**JPFSM: Review Article**

**Effects of the “live high-train high” and “live high-train low” protocols on physiological adaptations and athletic performance**

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Received: June 29, 2012 / Accepted: August 27, 2012

**Abstract** The present article reviews the effects of the traditional “live high-train high” (LHTH) protocol and the contemporary “live high-train low” (LHTL) protocol on physiological adaptations and on athletic performance at sea level based on results from studies in which athletes were assigned to an “altitude group” and “sea level group”. Consequently, the LHTH protocol and LHTL protocol were considered to provoke nearly similar physiological adaptations. On the other hand, the LHTL protocol appeared to be more effective than the LHTH protocol with respect to endurance performance at sea level. Furthermore, the LHTL protocol is suggested to possibly be effective for sprinting events as well. These results indicate that the LHTL protocol affords about 1 to 4% improvement in exercise of approximately 30-second to 17-minute duration. However, a recent meta-analysis suggested that the LHTH protocol improves the maximal power output of elite athletes. Furthermore, it is conceivable that interindividual differences greatly affect the results obtained from altitude training. Therefore, there is an urgent need to elucidate interindividual differences that are involved in physiological adaptations to hypoxic environments or improvements in athletic performance. Moreover, the relevant elucidation will require the adjustment of altitude (oxygen concentration), daily duration of exposure, and length of stay in concert with individual features. In some cases, a decision about whether or not to adopt the LHTL or LHTH protocol would be necessitated. In addition, the combination of the intermittent hypoxic training protocol with the LHTL protocol will require a detailed investigation.

**Keywords**: moderate altitude training, live high-train high protocol, live high-train low protocol, physiological adaptations, athletic performance

**Introduction**

Many countries have fully addressed altitude training, since around 1960, based on the great success of athletes in long-distance running events who came from highlands, including an Ethiopian marathon champion, Abebe Bikila. Furthermore, the fact that Mexico City—located at an altitude of 2,260 m—was selected for holding the 1968 Summer Olympic Games, can be considered another reason for the increased attention. Altitude training was conducted as part of preparation leading up to the 1968 Games, and has been conducted since then with the major objective of improving endurance performance at sea level.

At higher altitudes, atmospheric pressure and partial pressure of oxygen decrease in parallel with altitude. Therefore, exercise intensity is relatively enhanced in altitude training compared with training at sea level, and the status of hypoxia in skeletal muscles is further intensified. The resulting combination of the passive effect of extended stay (acclimatization to hypoxia) and training effect (positive effect) is considered to improve endurance performance at sea level. This assumption has afforded the conceptual basis for a number of research papers on altitude training in the last 40 years or more.

Following are the three types of altitude or hypoxic training: 1) the traditional “live high-train high (LHTH)” protocol, by which athletes stay and are trained at a moderate altitude; 2) the contemporary “live high-train low (LHTL)” protocol, by which athletes stay at a moderate altitude and are trained at sea level or at a low altitude; and 3) the “live low-train high (LLTH)” protocol by which athletes stay at sea level and are trained under hypoxia (at a moderate altitude). On the other hand, studies can be categorized according to research content: a) research on the effects of the stay itself at moderate altitude; and b) research on the effects of training the general population; and c) research on the effects of training athletes. Regarding b) and c), furthermore, there are two types of studies: A) research designed...
for intergroup comparisons by establishing an altitude group and sea level group; and B) research designed to make comparisons before and after training by establishing an altitude group only.

Altitude training is conducted for a variety of objectives. Obviously, however, the training is performed by athletes as part of their training. Furthermore, the evidence already exists that altitude training improves athletic performance at moderate to high altitude. On the other hand, the LLTH protocol differs from “altitude training” in its original meaning. Therefore, the present article reviews the effects of the LHTH and LHTL protocols on physiological adaptations and athletic performance at sea level based on the results from research c)-A) in which an altitude group and sea level group were established.

Effects of LHTH protocol on physiological adaptations and athletic performance at sea level

Effects on physiological adaptations. The most important physiological adaptation achieved with the LHTH protocol is an improvement in maximal aerobic power; in this improvement are involved an insufficient oxygen-induced increase in serum erythropoietin (EPO) levels and a series of accompanying physiological responses, e.g., increases in red cell volume (RCV) and hemoglobin (Hb) concentration, an increased erythrocyte concentration of 2,3-diphosphoglycerate (2,3-DPG) causing a rightward shift of the oxyhemoglobin dissociation curve, development of capillary density, an increase in mitochondrial capacity, an increase in oxidative enzyme activity, and an increase in muscle myoglobin content (Fig. 1). Consequently, both the oxygen transporting ability to skeletal muscles and oxygen availability therein are enhanced, causing an improvement in the maximal aerobic power of the trained athlete. Furthermore, an increase in 3-hydroxyacyl-CoA dehydrogenase activity accelerates the mobilization of free fatty acids and conserves muscular glycogen. In addition, improved muscle buffering capacity, increased lactate threshold, improved mechanical efficiency, and elevated psychological limits are all considered to effectively play a role in endurance events. Furthermore, increases in anaerobic capacity, muscle strength, and muscle power are also factors that enhance athletic performance in endurance athletes whose aerobic capacity has reached a plateau.

On the other hand, the LHTH protocol also provokes physiological adaptations that are considered to exert unfavorable effects on athletic performance. For instance, the excessive discharge of bicarbonate (a decrease in alkali reserves) occurs in association with hyperventilation at moderate to high altitude, and blood buffering capacity possibly decreases. Furthermore, an increase in hematocrit value (hemoconcentration) elevates blood viscosity and possibly reduces muscle blood flow. In addition, the downregulation of β-adrenergic receptors and the enhancement of the parasympathetic nervous system, in association with staying at moderate to high altitude, are considered to suppress glycogenolysis in skeletal muscle and to lower cardiac output. Furthermore, a decrease in glycolytic enzyme activity, increased blood concentrations of stress hormone, and a decrease in protein synthesis have been reported to occur (Fig. 1).

In addition to these effects, qualitative and quantitative decreases in training are considered the biggest problem inherent to the LHTH protocol. This issue is inevitable, to a greater or lesser extent, as long as athletes stay and continue training at a moderate to high altitude. Conse-
quently, athletes fall into the same status as discontinued training (detraining); neuromuscular adaptation in the locomotor system is damaged, thus causing a decrease in athletic performance\(^2\).

**Effects on athletic performance at sea level.** Studies assigning athletes to an “altitude group” and “sea level group”, which reported that the LHTH protocol was effective for athletic performance, are shown in Table 1\(^9\)\(^{11}\).

As is clear from the table, a very limited number of studies have reported that the LHTH protocol is effective for endurance performance at sea level. A recent review article of Loffredo and Glazer (2006)\(^{12}\) reported that the LHTH protocol is effective for anaerobic but not aerobic performance at sea level. Furthermore, Friedmann-Bette (2008)\(^9\) stated that there were three studies reporting the efficacy of the LHTH protocol for endurance performance at sea level. One of the studies (Mellerowicz et al., 1970) reported that a LHTH protocol lasting 4 weeks increased maximal oxygen uptake (\(\text{VO}_2\text{max}\)) and improved the 3-km time trial. The remaining two studies (Levine and Stray-Gundersen, 1997\(^{13}\); Burtscher et al., 1996\(^{14}\)) reported increases in \(\text{VO}_2\text{max}\); however, the former found no improvement in athletic performance at sea level\(^{13}\), while the latter compared the “altitude group” with the “sea level group” with respect to athletic performance by using training outcomes obtained from the “sea level group” 1 year later\(^{14}\).

Apart from these experimental studies, one study examined the effects of altitude training based on time-course changes in records\(^{15}\). The study investigated breaks in the world records in various running events (1,500 m, 5,000 m, and 10,000 m) over several years, and the means of the best 10 records for each year, and compared the records that were achieved before and after 1968, when altitude training was initiated, with the aim of improving athletic performance at sea level. Consequently, with the exception of the mean records for the 1,500 m running event, no evidence was obtained which indicated that occurrences of “breaking the record” subsequent to 1968 excelled occurrences prior to 1968 (Fig. 2).

These results may lead us to consider that the LHTH protocol is not effective for endurance performance at sea level. On the other hand, another admissible interpretation

![Fig. 2]. Progression of the running speed corresponding to the WR (filled squares), and MB (open squares) for the 1,500, 5,000, and 10,000 m, for men, between 1956 and 1991. The last WR observed before 1957 (filled triangle), the regression lines computed before 1968, and between 1968 and 1991 (WR) or 1985 (MB), and the associated coefficients of correlation (appended tables), are also shown. The annual ranking published yearly in “Track and Field News” was used as the database\(^{15}\).

<table>
<thead>
<tr>
<th>Authors (year)</th>
<th>Subjects</th>
<th>Altitude (live/train), Length of stay</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mellerowicz et al. (1970)</td>
<td>Endurance runners</td>
<td>2,020 m/1,800-2,500 m, 4 weeks</td>
<td>3 km time trial †</td>
</tr>
<tr>
<td>Karvonen et al. (1986)</td>
<td>Sprinter</td>
<td>1,850 m/1,850 m, 21 days</td>
<td>3 jumps/10 jumps distance †</td>
</tr>
<tr>
<td>Karvonen et al. (1990)</td>
<td>Sprinter</td>
<td>1,850 m/1,850 m, 15 days</td>
<td>150 m running speeds †</td>
</tr>
</tbody>
</table>

†: significant increase (P < 0.05)
is that there are large individual variations in adaptation to the LHTH protocol\(^{16,17}\), resulting in no significant difference between the “altitude” group and the “sea level” group when comparing them by means of the mean values. For instance, Rahkira and Ruskó (1982)\(^{19}\) compared skiers who were assigned to the training group at an altitude of 2,600 m and to the training group at sea level. Consequently, blood Hb concentrations increased significantly in the LHTH group. However, athletic performance improved in two of six athletes, remained unchanged in two, and decreased in two. Furthermore, Chapman et al. (1998)\(^{19}\) instructed university-level athletes to stay for a 28-day training program at moderate altitude. Consequently, the athletes were categorized into two types: responders whose 5-km running time improved significantly, and nonresponders who showed no such improvement. They reported that serum EPO levels increased more extensively in responders, than in nonresponders, and that RCV and VO\(_{\text{max}}\) increased significantly after training.

On the other hand, Bonetti and Hopkins (2009)\(^{20}\) suggested, in their recent review using meta-analysis, that the LHTH protocol elevates maximal power output of elite athletes. Based on this suggestion, Saunders et al. (2009)\(^{21}\) proposed the following requirements in order for the LHTH protocol to be effective: ensure a sufficient length of stay (not less than 2 weeks) at a sufficient altitude (1,800 to 2,500 m), design training meticulously, supply a sufficient amount of iron, and do camping several times (2 to 4 times) a year at moderate altitude.

**Methods to solve the problem of qualitative and quantitative decreases in training**

Qualitative and quantitative decreases in training are the biggest problem of the LHTH protocol and are considered to have greater effects on elite athletes. Furthermore, physical condition is difficult to control and keep at higher altitude compared to sea level. Therefore, the athlete gets out of shape at higher altitude and possibly experiences decreased athletic performance when returning to sea level. To solve this problem, therefore, Daniels and Oldridge (1970)\(^{22}\) introduced the intermittent exposure protocol in which the LHTH protocol, lasting approximately 2 weeks, and the training protocol, lasting approximately 1 week at sea level, is repeated. Consequently, they reported that VO\(_{\text{max}}\) increased, and that five among six athletes improved their personal best performances.

In the 1990s, Levine et al. developed a protocol by which athletes stay at moderate altitude and are trained at low altitude (the LHTL protocol utilizing natural environments). On the other hand, a stay at higher altitude is considered to exert its effect not through low atmospheric pressure, but principally through hypoxia\(^{4,6,7}\). Based on this concept, Rusko et al. invented a protocol by which athletes are trained at sea level while staying in an artificial hypoxia room under normal pressure (altitude house) for 12 hours or longer: the LHTL utilizing artificial environment.

**Effects of LHTL protocol on physiological adaptations and athletic performance at sea level**

**Effects on physiological adaptations.** Physiological effects, which are obtained through the LHTL protocol, utilizing natural environments or the altitude house, are nearly similar to those obtained through the conventional LHTH protocol (Table 2).\(^{23}\) However, what’s important in the protocol is daily duration of exposure at moderate altitude or in the altitude house. Table 3 shows the physiological parameters that are considered to be related to improvements in athletic performance and conditions for staying in the altitude house that increase the parameters (simulated altitude, daily duration of exposure, and length of stay).

As is clear from the table, simulated altitudes of 2,000 to 3,000 m are required for all the parameters. Furthermore, enhanced erythropoiesis (increases in Hb concentration and RCV) was found in daily duration of exposure (≥ 12 hours) and length of stay (≥ 20 days). Furthermore, VO\(_{\text{max}}\) also increased under the same conditions.

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**Table 2.** Summary of physiological adaptations to moderate natural altitude (1,500 to 3,000 m) or “live high, train low” for 2 to 4 weeks\(^{3}\)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Type of adaptation</th>
<th>Definite</th>
<th>Probable</th>
<th>Contentious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood</td>
<td>Plasma volume rapidly within 24 hours (\rightarrow) Hct, (\uparrow) Hb, (\downarrow) Hct and (\downarrow) Retinol cell count; Blood lactate during submaximal exercise; Resting pH for 1-4 wks;</td>
<td>2,3-DPG</td>
<td>Serum EPO</td>
<td>Soluble transferrin receptor</td>
</tr>
<tr>
<td>Erythropoiesis</td>
<td>Serum EPO</td>
<td>2,3-DPG</td>
<td>Cardiac output during submaximal exercise associated with stroke volume</td>
<td>Left ventricular contractility (below 2,000 m)</td>
</tr>
<tr>
<td>Heart</td>
<td>Production of or (\rightarrow) Clearance of lactate; Carbohydrate and Free fatty acid utilisation; Capillary : Fibre ratio; Oxidative enzyme activities</td>
<td>Muscle buffering capacity</td>
<td>Myoglobin content</td>
<td>Exercise content</td>
</tr>
<tr>
<td>Muscle</td>
<td>At rest and during exercise</td>
<td>Exercise efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation</td>
<td></td>
<td>Exercise efficiency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2,3-DPG = 2,3-diphosphoglycerate; EPO = erythropoietin-α; [Hb] = haemoglobin concentration; Hb\(_{\text{mass}}\) = haemoglobin mass; Hct = haematocrit;
\(\downarrow\) indicates decrease; \(\uparrow\) indicates increase; \(\rightarrow\) indicates "leads to"; \(\leftrightarrow\) indicates no change.
results lead us to consider that an athlete needs to stay in the altitude house at least 12 hours a day, and continue staying for 3 to 4 weeks, on the assumption that the effects of the LHTL protocol, on endurance performance at sea level, consist of improvements in maximal aerobic power associated mainly with increases in RCV. On the other hand, we requested athletes to stay at a simulated altitude of 2,500 m, for 10 or 12 hours a day, and found the following physiological responses in the two daily durations of exposure: a significant increase in serum EPO level on the next day, and a significant increase in the number of reticulocytes on day 7, after the onset of the training. To have an effect on erythropoiesis, therefore, athletes are recommended to stay for a certain period of time (12 to 17 hours a day). However, erythropoiesis is more likely to occur in Japanese athletes who stay for 10 hours a day.

To elevate endurance performance, it is necessary to improve not only maximal aerobic power, but also the ability to perform the same exercise at a less energy cost (mechanical efficiency and skill) and the level of oxygen uptake at which exercise can be maintained for a long time (anaerobic threshold: AT). No unanimous outlooks are available about the effects of the LHTL protocol on these requirements. However, recent studies have reported that the LHTL protocol is effective for them, showing its efficacy when athletes stayed for about 10 hours a day (daily duration of exposure) for about 2 weeks (length of stay). Furthermore, maximal oxygen deficit and anaerobic power were reported to increase when athletes stayed for a relatively short duration (about 8 hours a day) and a relatively brief period (about 1 week).

**Effects on athletic performance at sea level.** The results from studies on the LHTL protocol that reported its efficacy for athletic performance are shown in Tables 4 and 5. Not all studies on the LHTL protocol have reported an improvement in athletic performance. However, the number of studies reporting such improvement seems to be greater compared to the LHTH protocol. Based on these results, the LHTL protocol is considered to result in a 1 to 4% improvement in exercise lasting about 30 seconds to 17 minutes. Elite athletes also have shown such improvement.

### Table 3. Conditions for stay in the altitude house that increase physiological parameters

<table>
<thead>
<tr>
<th>Physiological &amp; Biochemical parameters</th>
<th>Simulated altitude (meters)</th>
<th>Daily duration of exposure (hours/day)</th>
<th>Length of stay (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPO †</td>
<td>2,000-3,000</td>
<td>8-18</td>
<td>2-30</td>
</tr>
<tr>
<td>Reticulocyte number †</td>
<td>2,000-3,000</td>
<td>10-18</td>
<td>2-30</td>
</tr>
<tr>
<td>Hb concentration, Red cell volume †</td>
<td>2,100-2,500</td>
<td>12.5-18</td>
<td>20-30</td>
</tr>
<tr>
<td>2,3-DPG †</td>
<td>2,500</td>
<td>12-18</td>
<td>7-28</td>
</tr>
<tr>
<td>VO₂max †</td>
<td>2,100-3,000</td>
<td>12-16</td>
<td>18-30</td>
</tr>
<tr>
<td>Efficiency, AT †</td>
<td>2,000-3,500</td>
<td>9-16</td>
<td>13-28</td>
</tr>
<tr>
<td>Anaerobic capacity †</td>
<td>2,100-3,000</td>
<td>8-18</td>
<td>7-30</td>
</tr>
</tbody>
</table>

Mechanisms related to performance improvement. No consensus of views has been obtained with respect to mechanisms by which the LHTL protocol improves endurance performance. Levine and Stray-Gundersen (2005) claimed that VO₂max increases due to an LHTL protocol-induced increase in serum EPO level, and an associated elevation in RCV, resulting in an endurance performance improvement. Furthermore, they purported that sufficient conditions for stay (living high enough, long enough, for enough hours per day) are required to be effective. In contrast, Gore and Hopkins (2005), who considered that about a 1% increase is observed as a placebo effect, mentioned that increases in VO₂max and improvements in endurance performance are not necessarily coupled, and claimed that improvements in exercise economy (improvements in efficiency and increases in AT) are rather important.

We consider that this dispute will continue in the future. In fact, the admissible possibility is that a variety of physiological adaptations are involved in a complex
fashion to improve endurance performance. On the other hand, involved mechanisms presumably differ, depending on differences in the physical fitness level (VO2max) of the subject and in length of stay at moderate altitude. For instance, an increase in VO2max and an improvement in exercise economy are possibly involved when physical fitness levels of the subject are low and high, respectively. When length of stay is short, another admissible possibility is that an improvement in anaerobic capacity leads to an improvement in athletic performance.

Guidelines for stay in the altitude house. While staying in the altitude house, it is also presumable that unfavorable physiological adaptations develop, as observed in the LHTH protocol. For instance, a study on staying at a simulated altitude of 2,500 m reported a decrease in plasma volume on day 3 of the stay. Furthermore, Hiller et al. instructed athletes to stay in the altitude house (simulated altitude: 2,000 m) for 12.5 hours a day, over 30 days, and reported decreases in fat-free mass up to week 2 of the stay, followed by an almost complete recovery to the prestay value not later than week 4 of the stay. This result suggests the possibility that muscle strength decreases transiently when an athlete stays in an altitude house. The authors requested athletes to stay in an altitude house (simulated altitude: 2,000 to 2,500 m) for 10 hours a day, over 6 days, while undergoing strenuous training sessions at sea level. Consequently, a limited number of athletes had a feeling of mild malaise, a sense of weakness, sleep disorder, and other complaints. These results suggest 1) interindividual differences in physiological adaptations possibly also exist in the LHTL protocol and 2) careful consideration is required for the control of an athlete’s physical condition and for training when utilizing an altitude house during a period of strenuous training. Points to consider about these items and conditions when utilizing the altitude house are shown in Table 6.

Table 4. Studies on the LHTL protocol using artificial environment that reported its efficacy for athletic performance at sea level

<table>
<thead>
<tr>
<th>Authors (year)</th>
<th>Subjects</th>
<th>Simulated altitude, Daily duration of exposure, Length of stay</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mattila and Rusko (1996)</td>
<td>Cyclists</td>
<td>3,000 m, 18 hours/day, 11 days</td>
<td>Pedaling speed ↑</td>
</tr>
<tr>
<td>Nummela and Rusko (2000)</td>
<td>400 m runners</td>
<td>2,200 m, 16.5 hours/day, 10 days</td>
<td>400 m race time ↑</td>
</tr>
<tr>
<td>Roberts et al. (2003)</td>
<td>Cyclists</td>
<td>2,650 m, 8-10 hours/day, 5,10,15 days</td>
<td>Maximal mean power output ↑</td>
</tr>
<tr>
<td>Muraoka et al. (2004)</td>
<td>Sprinter</td>
<td>2,500 m, 10 hours/day, 5 days</td>
<td>Mean power output ↑</td>
</tr>
<tr>
<td>Brugniaux et al. (2006)</td>
<td>Middle-distance runners</td>
<td>2,500-3,000 m (training at 1,200 m), 14 hours/day, 6-12 days</td>
<td>Maximal power output ↑</td>
</tr>
<tr>
<td>Schmitt et al. (2006)</td>
<td>Cyclists</td>
<td>2,500-3,500 m (training at 1,200 m), 14-16 hours/day, 5-12 days</td>
<td>Peak power output ↑</td>
</tr>
</tbody>
</table>

↑: significant increase (P < 0.05), ↗: increasing tendency (P < 0.10)

Table 5. Studies on the LHTL protocol using natural environment that reported its efficacy for athletic performance at sea level

<table>
<thead>
<tr>
<th>Authors (year)</th>
<th>Subjects</th>
<th>Altitude(live/train), Length of stay</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levine et al. (1991)</td>
<td>Runners</td>
<td>2,500 m/1,300 m, 4 weeks</td>
<td>5 km time trial ↑</td>
</tr>
<tr>
<td>Levine and Stray-Gundersen (1997)</td>
<td>Runners</td>
<td>2,500 m/1,300 m, 4 weeks</td>
<td>5 km time trial ↑</td>
</tr>
<tr>
<td>Stray-Gundersen et al. (2001)</td>
<td>Runners</td>
<td>2,500 m/1,250-1,300 m, 27 days</td>
<td>3 km time trial ↑</td>
</tr>
<tr>
<td>Dehnert et al. (2002)</td>
<td>Triathletes</td>
<td>1,956 m/800 m, 2 weeks</td>
<td>Time trial ↑</td>
</tr>
<tr>
<td>Wehrlin et al. (2006)</td>
<td>Orienteers</td>
<td>2,500 m (18 hours)/1,000 m, 24 days</td>
<td>5 km time trial ↑</td>
</tr>
</tbody>
</table>

↑: significant increase (P < 0.05), ↗: increasing tendency (P < 0.10)

Issues to be addressed in the future

As described above, studies showing that the LHTH protocol is not effective, for improvement in endurance performance at sea level, appeared to be predominant. However, a recent meta-analysis suggested that the LHTH protocol possibly improves maximal power output of elite athletes. Therefore, further study is required, with respect to conditions concerning stay, nutrition, rest, training, and other parameters, when conducting the LHTH protocol. In contrast, the LHTL protocol was considered to improve athletic performance lasting short to long periods at sea level. However, interindividual differences in athletic performance also seem to exist in the LHTL protocol. To efficiently perform altitude training, therefore, factors involved in these interindividual differences need to be elucidated as quickly as possible.

The involvement of tolerance to hypoxia, physical and
Methods of stay

1) Oxygen concentration (simulated altitude): In general, simulated altitudes of 2,000-2,500 m (oxygen concentration: 16.4-15.3%) are used. In some cases, however, a simulated altitude of ~3,000 m (oxygen concentration: ~14.2%) can be used. During the hard training phase, use simulated low altitude (high oxygen concentration) within this range, or start training at simulated low altitude and increase simulated altitude gradually (decrease oxygen concentration).

2) Daily duration of exposure: Stay for consecutive 12 to 17 hours a day to the extent possible. A stay for at least 10 consecutive hours a day is mandatory even in the case this span of time cannot be ensured.

3) Length of stay: It should be 1 to 2 weeks (approximately 10 days) for sprinting events and 3 to 4 weeks (at least 2 weeks) for endurance events.

Table 6. Guideline for the use of the altitude house

<table>
<thead>
<tr>
<th>Points to consider at the time of stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) To prevent the accelerated loss of water, control sufficiently the humidity of the altitude house or supply a slightly greater volume of water at the time of stay.</td>
</tr>
<tr>
<td>2) Perform supplementary training to sustain muscle strength because it is conceivable that the strength decreases transiently.</td>
</tr>
<tr>
<td>3) To early detect any deconditioning, check out physical condition regularly by using Lake Louise Acute Mountain Sickness Score, the profile of mood states, body weight, heart rate at wake up, and other variables.</td>
</tr>
<tr>
<td>4) Discontinue immediately the stay in the altitude house when finding difficulty in adaptations or when suspecting deconditioning.</td>
</tr>
</tbody>
</table>

psychological conditions before and during training, as well as iron and Hb concentrations before altitude training, have been indicated with respect to interindividual differences in physiological adaptations to a hypoxic environment[3,7,48,49]. Among these parameters, tolerance to hypoxia influences the physical condition under a hypoxic environment, and is especially related to the essential problem of “To what extent the athlete is capable of performing the training program.” On the other hand, increases in serum EPO level, when exposed to hypoxia, are reportedly involved in an improvement in athletic performance[39]. Furthermore, differences in hypoxic ventilatory response[6,47] and genetic predisposition[26,50] are possibly related to this improvement. Whatever the case, need will arise in the future to tailor altitude (oxygen concentration), daily duration of exposure, and length of stay in order to fit individual features and to determine whether or not to adopt the LHTL or LHTH protocol.

Recently, Millet et al. (2010)[7] reviewed the effects of the LHTH, LHTL, and LLTH protocols on physiological adaptations and athletic performance, and made reference to the effects of a procedure of combining the LHTL protocol and the intermittent hypoxic training protocol (LHTLHi). Furthermore, a recent study using the LHTLHi protocol reported an improvement in athletic performance[51], therefore, the authors suggest the protocol warrants a more detailed investigation.

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