Effect of 21 days of “Living High – Training High” training period on sea-level swimming performance and haematological blood results in competitive swimmers

D. ZORETIC ¹, P. KUTEROVAC ²

Aim. The aim of this study was to investigate whether the training and life at an altitude of 2200 meters during three week period improves the speed of swimming at aerobic and anaerobic threshold, and whether there is a difference in hematologic blood picture (hemoglobin [Hb], red blood cell [RBC] and hematocrit [Hct]) after returning to sea level.

Methods. Five categorized Croatian national team swimmers were tested. Blood sampling and progression swimming tests were performed to examine the physiological adaptation to altitude. Swimming tests and blood sampling were performed five days before altitude preparation and eight days after altitude preparation, when swimmers came on sea level.

Results. Statistically significant changes between two measurement points were determined in variables: the speed of swimming at aerobic threshold (Vaet1, Vaet2; t=-3.13; P=0.035), the speed of swimming at anaerobic threshold (Vant1, Vant2; t=-8.57; P=0.001) and Red blood cells (RBC1, RBC2; t=-3.34; P=0.029). The speed of swimming at aerobic threshold (Vaet) increased by 4.1%, and 3.3% anaerobic threshold (Vant) after returning from altitude training. In the hematologic blood results, it can be seen that the number of red blood cells increased by 3.7% after returning from altitude training, while the level of haemoglobin and the percentage of haematocrite remained the same.

Conclusion. Regarding the increase in Vaet and Vant, it can be said that the increase in speed measured during progressive swimming test occurred mainly because of a significant increase in the number of erythrocytes which is responsible for increased oxygen supply to muscles (increased max. oxygen consumption), and thus increased the speed of swimming.

Key words: Altitude - Hematology - Swimming.
increase in their red blood cell mass and haemoglobin. Some scientific studies reported a significant increase in total haemoglobin/red cell mass by 6-9% after 3-4 weeks of living and training at an altitude ≥2000 m in college runners, elite swimmers and elite biathletes. Only Levine and Stray-Gundersen described a weak, but significant (r=0.037, P=0.02) correlation between changes in red cell mass and changes in VO2 max after altitude training. After Olympic Games in Mexico City, several scientific studies about the effect of altitude training on athletic performance have been conducted. Many coaches and athletes use altitude training in order to enhance performance because they consider that altitude training improves aerobic performance and stimulate the release of EPO (erythropoietin), which subsequently leads to increments in erythrocyte and haemoglobin concentration.

Most of scientific studies on altitude training have evaluated the effect of LHTH altitude training on sea level endurance performance. The initial studies were conducted in the mid-1960s. The LHTH method of altitude training has largely been replaced by “live high – training low” altitude training. Some studies demonstrated that LHTH enhanced endurance performance upon return to sea level, whereas others showed that sea level endurance performance was not enhanced after LHTH altitude training.

The goal of this study was to investigate whether the training and life at an altitude of 2200 meters during three week period improves the speed of swimming at aerobic and anaerobic threshold, and whether there is a difference in hematologic blood picture (haemoglobin [Hb], red blood cell [RBC] and hematocrit [Hct]), after returning to sea level in five categorized swimmers of the Croatian national team.

### Materials and methods

#### Subjects

Five well-trained swimmers (5 men) volunteered for the study. All swimmers had been training intensively for at least 6 years prior to this study and they participated in European, World Championship and in European Junior Championship with a respective success. One of them is a world record holder, one is European champion, two are European vice champions, and one was third at the European junior championships.

The mean age of swimmers (N.=5) was 22.2±2.16 years. The swimmers’ basic anthropometric data were as follows: stature 1.89±3.31 m; body mass 86.8±4.14 kg (Table I).

| Table I.—Anthropometric features of the swimmers. Average values are mean (SD and MIN-MAX). |
|-------------------------------------------------|--------|--------|
| Age(year) | 22.2±2.16 | 20 | -25 |
| Stature (cm) | 189±3.31 | 185 | -194 |
| Body mass (kg) | 86.8±4.14 | 80 | -90 |

#### Experimental procedures

Each swimmer was tested at the swimming pool (SRC “Mladost”) and in the clinical-hospital center (KBC “Merkur”) in Zagreb. Prior to the day of the testing, all athletes were informed that they are obliged to report to the laboratory in a rested state, and not to consume food or caffeine within 2 hours before the test. Before testing, swimmers were given 15 minutes to warm up by combining easy swimming, sprints, pace work, drills and stretching in accordance with their usual habits.

The blood was analyzed on hematological analyzer (Cycmex Kx21, Japan). Lactate test was performed twice with the help of lactic measurement system (Lactat Scout, USA), before going to the training camp, and eight days after arrival from the altitude. In order to determine lactate curves, progressive continuous test was used, where the swimmer swims certain distance with fixed speed. Continuous swimming pace is very precisely controlled by electronic device (Leader, Pacer Products 942 Appleton), which is a light signal from the
bottom of the pool which gives swimmers guided swimming speed. Turning speed of light was controlled outside the pool in the control box of the “leader”. The speed of swimming was determined based on the 100 meter front crawl stroke, which was swum at maximum before the first day of testing. Seven days after returning from altitude training, the swimmers swam 100 meters crawl on competition “Victoria08” (Rijeka, On October 11th 2008) and on the basis of the results the swimming speed of the second swimming test was determined. The performance of the front crawl stroke technique is well controlled in the progressive test because of following factors: swimming technique is manifested in the minimum energy consumption, there is relatively easy control of continuous swimming, and cyclic repetition of the work of hands keeps stable energy consumption during swimming.

The incremental swimming test has five levels starting at an intensity of 70% of the personal best performance at the time of testing. These testings were conducted in a 25 m pool. Lactates were measured by an automated system (Lactat Scout, USA). Blood were drawn from the fingers at the end of each step and repeatedly after the maximal level. Heart rate was monitored and recorded using Polar R652x Finland. Cardio parameters were calculated automatically and stored on a PC for later analysis.

Test protocols

Tests before altitude training

Swimmers were tested one week before travelling to the altitude training camp as follows:

Day 1. Health checks including blood draws (to determine Hb, RBC, Hct)
Day 2. 100 meters freestyle maximal (1 RM)
Day 3. Incremental swimming test. (3x (3 x 100 m (70% - 80% - 90% of 1RM) + 100 m freestyle 100% of 1RM)

Test after altitude training

All swimmers performed the incremental swimming test and their total Hb, RBC and Hct were measured 10 days after return to sea level, the time when athletes and coaches considered that maximal sea level performance was achieved after altitude training.

Altitude training

Specific Altitude Training Plan.—Twenty-one day altitude training period was divided into three phases: adaptation (2 days), application (17 days) and regeneration (2 days).

Preparations were planned as an integral part of the plan and program for the European Championships in Rijeka (on December 11 to 14 of 2008) (Table II). Altitude center where swimmers lived and trained and the programme of the altitude training camp took place was Belmeken (Bulgarian), at an altitude of 2200 m, because “the ideal height for maintenance of altitude training should meet the conditions that partial pressure of oxygen is less than 65 mmHg, which is in meters 2100-3500 meters”.

Before going to the altitude training, 30 days of basic preparations were conducted, so the athletes should had been fully prepared for the specific part of the preparation. The highest volume of training was conducted in the aerobic zones intensity (Table II), but they trained for development of maximum speed, as well. Training on land, “in gym”, was based on the development of maximum strength, explosive strength and speed. The swimmers performed 70-80 km of swim training per week, mainly anaerobic threshold (Ant) training (35% from Aet). About 15% of the training was concentrated on improving swimming style. Training intensity during the altitude sojourn should be carefully monitored and, if possible, the erythropoietic response should be evaluated by measurement of total haemoglobin mass before and after altitude training. Training was supervised by experienced two Croatian coaches.
Swimmers swam the last part of the task 1 x 100 meters with 100% of the maximum intensity, and the blood sample was taken after 5 to 6 minutes of recovery.

Based on the four values of lactate and swimming speed, lactic curve was obtained and used to determine the swimming speed at 2.5 mmol (14) as the aerobic threshold and 4 mmol as ANT (1, 10).

**Nutritional**

Swimmers meals were conducted by coach orders. Pharmacological supplementation, which swimmers have taken, had the task to increase the immune (defence) mechanisms in the organism, was directly responsible for the production of erythrocyte and increase of haemoglobin. The swimmers were taking supplements by Bill Phillips diet 15 and by own experience of head coach and Table III shows all supplements that swimmers used (Table III).

Training was controlled every morning in order to control the positives and negatives of life and training in hypoxic conditions.
Table III.—Supplementary.

<table>
<thead>
<tr>
<th>Supplementary</th>
<th>Effect</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>Supplementary</td>
<td>30 g on the evening</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>Supplementary</td>
<td>30 g during training</td>
</tr>
<tr>
<td>Fite- active</td>
<td>Isotonic drink</td>
<td>5 g during training</td>
</tr>
<tr>
<td>Multivitamin</td>
<td>Metabolism</td>
<td>2 pills after dinner</td>
</tr>
<tr>
<td>Multimineral</td>
<td>Metabolism</td>
<td>2 pills after dinner</td>
</tr>
<tr>
<td>E- vitamin</td>
<td>Testosterone level</td>
<td>1 pill after dinner</td>
</tr>
<tr>
<td>ACE + Selene</td>
<td>Antioxidants</td>
<td>1 pill after breakfast</td>
</tr>
<tr>
<td>B-complex</td>
<td>Metabolism protein</td>
<td>2 pills after breakfast</td>
</tr>
<tr>
<td>Iron + Folic acid</td>
<td>Progeniture RBC and Hb</td>
<td>1 pill + 1 pill in the morning</td>
</tr>
<tr>
<td>Q- 10</td>
<td>Immunity</td>
<td>1 pill in the morning + 1 pill in the evening</td>
</tr>
<tr>
<td>Zinc</td>
<td>Immunity</td>
<td>1 pill after dinner</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Convulsions muscles</td>
<td>1 ampoule after training</td>
</tr>
<tr>
<td>L-glutamine</td>
<td>Recovery</td>
<td>5 g in the morning + 5 g in the evening</td>
</tr>
<tr>
<td>BCAA</td>
<td>Anticatabolit</td>
<td>3 pills in the morning + 3 pills in the evening</td>
</tr>
<tr>
<td>HMB</td>
<td>Anticatabolit</td>
<td>2 pills in the evening + 2 pills in the midday + 2 pills in the evening</td>
</tr>
</tbody>
</table>

Table IV.—Descriptive statistical parameters of swimming speed in aerobic and anaerobic threshold and hematologic blood results.

<table>
<thead>
<tr>
<th></th>
<th>Valid N</th>
<th>Mean + SD</th>
<th>MIN</th>
<th>MAX</th>
<th>t</th>
<th>P</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>V Aet1</td>
<td>5</td>
<td>1.45 ± 0.04</td>
<td>1.40</td>
<td>1.49</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>V Aet2</td>
<td>5</td>
<td>1.51 ± 0.07</td>
<td>1.45</td>
<td>1.62</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>V Ant1</td>
<td>5</td>
<td>1.53 ± 0.03</td>
<td>1.51</td>
<td>1.57</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>V Ant2</td>
<td>5</td>
<td>1.58 ± 0.02</td>
<td>1.56</td>
<td>1.60</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>RBC1</td>
<td>5</td>
<td>4.93 ± 0.28</td>
<td>4.59</td>
<td>5.21</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>RBC2</td>
<td>5</td>
<td>5.41 ± 0.24</td>
<td>4.83</td>
<td>5.37</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>Hb1</td>
<td>5</td>
<td>151 ± 6</td>
<td>145</td>
<td>156</td>
<td>-3.13</td>
<td>0.035</td>
<td>-0.058</td>
</tr>
<tr>
<td>Hb2</td>
<td>5</td>
<td>154 ± 5</td>
<td>149</td>
<td>162</td>
<td>-2.01</td>
<td>0.115</td>
<td>-2.80</td>
</tr>
<tr>
<td>Htc1</td>
<td>5</td>
<td>0.45 ± 0.01</td>
<td>0.41</td>
<td>0.46</td>
<td>-2.14</td>
<td>0.099</td>
<td>-0.008</td>
</tr>
<tr>
<td>Htc2</td>
<td>5</td>
<td>0.46 ± 0.01</td>
<td>0.45</td>
<td>0.48</td>
<td>-2.14</td>
<td>0.099</td>
<td>-0.008</td>
</tr>
</tbody>
</table>


The following tests were conducted: orthostatic test (recovery), measurement of the amount of blood glucose (possible hypoglycaemia) and weighting the body mass in order to prevent catabolic processes. During the main series, periodical lactate checking was done in order to be sure that planned training is carried out (if lactate were higher than planned intensity would be decreased and recovery increased. Recovery was implemented with classic services: massage, sauna, and stretching.

**Statistical Analysis**

The Statistic release 7.0 for Windows was used to process and report the data. Descriptive statistics were calculated for all data and have been reported as a mean value, standard deviations (± SD), Minimums (MIN) and maximums (MAX). Paired t-tests for normal distribution were used to discern any significant differences between measurements in before and after altitude training in variables of blood sampling, swimming.
before and after altitude training. There are significant differences at the level of reliability of 0.05 for the variables: the speed of swimming at the aerobic threshold (Vaet), swimming speed at the anaerobic threshold (Vant) and the number of erythrocytes (E).

Statistically significant increase in swimming speed can be combined with the increasing number of erythrocytes (both intensity zones in swimming take place in aerobic conditions).

As there was no control group that trained at sea level, it cannot be fully said that the total volume of training (Table II) (at 80% of total volume of training was at the same swimming speed) was single one responsible for the improvement in results in swimming speed, but “LHTH” training as well. Some studies have reported no increase, whereas others have reported only a small improvement (approximately 8%) by training at sea level. On the other hand, several studies have reported gains of 7% to 18% in the haemoglobin content of blood after altitude training.

Statistically significant changes between measurement points were determined in variables: the speed of swimming at aerobic threshold (Vaet1, Vaet2; t=-3.13; P=0.035), the speed of swimming at anaerobic threshold (Vant1, Vant2; t=-8.57; P=0.001) before and after altitude training. There are significant differences at the level of reliability of 0.05 for the variables: the speed of swimming at the aerobic threshold (Vaet), swimming speed at the anaerobic threshold (Vant) and the number of erythrocytes (E).

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and Red blood cells (RBC1, RBC2; t=-3.34; P=0.029). There are no statistically changes in variables: haemoglobin (Hb1, Hb2) and hematocrite (Htc1, Htc2).

Variable haemoglobin, in absolute results shows that there was an increase between the first and second test, obviously not as much as it would be statistically significant. Additional supplementation of athletes with iron, as well as bigger sample of treated entities would probably reveal statistical significance of difference between absolute results of level of haemoglobin and blood sampling in the first and the second testing. This data will be used for next altitude training.

In absolute values there was an increase of hematocrite between two testings, but without statistical relevance.

Hematocrite, which is in medicine defined as the total amount of all blood cells, shows no statistical relevance. In absolute values we can see an increase between the first and second tests. So the logical answer is that the total quantity of blood plasma has been increased, and thus value of hematocrite has been reduced.

Based on the obtained average values of heart rates and speed of swimming on those heart rates in four measuring points, curves with pulse values were obtained (Figure 1). The swimming speed (m/s) is on the abscissa while the frequency of heart (beats per minute) is on ordinate. By comparing these two curves it can be seen that there are no relevant differences between heart rates at specific speeds of swimming. This can support the argument that swimmers acclimatized to sea level after returning from training camp. Within the first few days of exposure to altitude, heart rate at rest and during submaximal exercise is elevated compared with that at sea level, whereas heart rate during maximal exercise at altitude may be similar to or lower then that at sea level. Sea level heart rates are difficult to use as an indication of intensity at altitude. Resting heart rate can be higher by 10% for the first week, while maximum heart rate can be as much as 10% lower.

The median value of all respondents results in two testings (before and after) altitude training (Figure 2) The ordinate shows lactate (mmol) while the abscissa shows swimming speed (m / s). Looking at these two curves, it is clear that the curve moved left after training tip, which means that the speed of swimming increased during Act and Ant training.

Conclusions

The goal of practice in hypoxic conditions is to stimulate production of enzymatic antioxidants which leads to the elimination of free radicals that are created in the muscles during training and which cause tiredness. Increased erythropoietin production leads to increase of haematocrite, which strengthens the immune system and stimulates sympathetic. Elevation and length of altitude training period are important part of preconditions for achieving the best results. There is great importance of programming all the factors above for each athlete individually. The intensity of the training was lower than in the valley and after an adaptation period because VO2max declines by 2% every 300 m above 1500 meters. Staying at altitude with the altitude training (LHTH) gives advantage to the sprinters because there is no adaptation for anaerobic activities, and because puffr ability increases (6% after 2 weeks at 2700m).

Results indicate that this research is in accordace with previous research and that staying in hypoxic conditions, with respective statistical significance increases the number of erythrocyte (red blood cells) in the blood.

Hematologic changes, as the most visible physiological adaptation of organisms to hypoxic conditions, increase the capacity of blood to transport oxygen naturally, and are considered to be effective, non-invasive and legal method of blood doping. Regarding the increase in Vaet and Vant, it can be said that the increase in speed measured during progressive swimming test occurred because of a significant increase in the number of erythrocytes which is re-
Responsabile per l'aumento della velocità di consumo di ossigeno di conseguenza dell'aumento della velocità di consumo di ossigeno e della percentuale di ematocrito sono rimasti gli stessi.

**Conclusion.** Riguardo l'aumento di Vaet e Vant, può essere affermato che si è verificato principalmente un aumento della misurazione della velocità durante il test di nuoto progressivo a causa di un aumento significativo del numero di eritrociti, responsabile dell'aumento dell'apporto di ossigeno ai muscoli (incremento del consumo massimo di ossigeno) e di conseguenza dell'aumento della velocità della prestazione.

Parole chiave: Altitudine - Ematologia - Nuoto.

**References**


