Use of Altitude/Hypoxic Training by Olympic Athletes

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United States Olympic Committee
Gracias / Obrigado!
Kamsa hamnida (Korean)
Danke schön (German)
Ameseginalhu (Ethiopia)
Спасибо (Russian)
Arigato (Japanese)
Asante sana (Swahili/Kenyan)
Meitaki Ma’ata (Maori)
Paldies (Latvian)
Fa’afetai (Samoan)
Дziekuje (Polish)
Terima kasih (Malaysian + Indonesian)
Gracias (Spanish)
धन्यवाद (Hindi)
Dank u wel (Dutch)
Merci beaucoup (French)
شكراً جزيلاً (Arabic)
Kiitoksia (Finnish)
ευχαριστώ (Greek)
Благодаря (Bulgarian)
Grazie (Italian)
Obrigado (Portuguese/Brazilian)
Cheers (Australian / New Zealand)
Mahalo (Hawaiian)
Xie xie (Chinese)
Thank you (English)
Felicitaciones!
“There is no higher ideal for the human race, than promoting peace through international sport.”

Baron Pierre de Coubertin
Founder of the Modern Olympic Games
Randall L. Wilber, PhD, FACSM
US Olympic Committee

**TRACK/CC COACH (1976-1993)**
- Pennsylvania
- Wisconsin
- Florida

**SPORT PHYSIOLOGIST (1993-present)**
US Olympic Committee
- Salt Lake City 2002
- Athens 2004
- Torino 2006
- Beijing 2008
- Vancouver 2010
- London 2012
- Sochi 2014
US Olympic Training Center
Colorado Springs
Environmental Physiology
Use of Altitude/Hypoxic Training by Olympic Athletes

- **Introduction**
- **Altitude Training Models**
  - LH + TH
  - LH + TL
  - LL + TH
- **Practical Recommendations**
  - Preparation Before the Altitude Training Camp
  - During the Altitude Training Camp
  - Return to Sea Level After the Altitude Training Camp
  - Annual Plan for Altitude Training
- **Physiological Benefits**
- **Summary & Resources**
US Olympic Training Center
Colorado Springs

Pikes Peak (4300m / 14,115ft)

Colorado Springs (1885m / 6180ft)
USOC Sport Science Center of Excellence
High Altitude Training Center
US Olympic Training Center
Colorado Springs  1860 m / 6200 ft

Pikes Peak
(4300 m / 14,115 ft)

Colorado Springs
(1860+ m / 6200+ ft)

US Olympic Training Center
(1860 m / 6200 ft)
US Olympic Training Center
Colorado Springs  1860 m / 6200 ft
US Air Force Academy
Colorado Springs  2000-2300 m / 6560-7544 ft

Pikes Peak
(4300m / 14,115ft)

Colorado Springs
(1860+ m / 6100+ ft)

US Olympic Training Center
(1860 m / 6100 ft)

US Air Force Academy
(2000-2300 m / 6560-7544 ft)
US Air Force Academy
Colorado Springs  2000-2300 m / 6560-7544 ft
Woodland Park Recreational Area

Woodland Park  
2745-2775 m / 9000-9100 ft

Woodland Park  
(2745-2775 m / 9000-9100 ft)

US Air Force Academy  
(2000-2300 m / 6560-7544 ft)

Pikes Peak  
(4300 m / 14,115 ft)

Colorado Springs  
(1860+ m / 6100+ ft)

US Olympic Training Center  
(1860 m / 6100 ft)
Woodland Park Recreational Area

Woodland Park 2745-2775 m / 9000-9100 ft
Team USA Altitude Training Network

- Mammoth Lakes, CA 2440 m / 8000 ft
- Park City, UT 2500 m / 8200 ft
- Steamboat Springs, CO 2052 m / 6728 ft
- Colorado Springs / Boulder, CO 1900-2775 m / 6230-9100 ft
- Alamosa, CO 2300 m / 7544 ft
- Albuquerque, NM 1620+ m / 5314+ ft
- Flagstaff, AZ 2135 m / 7000 ft
- Chula Vista, CA 21 m / 70 ft
“Altitude” defined

EXTREME/LETHAL Altitude
>7500 m

HIGH Altitude
3000 - 7500 m

MODERATE Altitude
1500 - 3000 m

LOW Altitude
<1500 m
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ALTITUDE / HYPOXIC TRAINING

LH + TH
Kenya
Great Rift Valley (2300 m)
Ethiopia

Great Rift Valley (2300 m)

Addis Ababa 2355 m
Kenyan and Ethiopian Distance Runners: What Makes Them So Good?

Randall L. Wilber and Yannis P. Pitsiladis
June 2012

[based on proceedings of 2011 ACSM Annual Meeting]
Kenyan and Ethiopian Distance Runners
Hypothetical Model for Success

Biomechanical & Physiological
Ectomorphic somatotype leading to exceptional biomechanical and metabolic economy.
Kenyan and Ethiopian Distance Runners
Hypothetical Model for Success

**Psychological #1**
High motivation to succeed for the purpose of improving socio-economic status.

**Psychological #2**
“Tradition of Excellence”
Kenyan and Ethiopian Distance Runners
Hypothetical Model for Success

Training #1
Consistent aerobic training at young age as main method of transport to/from school.

Training #2
Moderate-volume, high-intensity training at altitude (2000-3000 m)
ALTITUDE / HYPOXIC TRAINING

LH + TH

LH + TL
SEA LEVEL

BP 760 mm Hg

O₂ 20.93%

P₁O₂ ~ 150 mm Hg

ALTITUDE

BP 600 mm Hg

O₂ 20.93%

P₁O₂ ~ 126 mm Hg
ALTITUDE

BP
600 mm Hg

$O_2$
20.93%

$P_{1O_2} \sim 126$ mm Hg
ALTITUDE

\[ \downarrow P_{1}O_2 \]
\[ \downarrow P_{a}O_2 \]

\[ \downarrow S_{a}O_2 \]

\[ \downarrow VO_2 \text{ max} \]

\[ \downarrow \text{Aerobic Performance} \]
\[ \downarrow \text{Training Capacity} \]
LH + TL
Theoretical Foundation

LH  +  TL

HEMATOLOGICAL  +  PERIPHERAL
ALTITUDE / HYPOXIC TRAINING

- LH + TH
- LH + TL
- Natural / Terrestrial
LH + TL
Natural/Terrestrial Hypobaric Hypoxia
LH + TL
Natural/Terrestrial Hypobaric Hypoxia

PARK CITY
2500 m / 8200 ft

UTAH OLYMPIC OVAL
1425 m / 4675 ft
LH + TL
Natural/Terrestrial Hypobaric Hypoxia

WRs  2
LH + TL
Natural/Terrestrial Hypobaric Hypoxia

CAR Sierra Nevada
2320 m / 7610 ft

Granada
738 m / 2421 ft
LH + TL
Natural/Terrestrial Hypobaric Hypoxia

Muottas Muragl
2500 m / 8200 ft

St. Moritz
1800 m / 5900 ft
LH + TL
Natural/Terrestrial Hypobaric Hypoxia

Bogota
2600 m / 8528 ft

La Mesa
1200 m / 3936 ft
LH + TL
Natural/Terrestrial Hypobaric Hypoxia
ALTITUDE / HYPOXIC TRAINING

LH + TH

LH + TL

Natural / Terrestrial

Simulated

N₂ Dilution

O₂ Filtration
LH + TL
Normobaric Hypoxia via $\text{N}_2$ Dilution

Nitrogen apartment

Fig. 1. Schematic representation of a normobaric hypoxic apartment. $F_{\text{IN}_2}$ = fraction of inspired nitrogen; $F_{\text{IO}_2}$ = fraction of inspired oxygen.
LH + TL
Normobaric Hypoxia via $\text{O}_2$ Filtration
LH + TL
Normobaric Hypoxia via O$_2$ Filtration

NIKE Oregon Project
PORTLAND
52.5 m / 173 ft

TOKYO
8 m / 26 ft

JISS
Japan Institute of Sports Sciences

BEIJING
44 m / 144 ft

CHULA VISTA
21 m / 70 ft

DOHA
10 m / 33 ft

NIKE Oregon Project
PORTLAND
52.5 m / 173 ft

TOKYO
8 m / 26 ft

JISS
Japan Institute of Sports Sciences

BEIJING
44 m / 144 ft

CHULA VISTA
21 m / 70 ft

DOHA
10 m / 33 ft
Artificially-Induced Hypoxic Conditions:

“In response to our stakeholders who requested that there be full consideration of hypoxic conditions in the context of the Prohibited List, WADA performed a scientific and ethical review of the matter, and engaged in a thorough consultation with experts and stakeholders. While we do not deem this method appropriate for inclusion on the List at this time, we still wish to express the concern that, in addition to the results varying individually from case to case, use of this method may pose health risks if not properly implemented and under medical supervision.”

Richard Pound
WADA Chairman
September 16, 2006
Simulated Altitude
Legal and Ethical Issues

Decree of the Italian Ministry of Health
13.04.2005. Section 5. Subsection M.1
03 June 2005

... “all hypobaric/hypoxic practices are currently prohibited in Italy” ...

2005 Giro d’Italia
Stage 10
18 May 2005
The International Olympic and Paralympic Committees have prohibited the use of simulated altitude devices within the boundaries of the Olympic Village since the 2000 Sydney Olympics, and this mandate is expected to apply to all future summer and winter Olympic Games.
ALTITUDE / HYPOXIC TRAINING

LH + TH

LH + TL

Natural / Terrestrial

Simulated

N₂ Dilution

O₂ Filtration

Supplemental O₂
Colorado Springs (1860 m / 6200 ft)

BP
610 mm Hg

$O_2$
20.93%

$P_{O_2}$ ~ 128 mm Hg
Colorado Springs (1860 m / 6200 ft)

BP
610 mm Hg

$O_2$
20.93%

$P_{1O_2}$ ~ 128 mm Hg

Colorado Springs (supplemental $O_2$)

BP
610 mm Hg

$O_2$
26.47%

$P_{1O_2}$ ~ 150 mm Hg
Sea level

- BP 760 mm Hg
- $O_2$ 20.93%
- $P_{\text{O}_2}$ ~ 150 mm Hg

Colorado Springs (1860 m / 6200 ft)

- BP 610 mm Hg
- $O_2$ 20.93%
- $P_{\text{O}_2}$ ~ 128 mm Hg

Colorado Springs (supplemental $O_2$)

- BP 610 mm Hg
- $O_2$ 26.47%
- $P_{\text{O}_2}$ ~ 150 mm Hg

- CO2 5.08%
- Pao2 ~ 128 mm Hg
2010 PROHIBITED LIST

M1. ENHANCEMENT OF OXYGEN TRANSFER

The following are prohibited:

1) Blood doping, including the use of autologous, homologous or heterologous blood or red blood cell products of any origin.

2) Artificially enhancing the uptake, transport or delivery of oxygen, including but not limited to perfluorochemicals, efaproxiral (RSR13) and modified haemoglobin products (e.g., haemoglobin-based blood substitutes, microencapsulated haemoglobin products), excluding supplemental oxygen.
Supplemental O₂ Training (LH + TLO₂)
USOC Sport Science Center of Excellence
High Altitude Training Center
LH + TL

Hypobaric Normoxia via Supplemental O\textsubscript{2} (LH + TLO\textsubscript{2})

UTAH OLYMPIC OVAL
1425 m / 4675 ft

Photo credit: Dr. Andy Subudhi
LH + TL
Hypobaric Normoxia via Supplemental O₂ (LH + TLO₂)

SOLDIER HOLLOW, UT
1685 – 1750 m
5528 – 5742 ft
LH + TL
Hypobaric Normoxia via Supplemental O₂ (LH + TLO₂)

Effect of F>O₂ on Physiological Responses and Cycling Performance at Moderate Altitude

Effect of F>O₂ on Oxidative Stress during Interval Training at Moderate Altitude

Application of Altitude/Hypoxic Training by Elite Athletes

Effect of Hypoxic “Dose” on Physiological Responses and Sea-Level Performance
ALTITUDE / HYPOXIC TRAINING

- LH + TH
  - Natural / Terrestrial
    - N₂ Dilution
    - O₂ Filtration
    - Supplemental O₂
  - Simulated

- LH + TL

- LL + TH
  - IHE
  - IHT
LL + TH

Intermittent Hypoxic Exposure (IHE) / Training (IHT)

Intermittent Hypoxic Exposure (IHE)

Altitrainer 200°

Intermittent Hypoxic Training (IHT)
Use of Altitude/Hypoxic Training by Olympic Athletes

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  - Annual Plan for Altitude Training
- Physiological Benefits
- Summary & Resources
BEFORE Altitude Training Camp
Altitude Training

Contraindications

- Poor level of fitness
- Bacterial or viral infection
- Fe-depleted
- Fe-deficient non-anemia
- Fe-deficient anemia
- Sickle-cell trait or anemia
- Medications that might affect the kidneys and EPO response
- Medications that might exacerbate diuresis
- Chronic sleep disorders
(a) Hemoglobin

(b) Iron-containing heme group
If serum Ferritin is low:

- Attention to “heme Fe” in diet.
- Moderate Fe supplementation
  - 120-130 mg “elemental Fe” divided into 2 doses
  - taken with Vitamin C
  - taken 30 min before or 60 min after meals to increase absorption and decrease GI distress
  - taken daily
IRON SUPPLEMENTATION

Hemoglobin

Cytochrome-c Oxidase

Electron Transport Chain

ATP Synthase
Impact of Iron Depletion Without Anemia on Performance in Trained Endurance Athletes at the Beginning of a Training Season: A Study of Female Collegiate Rowers

Diane M. DellaValle and Jere D. Haas


21 s slower ($P<0.05$)
DURING Altitude Training Camp
Hb saturation, %

$P_a\text{CO}_2$, mm Hg

Upper limit for permanent residence

Mt. Everest

Impending collapse

Lethargy, general weakness

Dyspnea, anorexia, GI disturbances

Insomnia, nausea, vomiting, pulmonary

Lightheadedness, headache

NAME
USA Biathlon
Altitude Training Camp
Antholz, ITALY (1644 m / 5392 ft)
July 29 to August 7, 2010

ACCLIMATIZATION = Day 5
TRAINING PROGRESSION

Base model: combination between hypoxic training and normoxic training in the preparatory training period

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Sea Level</th>
</tr>
</thead>
</table>

- **Training load**
  - Very high
  - High
  - Medium
  - Low
  - Very low

- **Training Int**
  - Int ≤ VT<sub>1</sub> strength training
  - Int ≤ VT<sub>2</sub> strength training
  - Int ≤ VT<sub>1</sub> strength training
  - Int ≤ MAP strength training

- **Days**
  - 7  7  7  7  7  7  7  7  7  7  7
↑ Submaximal HR
→ 
↓ Maximal HR
DEHYDRATION

Respiratory $\text{H}_2\text{O}$ loss

Urinary $\text{H}_2\text{O}$ loss

Urine

- 0.05% Ammonia
- 0.18% Sulphate
- 0.12% Phosphate
- 0.6% Chloride
- 0.01% Magnesium
- 0.015% Calcium
- 0.6% Potassium
- 0.1% Sodium
- 0.1% Creatinine
- 0.03% Uric acid
- 2% Urea

95% Water
Monitor dehydration
- Post-WO total body weight (TBW)
- Drink 10-12 oz fluid for every pound lost
- Check post-WO urine color and/or urine specific gravity (USG)

<table>
<thead>
<tr>
<th>Hydration Status</th>
<th>USG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well hydrated</td>
<td>&lt; 1.010</td>
</tr>
<tr>
<td>Minimal dehydration</td>
<td>1.010 – 1.020</td>
</tr>
<tr>
<td>Significant dehydration</td>
<td>1.020 – 1.030</td>
</tr>
<tr>
<td>Serious dehydration</td>
<td>&gt; 1.030</td>
</tr>
</tbody>
</table>
Training Questionnaire

NAME __________________________ DATE ______________
LOCATION ______________________

IN THE LAST 24 HOURS . . . HAVE YOU EXPERIENCED:

HEADACHE
- ___ No headache
- ___ Light headache
- ___ Painful headache
- ___ Severe, incapacitating headache

GASTROINTESTINAL
- ___ No GI problems
- ___ Poor appetite or nausea
- ___ Moderate nausea or vomiting
- ___ Severe nausea and vomiting

FATIGUE
- ___ Not tired or weak
- ___ Light fatigue/weakness
- ___ Moderate fatigue/weakness
- ___ Severe fatigue/weakness

SLEEP
- ___ Slept well as usual
- ___ Did not sleep as well as usual
- ___ Poor night’s sleep . . . woke many times
- ___ Could not sleep at all

ILLNESS
- ___ No illness
- ___ Minor illness, but it has not significantly limited my training/racing
  Illness that has forced me to take 2-3 days off [list illness here__________________________]
- ___ Illness that has forced me to take >3 days off [list illness here__________________________]

INJURY
- ___ No injury
- ___ Minor injury, but it has not significantly limited my training/racing
  Injury that has forced me to take 2-3 days off [list injury here__________________________]
- ___ Injury that has forced me to take >3 days off [list injury here__________________________]

IS THE CURRENT TRAINING LOAD
- ___ Too Hard
- ___ Just Right
- ___ Too Easy

COMMENTS [Please list any specific aches, pains or injuries. Please list any other comments]:

______________________________
Effective “Dose”

Δ Red Cell Mass (%)

1-2 Weeks

3 Weeks

4 Weeks

AFTER Altitude Training Camp
Return to Sea Level

Return to Sea Level


Annual Plan for Altitude Training
US Olympic Training Center
Colorado Springs  1860 m / 6200 ft

US OLYMPIC TRAINING CENTER
Aquatics Complex

MICHAEL PHELPS
Beijing 2008
8 Gold medals
22 Olympic medals

MISSY FRANKLIN
London 2012
4 Gold medals

ALLISON SCHMITT
London 2012
3 Gold medals
Use of Altitude/Hypoxic Training by Olympic Athletes

Introduction

Altitude Training Models
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- LL + TH

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- Annual Plan for Altitude Training

Physiological Benefits

Summary & Resources
Physiological Benefits
(a) Hemoglobin
Altitude Training → RBC ↑ → VO₂ max → SL Performance
Physiological Benefits

- RBC
- Hypoxic Ventilatory Response (HVR)
ALTITUDE

BP
600 mm Hg

O₂
20.93%

P₃O₂ ∼ 126 mm Hg
HYPOXIC VENTILATORY RESPONSE
Altitude Training

Hypoxic Ventilatory Response (HVR)

$\text{VO}_2\text{ max}$

SL Performance
Physiological Benefits

- RBC
- Hypoxic Ventilatory Response (HVR)
- Skeletal mm. Buffering Capacity
$\text{GLUCOSE} \rightarrow $ PFK

$2 \text{ Pyruvic acid}$

$2 \text{ Lactic acid} + 2 \text{ ATP}$

$\text{C}_3\text{H}_5\text{O}_8^- + \text{H}^+ \rightarrow \text{LACTATE}$

$\text{NO } \text{O}_2$
$C_3H_5O_8^- + H^+ \rightarrow H_2CO_3$

LACTATE

$H^+ + HCO_3^- \rightarrow H_2CO_3$

BICARBONATE BUFFER

$H_2O + CO_2$
Altitude Training

Skeletal mm. Buffering Capacity ↑

H₂O + CO₂

H⁺ Removal

SL Performance
Physiological Benefits

- RBC
- Hypoxic Ventilatory Response (HVR)
- Skeletal mm. Buffering Capacity
- Exercise Economy
Altitude Training → Mitochondrial Efficiency → Exercise Economy → SL Performance
FIG. 5. Schematic representation of the regulation of HIF-1α complex-mediated gene transcription by hypoxia (Wenger et al., 1999)

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    - O₂ Filtration
    - Supplemental O₂
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- LL + TH
  - IHE
  - IHT
Physiological Benefits

- RBC
- Hypoxic Ventilatory Response (HVR)
- Skeletal mm. Buffering Capacity
- Mitochondrial Efficiency
Upper limit for permanent residence

Mt. Everest

Impending collapse

Lethargy, general weakness

Dyspnea, anorexia, GI disturbances

Insomnia, nausea, vomiting, pulmonary

Lightheadedness, headache

Effective “Dose”

1-2 Weeks

3 Weeks

4 Weeks

Return to Sea Level


Application of Altitude/Hypoxic Training by Elite Athletes

RANDALL L. WILBER
Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO
MSSE, 39: 1610-1624, 2007

Effect of Hypoxic “Dose” on Physiological Responses and Sea-Level Performance

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1Athlete Performance Laboratory, United States Olympic Committee, Colorado Springs, CO; 2Department of Health, University of Utah, Salt Lake City, UT; and 3Institute for Exercise and Environmental Medicine, Presbyterian Hospital of Dallas, University of Texas Southwestern Medical Center, Dallas, TX
MSSE, 39: 1590-1599, 2007

Altitude Training and Athletic Performance

www.humankinetics.com
Gracias!