Acclimatization to High Altitude

Peter Bärtsch

www.klinikum.uni-heidelberg.de/sportmedizin
Barometric Pressure decreases with Altitude

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Barometric Pressure (mmHg)</th>
<th>Oxygen Pressure (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>760</td>
<td>159</td>
</tr>
<tr>
<td>14'700</td>
<td>440</td>
<td>92</td>
</tr>
<tr>
<td>29'000</td>
<td>250</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>300 feet</td>
<td>17‘000 feet</td>
</tr>
<tr>
<td>-------------------------</td>
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<td>-------------</td>
</tr>
<tr>
<td>Exercise (W)</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>O2 demand (L/min)</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>O2 pressure</td>
<td>normal</td>
<td>50 % ▼</td>
</tr>
<tr>
<td>Breathing (L/min)</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>O2 loading (%)</td>
<td>95</td>
<td>63</td>
</tr>
<tr>
<td>O2 in blood (ml/L)</td>
<td>174</td>
<td>135 - 22 %</td>
</tr>
<tr>
<td>Heart rate (/min)</td>
<td>110</td>
<td>159</td>
</tr>
<tr>
<td>Perception</td>
<td>moderate</td>
<td>very hard</td>
</tr>
</tbody>
</table>

Calbet, AJP 2003
Köpfe Kriippeln in den Fingern, Rückwinkel setzt sich ein.

Werde müde, schneller Kopf, Konzentration lässt nach.

Näel Nr.
Schürblingentweg 15
8502 Kloten/ZH

849 846 843 840

832

825 822
819 816 813 810
801 798 795 792
783 780 777 774
758 753 752 749 746

857

8502

831

840 837 834 831 828
849 846 843 840

Köpfe Kriippeln in den Fingern, Rückwinkel setzt sich ein.

Werde müde, schneller Kopf, Konzentration lässt nach.
Schwerer Kopf, leichte Kopfschmerzen, keine Konzentration

Kal 10,2
Schwindelgefühl
30 Sloten
700 697 697 694
691 688 673 684 682
756 755 7526 749 748
746 743 740 737

Gesichtsfeld-Einschränkung
1. Increase of oxygen-carrying capacity of blood:
   - Decrease of plasma volume starts within hours
   - Increase of red blood cells, effective within several days - weeks

2. Ventilatory acclimatization:
   - Ventilation increases over 2 weeks, starts within hours
SaO$_2$: % of occupied O2 binding sites
($\approx 95\%$ at sea level)

Hemoglobin

Fluid between red blood cells: plasma
Acclimatization: Red Blood Cells

- 60 days on Mt. Everest → 25% increase (AMREE study)
- 65 days at 17’000 feet → 35% increase (Chacaltaya study)
- 8000 feet: 5% increase after 3-4 weeks

Milledge, Ward and West. High Altitude Physiology and Medicine, Chapman and Hall
Acclimatization to High Altitude

1. Increase of oxygen-carrying capacity of blood:
   - Decrease of plasma volume starts within hours
   - Increase of red blood cells, effective within several days

2. Ventilatory acclimatization:
   - Ventilation increases over 2 weeks, starts within hours
Ventilation and SaO₂ at 14‘100 feet

Normal values of SaO₂ depend on days spent at altitude

SaO₂: 78 → 87 %

Increase of Ventilation:
• day 1: 8.5 → 10 l (18%)
• day 1-10: 10 → 15 l (50 %)

Bender PR, JAP 1989;66:2733
Variability of Ventilation in Hypoxia

Risk factor for AMS?

\[ \Delta = 50 \text{ l/min} \]

\[ \Delta = 2 \text{ l/min} \]

Effect of acclimatization on \( \text{O}_2 \) transport at \( \approx 17'000 \) feet altitude

- Increase of Ventilation 50%
- Increase in red blood cells \( \approx 30 \% \),

At 13’500 feet acclimatization (ventilation and red cells) is completed after 2 weeks

Lundby, AJP 2004
## Effects of Acclimatization on O2 Transport

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<td>50 % ▼</td>
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</tr>
<tr>
<td>Hemoglobin (mg%)</td>
<td>13.5</td>
<td>13.8</td>
<td>18.0</td>
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<td>75</td>
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Calbet, AJP 2003
Significance for Acute High Altitude Illnesses

- A considerable part of ventilatory acclimatization occurs already in the first few days and coincides with improvement of acute mountain sickness (AMS)

- Acclimatization prevents AMS

- Diamox increases ventilation – enhances ventilatory acclimatization and prevents AMS

- Acclimatization normalizes increased brain blood flow, which plays a role for preventing AMS and HACE

- Normal values of SaO2 show a large variation between individuals and also depend on the degree of acclimatization