Altitude training and practical solutions.

Dra Carmen Calderón Soto, Unidad de Medicina del Deporte
CAR Sierra Nevada. CSD. Oct 2016.

La Alcazaba 3371 m       Mulhacen 3479 m
Environmental conditions

- **Atm P. = Hypoxia:**
  - SL - Pat 760 mmHg - PiO2 159 mmHg - SaO2 97-99%
  - 3000m - Pat 523 mmHg - PiO2 100 mmHg - SaO2 90%

- **Temperature:**
  - **↓ 0.5° - 1°C / 100 m**
  - Humidity, latitude, wind ...

- **Low humidity – dehydration.**
- **Increased radiation.**
- **Less gravidity and air density.**

Altitude levels

**Table 1. Definition of Altitude Proposed by P. Bärtsch and B. Saltin (2008)**

<table>
<thead>
<tr>
<th>Definition</th>
<th>Altitude, meters above sea level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near sea level</td>
<td>0–500</td>
</tr>
<tr>
<td>Low altitude</td>
<td>500–2000</td>
</tr>
<tr>
<td>Moderate altitude</td>
<td>2000–3000</td>
</tr>
<tr>
<td>High altitude</td>
<td>3000–5000</td>
</tr>
<tr>
<td>Extreme altitude</td>
<td>Above 5000</td>
</tr>
</tbody>
</table>
## Altitude levels

<table>
<thead>
<tr>
<th>Altitude Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8848 m</td>
<td>Extreme altitude</td>
</tr>
<tr>
<td>5500 m</td>
<td>High altitude</td>
</tr>
<tr>
<td>3000 m</td>
<td>Moderate altitude</td>
</tr>
<tr>
<td>2000 m</td>
<td></td>
</tr>
<tr>
<td>1000 m</td>
<td>Low altitude</td>
</tr>
<tr>
<td>500-2000 m</td>
<td></td>
</tr>
</tbody>
</table>

### Rest effects.
- Permanent life impossible?
- Rest effects.
- AMS / acclimatization become clinically relevant.
- Performance is considerably impaired.

### Effects on aerobic exercise.
- AMS starts.
- Acclimatization is important.
- Minor impairment in aerobic performance.

### HYPOXIA

<table>
<thead>
<tr>
<th>Altitude (m)</th>
<th>Pressure (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>760</td>
</tr>
<tr>
<td>1000</td>
<td>590</td>
</tr>
<tr>
<td>3000</td>
<td>380</td>
</tr>
<tr>
<td>5000</td>
<td>200</td>
</tr>
</tbody>
</table>

6/10/2106 – Pat: 586 mmHg – $P_dO_2$: 123 – 16.2% $O_2$
WHY ALTITUDE?

Sports mountain
Alpinism

Altitude training
Sport performance

Health and
quality of life

Stimulus
(hypoxia)

Acute respond

Adaptation
(chronic)

ALITUDE TRAINING

To compete at altitude

To compete at sea level
Controversial results....

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Sample size</th>
<th>Exercise (type)</th>
<th>Hypoxic stimulus</th>
<th>Submaximal exercise (%)</th>
<th>Change in VO2</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey et al. (1996)</td>
<td>Humans</td>
<td>40</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>35</td>
<td>69</td>
</tr>
<tr>
<td>Barthelemy et al. (1994)</td>
<td>Humans</td>
<td>10</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>Friedman et al. (1996)</td>
<td>Humans</td>
<td>25</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>18</td>
<td>69</td>
</tr>
<tr>
<td>Gems et al. (1999)</td>
<td>Humans</td>
<td>20</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>28</td>
<td>69</td>
</tr>
<tr>
<td>Ingles and Wyndham (2001)</td>
<td>Humans</td>
<td>15</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>21</td>
<td>123</td>
</tr>
<tr>
<td>Jones et al. (2001)</td>
<td>Humans</td>
<td>15</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>24</td>
<td>230</td>
</tr>
<tr>
<td>Kendall et al. (2003)</td>
<td>Humans</td>
<td>15</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>24</td>
<td>230</td>
</tr>
<tr>
<td>Sneyd-Gudderstadt and Sanders (2005)</td>
<td>Humans</td>
<td>15</td>
<td>Cycling</td>
<td>Hypoxic</td>
<td>24</td>
<td>24</td>
<td>230</td>
</tr>
</tbody>
</table>

Controversial results…

<table>
<thead>
<tr>
<th>Effect</th>
<th>Natural altitude protocols</th>
<th>Artificial altitude protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>live-high</td>
<td>live-high</td>
</tr>
<tr>
<td>Elite</td>
<td></td>
<td>1.6; ±2.7</td>
</tr>
<tr>
<td>Subelite</td>
<td>0.9; ±2.4</td>
<td>4.2; ±2.9</td>
</tr>
</tbody>
</table>

Effect of enhanced protocol (%): ±90% CL

| Elite   | 4.2; ±4.1 | 4.3; ±5.0 | (4.0); ±5.5 |
| Subelite | 4.5; ±4.1 | 4.6; ±3.0 | 4.8; ±5.3 |

Some clues

ALTITUDE TRAINING

“Elite athletes have used altitude/hypoxic training for several years. Although the efficacy of altitude/ hypoxic training relative to sea-level performance remains controversial from a research perspective, athletes continue to use it in preparation for elite level competition”.


“….Enhancing protocols by appropriate manipulation of study characteristics produced clear effects with all protocols (3.5–6.8%) in subelite athletes, but only with LHTH (5.2%) and LHTL (4.3%) in elite athletes.

Altitude training

1. Altitude / Hypoxia clearly affects human body
2. Hypoxia + Exercise = more hypoxia.
3. The stimulus of hypoxia associated with the training stimulus seemed to induce:
   a) erythropoietic changes: EPO, RBC, Hb mass…
   b) non-erythropoietic changes:
      • Ventilatory acclimatization (decreased cost of ventilation)
      • Glucose metabolism
      • Improved mitochondrial efficiency
      • pH regulation and buffer capacity
      • Improvements in tolerance and kinetics of lactate
      • Angiogenesis
      • Stress adaptogenesis
      • Mechanical efficiency
Altitude training

- Great individual variability.
- Genetic factors:
  - Altitude natives.
  - Individual gene polymorphism.
  - KEY POINT: hypoxia inducible factors (HIF).

¿Responders or not responders?

“Individual variation in response to altitude training”


ALTITUDE TRAINING

Where?
When?
How?
How long?
Any risk?
Altitude training. Some clues

- What is the optimal altitude?
  - 2000 m - 2500 m

- How long?
  - 2 - 4 weeks
  - for > 22 hours/day or > 300 h

- Is simulated altitude as effective as natural altitude?

There is evidence that N2 dilution and O2 filtration are effective if provided the “hypoxic dose” is attained. It appears that fewer hours of hypoxic exposure (12-16 hr), but at a higher simulated elevation (2500 - 3000 m) is required to achieve similar erythropoietic effects vs. natural/terrestrial altitude (> 22 hr/d).
(Wilber 2007)
The altitude-induced increase in EPO is “dose” dependent

“Determinants of EPo release in response to short-term hypobaric hypoxia”
Ri-Li Ge et al, JAP 2002

“Altitude and endurance training”
Rusko et al., JSS 2004

Table 1. Recommendations of top coaches and applied sport scientists on when to compete after return from altitude training

<table>
<thead>
<tr>
<th>Author (Reference)</th>
<th>Recommended best time to compete after return from altitude training</th>
<th>Recommended time to avoid competition after return from altitude training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruno (9)</td>
<td>Day 12 “prime date for best performances”</td>
<td>Days 3–9</td>
</tr>
<tr>
<td>Dick (20)</td>
<td>After Day 13</td>
<td>Days 1–13</td>
</tr>
<tr>
<td>IAAF technical publication (6)</td>
<td>After Days 12–14</td>
<td>Days 14–25</td>
</tr>
<tr>
<td>Mann (personal communication)</td>
<td>Within the first 48 h after 10 days</td>
<td>Days 5–13</td>
</tr>
<tr>
<td>Popov (37)</td>
<td>Days 18–21 “95% of best performance”</td>
<td>Days 6–13</td>
</tr>
<tr>
<td>Soder (41)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When come back?

Fig. 3. Percentage changes (%) in the mean total red cell volume (RCV) or haemoglobin (HbM) mass during HILo in relation to the number of days of the HILo period.

Sea-level exercise performance following adaptation to hypoxia: a meta-analysis.
Ruszti, Sz, Szilágyi, G.
When come back?

- Performance
  
  A change in Hb-mass by 1% changed performance by 1.8 points. Participation at an ATC tended to decrease performance by 11 points until 14 days after return, had no effect the following 10 days, and significantly improved performance by 23 points 25–35 days after return. Illness reduced swimming performance by 25 points and injury by 16 points.

  (Wachsmuth et al, EJAP 2013)

<table>
<thead>
<tr>
<th>Factor/variable</th>
<th>Competitions (count)</th>
<th>Significance p&gt;</th>
<th>Effect (points)</th>
<th>CL (95 %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude influence</td>
<td>799</td>
<td>0.014</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0–14 days after return</td>
<td>80</td>
<td>0.06</td>
<td>−11</td>
<td>−21−0</td>
</tr>
<tr>
<td>15–35 days after return</td>
<td>26</td>
<td>0.02</td>
<td>+4</td>
<td>−12−18</td>
</tr>
<tr>
<td>Health status</td>
<td></td>
<td>0.016</td>
<td>+23</td>
<td>0.012</td>
</tr>
<tr>
<td>No problems</td>
<td>829</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Injured</td>
<td>37</td>
<td></td>
<td>−16</td>
<td>−30−3</td>
</tr>
<tr>
<td>Sick</td>
<td>28</td>
<td></td>
<td>−25</td>
<td>−44−6</td>
</tr>
<tr>
<td>Hb-mass</td>
<td>1 % of Hb-mass</td>
<td>894</td>
<td>0.003</td>
<td>1.8</td>
</tr>
</tbody>
</table>

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When come back?

The recommendation of when to compete after completing an altitude training sojourn may ultimately be dependent on the individual responses to altitude training and altitudinal acclimatization, altitude deacclimatization, as well as the training response that occurs within the first several days postaltitude.

Future research should simultaneously explore in detail the time course of the changes in red blood cell mass, ventilatory acclimatization, biomechanical and/or neuromuscular factors, and performance in elite endurance athletes after return to sea level. We believe the interaction between these variables will strongly influence the ideal time to compete after altitude training. Each athlete may display his or her own signature of deacclimatization with sea level residence, and knowledge of personal decay rates may allow for individualized prescriptions of when best to complete postaltitude camp.

(Chapman RF et al, JAP 2014)

Consider:

- Past altitude training.
- Combining other hypoxic methods.
- Other factor (travel, nutrition, temperature...)
How to train?

Altitude/Hypoxic Training Phases

But .......altitude is much more

- **Other objectives:**
  - To increase sports training capacity.
  - Socialization / Team Building / Psychological aspects.
  - Training environment (mild temperature, clear air...).
  - To recover (train while resting) – “The resting value”.
  - To obtain a record.
  - To mask or disguise the use of exogenous EPO.
  - Alternative to doping.
  - To imitate champions.

- **Other strategies:**
  - Short stages more frequent.
  - Combine methods.
  - Strength training.
  - RSH or RST.
  - Altitude + heat.
  - Respiratory training
  - .......
So …… altitude training should be planned

- Depending on:
  - Aim of the stage.
  - Moment of the season.
  - Net altitude.
  - Resources (technological, medial, sports facilities…)
  - Sport.
  - Age and sports experience.
  - Previous stages.
  - Health status, morphological and physiological characteristics…….

Risk of altitude training

- Environmental factors
- Overload
- Slower recovery
- Dehydration
- Nutritional deficits
- ….
AMS

<table>
<thead>
<tr>
<th>Clinical symptoms in altitude training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodo altura (3 sem.)</td>
</tr>
<tr>
<td>Síntomas</td>
</tr>
<tr>
<td>Generales</td>
</tr>
<tr>
<td>Respiratorios</td>
</tr>
<tr>
<td>Digestivos</td>
</tr>
<tr>
<td>Cardiovasculares</td>
</tr>
<tr>
<td>Musculoesqueléticos</td>
</tr>
<tr>
<td>Alteraciones estado animal</td>
</tr>
</tbody>
</table>

Optimizing Altitude Training

Control training and loads assimilation

- Subjective parameters:
  - Fatigue, feeling, appetite, sleep pattern...
- Physiological/biological parameters
  - Weight lost
  - HR (rest, submaximal)
  - Analytical test: HB (Hb mass), leukos, CK, urea, etc
  - SaO2
  - HRV
  - VO2 - load
  - Lactate curve shift
  - RPE/lactate
Basic advice for coaches

1. AT should be introduced in the annual program as an special or additional stimulus.
2. AT should be individualized.
3. Long term approach- Cumulative effect.
4. Proper Planning:
   • 2-4 weeks
   • Adaptation phase
   • Quality workouts at low level
   • Take care after the descent
5. Progression:
   • Longer stages, more frequently, more volume and/or intensity
6. Control training load and assimilation.

7. Health, hydration and nutrition (iron stores).
8. Recovery:
   • More sleep hours (9+1).
   • More recovery intra-microcycle.
   • Massage, Contrasts, Jacuzzi, sauna.
9. Combining methods:
   • Allows more quality workouts.
   • When it is not possible to train in altitude.
   • "Around" altitude training: Before /after.
10. Evaluation of results:
    • Analytics: Improvements in the red series.
    • Practice: how is training the athlete.
    • Final: performance improvement, competitions.
Conclusions

- Altitude training is still in force.
- HiHiLo is probably the best.
- To take care in altitude training:
  - Proper planning
  - Good physical fitness and health
  - Medical and Physiological control
  - Nutrition and hydration
  - Physiotherapeutic treatments
- Try new things without risks.
- Take advantage of new techniques.
- Team work – study – learn.

GENERAL INFORMATION
www.carsierranevada.com
car.granada@csd.gob.es

SPOR MEDICINE UNIT
serv.medicos@csd.gob.es
carmen.calderon@csd.gob.es

Thanks