

Training in High Altitude from 1800 to 2000 meters

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General Conditions at High Altitude

At the altitude of 1800 meters the air pressure decreases from 760 mm Hg (mercury) at sea level to 595 mm Hg (St. Moritz is 610 to 615 mm Hg). The oxygen partial pressure in the arterial system decreases by about 20 mm Hg. The consequence of this is that the body at high altitude is offered less oxygen at the same cardiac output and respiratory minute volume when compared to sea level. After 23 to 25 days these negative effects can be compensated for in accordance with the correct amount and intensity of training. When the body is adapted to a higher oxygen transport capacity, this profit is the main positive effect in the form of a capacity reserve.

At high altitude the respiratory work is also reduced because of the decreased pressure. This results in a higher respiratory minute volume. The adaptation to higher breathing work during intensive loads in training is also of advantage during the forthcoming competition phase.

At high altitude the water-vapour pressure in the air decreases to 55% of the sea level value. The air gets drier, and this - in combination with a high amount of physical work - leads to an irritation of the respiratory tract and is followed by a high fluid elimination. At the same time with increasing altitude, the air temperature decreases. One thousand meters' difference in altitude leads to decrease in the temperature by about 6.5°C. The solar radiation is more intense because of the direct ultraviolet rays. This has an activating effect on the sympathetic tone.

Time Course and Physiological Reaction of Adaptation

1) Early transition/adaptation period (duration 3 to 5 days).

Reaction: Increasing respiratory work with the aim to compensate for the lack of oxygen pressure.

- Decrease of PCO₂,
- Alkalosis with impairment of the peripheral O₂ utilisation.

Objective consequences caused by haematological research results:

- Concentration and decrease of blood volume (increase of haemoglobin by about 1-1.5%, increase of haematocrit to the value of 50 or more in men, and 47 or more in women),

- Reduced cardiac output during rest and also during submaximal load,
- During maximal load, increased cardiac output,
- Decreasing oxygen uptake by about 13% caused by reduction of the cardiac output,
- Increased heart rate (HR), as compared to the same load at sea level,
- Excretion of stress hormones (adrenaline, noradrenaline and corticosteroids, changes in electrolytes, minerals, etc.)

Subjective consequences:

- Subjective feeling of a high physiological load range caused by the increased sympathetic tone. The consequences could be a hidden effect of overtraining with long lasting decrease of power output.

2) Normal training phase after passing the early transition/adaptation period (4th/5th until 10th/12th day):

- Physiological load range and endurance trainability return to normal levels,
- Adaptation and normalisation of the work of the cardiac system to the conditions of high altitude,
- Blood volume returns to normal levels,
- Start of an intensive phase of erythropoiesis. Taking iron, vitamin C and vitamin B₁₂ supplements could be helpful,
- Normalisation of stress hormone excretion and acid-base-equilibrium,
- Because of the reduced buffer capacity for lactate, it is not effective to do training with high intensity during this phase of altitude training,

3) Late adaptation period, connected with higher intensity (13th/14th to 18th/19th day):

- More intensive loads are possible, but without provocation of an "early top form."

4) Late transition period (19th/20th day):

- Reduced intensity with medium amount (active regeneration/"super-compensation").

5) Active regeneration (2 1/2 days), connected with early transition (maximal 3 to 5 days):

- Adaptation to sea level and climate (see below). Nearly normal training process, like at sea level. Addition of some high intensive loads is possible.

6) Competition phase (6th to 20th day after high altitude training camp):

As far as the problem of the maximally advanced form after high altitude training is concerned, the opinions are divided. They vary from the 9th to the 23rd day. According to our results, an optimum of physiological power output can be assumed between the 10th and 13th day. In accordance with scientific and theoretical results, during the following 10 days a decrease in the physiological effects can be assumed. This can not be verified by practical reasons or with experiments.

Implications for Training and General Framework Training Plan

1) Early Transition/Adaptation Period:

Because of physiological and psychological reasons there should be a load with high intensity just before going to altitude. During the first days at altitude the training dose should be long distance/steady state, or an aerobic training at a low intensity should be conducted. There should be a framework of training for each type of boat. The maximum of training is long distance training of a normal or somewhat reduced volume when compared to sea level. Once or twice per week there should be a strength-endurance training session at low intensity and with long recovery intervals between the repetitions. On the third or fourth day at altitude, half a day of rest should be planned. This early adaptation period should be a type of training between normal and regeneration training.

2) Normal training phase after passing the early transition/adaptation period:

As the load capacity normalises there is also a normalisation of the training process with two or three sessions per day. Too many intensive training loads should be avoided. A strength-endurance training at nearly the same intensity compared to sea level can take place. Monitoring of training should be exact and individualised.

3) Late adaptation period:

At the end of the high altitude training camp, more intensive load, such as going for distances, time relation distances and ergometer tests, are possible. Reaching for an early top form should be avoided by setting individual intensities for training sessions and by individually monitoring the training process. The intensive loads at the end of the altitude camp should be regarded as a stimulus to develop anaerobic capacity.

4) Late transition period:

The last two days at altitude are to be regarded as days of active regeneration (phase of "super-compensation"). During these days the return back to sea level will take place.

5) Active regeneration phase, connected with early transition phase at sea level:

During the first two or three days at sea level a reduced performance capacity should be expected. Four or 5 days after the altitude camp, an individually increased high intensive load should take place. The same load can be repeated some days later. After this, a nearly normal competition state can be expected.

Processes of Monitoring Training

Ergometer testing as an objective method of performance at the beginning and the end of the training camp is highly recommended. If possible, a spiroergometry test should also take place. Control of urea as an indicator of overtraining at least every three days is useful as additional support. Registration and monitoring of heart rate during training is important for individual reaction to training intensity.

Measurement of lactate to determine the intensity of training and the athlete's maximum load tolerance is also extremely helpful.

If possible, one should check the level of creatine kinase as an indicator of muscular damages after intensive work on the water and after intensive strength training. Controlling the levels of haemoglobin and haematocrit as an indicator of the water content of the body is useful as well.

Other Comments

The training at high altitude can only be long distance/steady state training. Basic technical improvements (e.g., during racing or in the range of high stroke rates) cannot be safely attempted because of the need for high intensity. These have to be trained during the year and in the course of other training measures.

There are indications that those athletes who have been at altitude before adapt much faster than others. From the theoretical point of view a high altitude camp three times per year should be optimal. The result of this is the repeated stimulus which causes the excretion of erythropoetin which is followed by the development of a higher amount of red blood cells and connected to a higher blood volume.

The precondition for a positive training adaptation at high altitude is health and a good, trained condition in the athlete. Infections which are developing or latent (especially in the area of the teeth) have to be under medical control early enough and, in any case, before the high altitude camp.

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