the measurements of the radioactivity was digested in 4.7 ml N KOH for 24 h and the activity of 51Cr and 125I was determined in a well scintillation counter (Philips). From the administered activity, the activity in the blood sample and the corrected arterial haematocrit (Ahct), RCV and PB were calculated. The volumes of the added erythrocytes and the albumin were subtracted. The sum of RCV and PV equals the total circulating BV, assuming that the volume of leucocytes and thrombocytes is negligible. The ratio of RCV and BV in per cent corresponds to the body haematocrit (Bhct).

Statistical evaluations were done according to Snedecor and Cochran (1967). For the evaluation of differences between groups the t-test was used. P < 0.05 was assumed as a criterion of significance.

### Results

The results are shown in Table 1. The rats of all three groups are of the same age, but rats exposed to chronic hypoxic hypoxia grew more slowly, particularly the "natives", as seen from the weights. Arterial haematocrit is larger in "newcomers" than in controls and much larger in "natives". Contrary to previous studies (Turek et al., 1973, 1975), the values in Table 1 were corrected for plasma trapping but this difference is minor. Because of the difference in body weight (b.w.), RCV, PV and BV are expressed per kg b.w. to make them comparable. RCV per kg b.w. in both "newcomers" and "natives" is larger than in control animals, the difference between "newcomers" and "natives" not