CLIMBING HIGH

Mary Boudreau Conover BSNed with
Marshall G. Delk, B.S., M.S., CrossFitter, Mountaineer

- How high is high?
- It's the altitude, man!
- The body's normal response to altitude
- Fitness, survival, and the myth of safety
- Formula for acclimatization--from Russia with love
- Our CrossFit mountaineer, Marshall Delk
- Alcohol, sedatives, and tobacco
- Coming from sea level?
- The brain at altitude
- High altitude mountain sickness
- High altitude cerebral edema
- High altitude pulmonary edema
- The "death zone"
- The eyes at altitude
- The three golden rules of altitude sickness
- Anatoli Boukreev

"Are the Mountains Killing Your Brain?" Recently, a scholarly article with this alarming title by R. Douglas Fields, M.A., Ph.D, appeared in "OUTSIDE" online. Some of our athletes do climb high---or are planning to do so in the near future, spurred on by their own improved fitness level and the challenge of climbing into high altitudes where the partial pressure of oxygen is low.

HOW HIGH IS HIGH?

High: 8,000 to 12,000 ft. (2438 to 3658 m.) Mammoth Mt. in California is high--tops out at 11,053 ft. (3369 m.) There's not another ski area in California as high as that. Heavenly ski area at Tahoe is 10,000 ft. (3048 m.).

Very high: 12,000 to 18,000 ft. (3658 to 5486 m.). The North American Rockies are the result of shifting continental plates and stretch for 2,980 miles, from Alaska through western Canada and the U.S. into northern Mexico. Part of that stretch runs through the Colorado Rockies, where you will find 54 peaks higher than 14,000 ft--dubbed the "Fourteeners" by climbers. Two of the more well known ones are Pikes's Peak out of Colorado Springs at about 14,115 ft. and Snowmass in Aspen, 14,092 ft. The Cascade mountain range has two well known "Fourteeners", Mt. Rainier at 14,411 ft.; and Mt. Shasta, 14,162

Extremely high: 18,000 ft. (5486 m.). In Yukon Territory of Canada, Mt. Logan is extremely high at 19,850 ft (6,050 m.)--still rising and extremely cold with artic air. A temperature of -106°F. was recorded on May 26, 1991. There are 14 peaks that are 8,000 m (26,400 ft.) or higher above sea level. Among mountaineers they are known as the "eight-thousanders". They are all in the Himalya range. In 1999, a US Expedition Team used *GPS* technology to re-measure the elevation of Mt. Everest---29,035 ft. (8850 m.).

Mt. Everest, the great "Chomolungma"
(Picture captured 1/30/2010)

IT'S THE ALTITUDE, MAN!

Mt. Everest. Although Mt. Everest is the highest mountain on the planet, its vertical rise is only 12,000 ft (3,700 m) because its base is on the high Tibetan Plateau. For a person with technical mountaineering skills, strength, and aerobic endurance, it's not the distance--it's the altitude along with the severe storms where the jet stream can punish.

Mt. Whitney, although not "extremely" high above sea level--14,505 ft (4,421 m), its vertical rise is 10,778 ft. (3,285 m). This is because it rises west of the town of Lone Pine, California in the Owens Valley. Its base is only 76 miles from the lowest point in North America--Badwater, Calif., 282 ft (86 m).

Mt. McKinley (Denali), the highest point in North America, is 20,320 ft (6,194 m) above sea level, lower than Mt. Everest in altitude, but higher in vertical rise at a whopping 18,000 ft (5,500 m). At that extremely high altitude, your only advantage is that you're not in the "death zone", a term that usually refers to altitudes above 23,000 ft (7,000 m). It's a very long, technical climb.

THE BODY'S NORMAL RESPONSE TO ALTITUDE

- Hyperventilation
- Frequent urination
- Dehydration
- Red blood cell production
- Shortness of breath during exertion--resolving quickly at rest
- Periodic breathing during sleep--resulting in frequent arousals from sleep

Hyperventilation

The first response to less oxygen in the air we breathe is to increase ventilation--a normal response and an important one to survival. This is **not** a sign that you are "out of shape"; it is the body's normal protective response to less oxygen in the air you breathe. Faster, deeper breathing may begin immediately at altitudes as low as 5,000 ft. (1524 m). After several days at approximately 16,400 ft (4877 m), hyperventilation results in a resting ventilation rate approximately 60% higher than at sea-level.[1] Even so, you will still be somewhat deprived of oxygen while at high altitudes. The respiratory system works hard when the oxygen gets scarce. It is therefore important that you do not smoke or take anything to depress respirations such as alcohol or sedatives.

Frequent Urination and Dehydration

Diuresis. With hyperventilation the partial pressure of carbon dioxide in the alveoli is reduced and so is the carbonic acid in the blood, making the blood more alkaline. The kidneys respond by increasing bicarbonate excretion in order to return blood pH to near its normal value. Thus, frequent urination is the body's attempt to acclimatize. This response starts within 24 hrs, lasts for several days and may be associated with early fatigue because of associated physiological adjustments. With diuresis, water and sodium are lost and this places the individual at risk for dehydration, especially when maximal exercise is involved. Diuresis is part and parcel of a successful adaptation to altitude. An unsuccessful adaptation to altitude would be acute mountain sickness with <u>diminished</u> diuresis so that fluids that are normally in the plasma volume move into the cells and tissues, resulting in facial and extremity edema.[2]

Red Blood Cell Production

Red blood cell production increases at altitude, but it takes about a week before the new red cells being generated in the bone marrow begin reaching the bloodstream.[3] The increased production of new red blood cells results in a hematocrit (concentration of red blood cells) of at least 10 % higher than sea-level. Because individuals with low iron stores are unable to increase their red cell mass for effective acclimatization, the diet should be supplemented with iron for those at risk, particularly premenopausal women.

Periodic Breathing

Periods of sound sleep are shortened at altitude because of hyperventilation repeatedly alternating with short periods of apnea (no breathing). The period of apnea may last up to 10-15 seconds. This disturbance of the normal sleep pattern in those who breathe normally during sleep at sea level is known as *altitude-induced periodic breathing* and is one form of central sleep apnea.[4] It differs from obstructive sleep apnea, in which ongoing respiratory efforts continue during depressed breathing periods. In altitude-induced periodic breathing there is no effort to inspire during cessations of airflow, nor is there a stimulus to do so until the level of CO_2 in the blood rises. In the clinical setting, this type of breathing is called Cheyne-Stokes syndrome and has serious--even ominous implications.

Periodic breathing is present in most healthy mountaineers[5] whose rapidity of ascent is enough to cause significant hypoxia. At elevations of around 10,000 ft (3,048 m), a moderate degree of periodic breathing during sleep may actually be an advantage in that the intermittent hyperventilation stabilizes the O_2 saturation of the blood, keeping it relatively constant--a sort of oscillatory stability. However, at higher elevations, frequent arousals from sleep, nearly three/minute at extreme altitude, translate into a state of total sleep deprivation and daytime sleepiness that impairs the mental acuity and physical performance so vital to survival at extreme altitudes.[6] One high altitude mountaineer has said that when he sleeps well at altitude, he knows that he is acclimatizing well.[7]

Mechanism. As one ascends into altitudes above 9,000 ft. (2743 m), the significant decrease in atmospheric pressure causes the partial pressure of oxygen in the blood (PaO_2) to decrease. During sleep, this results in hyperventilation which increases the PaO_2 and rapidly decreases the partial pressure of carbon dioxide ($PaCO_2$) to a critical level that suppresses inspiration for periods of 10-15 seconds.

These events are regulated by the sensitivity of chemoreceptors in the carotid sinus, aortic arch and respiratory center of the brain. The magnitude of the hyperventilation is too robust for the hypoxia that triggered it, causing the $PaCO_2$ to decrease too much-too fast, suppressing the drive to inspire. The plunge in $PaCO_2$ is the main trigger in the loop. During the period of apnea the $PaCO_2$ again increases, triggering hyperventilation---and so the closed loop feedback continues.[6]

FITNESS, SURVIVAL, AND THE MYTH OF SAFETY

Fitness cannot be said to accelerate acclimatization, but it does improve aerobic capacity and is not an acclimatization issue--it is a strength and endurance issue that will help you save yourself and others when the chips are down. However, it should be remembered that in the 50 years of Everest climbing history, no nonambulatory climber has ever been brought down from above 8000 meters.[7] You need to be able to climb down under your own power.

Anatoli Boukreev has many wise words about fitness and strength at altitude. Here are his thoughts on "the myth of safety."

"Money and oxygen make it possible to ascend into a zone where it is easy to die--to a place where no one can rescue you if suddenly your own strength is insufficient. The myth of safety is a delusion for dilettantes. It is better to shatter that myth than perpetuate it with the notion that supplemental oxygen or a top guide can save you." [8]

Anatoli will also tell you that, although being fit and prepared in mind and body is imperative before climbing to extreme heights, being strong will not necessarily save you if you use poor judgment. Competitive conditioning increases your ability to perform not only because it makes you fit, but also because it teaches you to wring out the last reserves of your energy again and again during your workouts. An untrained person would find it almost impossible to work so hard as to dip into energy reserves. In the latter case, the body is protecting itself, but the CrossFit trained athletes might override these warnings simply because they are accustomed to not heeding them. At extreme altitude, where mental acuity is dulled, this translates into possibly making a bad decision to "never give up" in the face of a situation that clearly calls for it.

FORMULA FOR ACCLIMATIZATION--FROM RUSSIA WITH LOVE

Prior to the collapse of the Soviet Union in 1991, mountaineering was supported by the government in Moscow as were many other sports--especially those destined for the Olympics. The mountaineers were part of the Soviet Army and the data gathered from the Soviet expeditions made by many young men to 8,000 meters during those decades of Soviet rule resulted in a formula for acclimatization that was, during the Iron Curtain days, Top Secret. Anatoli Boukreev, from Kazahstan was a civilian mountaineer in that army and he recorded their formula for acclimatization in a footnote on p. 76 of his journals.[7] He has laid out an example climb for K2 (8,611 metres; 28,251 ft) on pages 75-76. The two leaders of that expedition, Anatoli's friend, 50 year old Reinmar Joswig and Peter Metzger refused his acclimatization plan out of hand, thinking it too demanding to return to a lower camp to recover and gain strength before the summit attempt. Peter reached the summit, but perished during the descent; it is not known what happened to Reinmar; he was last seen climbing toward the summit in an exhausted state and could not be convinced to turn around.

The Formula. The heart of the Russian Army formula for success and strength on the climb is an incremental pattern of acclimatization and rehabilitation based on the height of the peak and the speed of the climber at different elevations--something like Rippetoe's simple progressive overload for strength training.[9] Essentially, the formula evolves as a repetitive leap-frog pattern marked with incremental climbs with loads, followed by descents for rehabilitation and then a higher climb with loads for the higher camp, all of which prepares the body for long hours of climbing on summit day. The book containing Anatoli's journals is a good read and a valuable tutorial for those who climb high.[8]

"...the commitment of time and effort to adequate acclimatization improves personal performance and decreases the odds of developing acute mountain sickness. Proper acclimatization is the most important variable of safety an individual can affect when climbing at [extreme] altitude. Ignoring that responsibility, a climber raises the risk to himself and his team."----somber, sorrowful words from Anatoli Boukreev.

ALCOHOL, SEDATIVES AND TOBACCO

- **Alcohol** is a diuretic and exacerbates dehydration at altitude. It impairs judgment and depresses respiration when breathing well is critical.
- **Sedatives** and hypnotic agents compromise the altitude-related periodic breathing, reducing arterial oxygen saturation. Uninformed altitude travelers may use a sedative, thinking to improve the poor quality of sleep that is commonly experienced.
- **Tobacco** inhaled at altitude causes an accumulation of carbon monoxide. This toxic gas is present in tobacco smoke and once in the blood, poisons the binding site of hemoglobin for oxygen. The added insult to the body it that carbon monoxide prevents the utilization of oxygen in cellular respiration, defeating one of the key ways the body gains energy. It is frightening to consider a combination of any of these products at altitude.

OUR CROSSFIT MOUNTAINEER, MARSHALL DELK

Marshall Delk, super-athlete at CrossFit Santa Cruz Central also skis and climbs tall mountains. Here is his story in his own words.

Since 2003, I have challenged myself with mountaineering experiences at a number of California peaks. Prior to these outings I had experience at elevation only when skiing. The highest I had been was probably 10,000'+. In the course of those years I have submitted the following peaks:

Mt. Shasta 14,162'
Mt. Whitney 14,491', twice
White Mountain 14,246'
Mt. Langley 14,026'
Mt. Muir 14,015'

“Alpine glow” of Mt. Whitney in the early morning

While I have seen altitude sickness, I have avoided any severe symptoms. What I have learned from my trips, is you have to be physically prepared, however, assuming good conditioning, there are two reasons people do not summit, foul weather, and reaction to altitude. The best accommodation for altitude is acclimatization, however I, like most people, do not take the time to properly acclimatize. In no case have I taken more than two days to summit. Typically, my trips have begun at approximately 5,000’ to 6,000’ and I've hiked to “base camp” at approximately 10,000’. While always tired when gaining base camp, I have never been sick nor experienced altitude sickness. The second day of my trips has always been more arduous. At approximately 13,000’ lack of oxygen has become an issue. I always develop a “case of the slows”. My pace slows, heart rate goes up, depending on incline my stride shortens, and my desire for the summit rises. Once above 13,000’ my appetite disappears, even water holds no appeal. Yet staying hydrated and providing your body with adequate fluids is critical.

Marshall on the summit of Mt. Whitney, 14,505 ft (4,421 m)

The rigors of mountaineering are many. The rewards are many, the demands even more, but in the end, life is that way. --Marshall Delk

COMING FROM SEA LEVEL?

The following is advice from Douglas Fields Ph.D, published in his article "Are the Mountains Killing Your Brain?" Online "Outside". You can find the entire article online.

- Spend the first night at about 5,000 ft.
- The safest ascent rate is 1,000 ft per day once you reach 9,000 ft.
- Minimize time above 19,500 ft.
- Climb high, sleep low.
- Listen to your body. Never ascend with obvious symptoms of altitude sickness; descend if symptoms worsen.
- Stay hydrated, avoid excess salt, and eat foods easy to digest (carbohydrates).
- Don't drink alcohol—it's dehydrating and depresses breathing

The reason that Dr. Fields recommends carbohydrates is because some of the oxygen supply to your gut at high altitude is being sent to your vital organs--heart, brain, kidneys, significantly compromising the digestive process and impacting your appetite. So the foods you consume need to be easily digested and metabolized.

THE BRAIN AT ALTITUDE

Dr. Nicholás Fayed is a neuro-radiologist who studies the brains of high altitude trekkers. His MRI scans are alarming in that they show brain damage in mountaineers. Dr. Fayed and his associates found more brain damage in amateur than in professional climbers, and concluded, in a 2009 study, that amateur climbers are more susceptible to suffer acute mountain sickness and permanent cerebral damage than professional climbers after high altitude exposure, even without having had symptoms of high altitude sickness.[10]

In an earlier study (2006), the Fayed group recruited 35 climbers (12 professional and 23 amateurs) for four expeditions without supplementary oxygen. The mountains climbed were Mt. Everest, Mt. Aconcagua, Mont Blanc, and Mt. Kilimanjaro. The 12 professionals and one amateur climbed Mt Everest and the remainder of the amateurs were spread across the other three mountains.[11] Only one of the Everest climbers had a normal MRI, with the amateur showing frontal *subcortical lesions*; the remainder on the Everest climb--all professionals, had *cortical atrophy* and *enlarged Virchow-Robin spaces* but no lesions. Among the remaining amateurs on the other mountains, five had subcortical irreversible lesions and 10 had enlarged Virchow-Robin spaces.

Dr. Fields Damage Dictionary [12]

-Enlarged Virchow-Robin spaces--Refers to widening of spaces surrounding blood vessels in the brain caused by brain swelling or atrophy and associated with age-related cognitive decline, dementia, and various brain diseases.

-Cortical atrophy--Reflects the loss of neurons in the cerebral cortex, the brain's surface layer which carries out conscious thought, physical perception, and higher-level control of body movements.

-Subcortical lesion--Reflects damage to the white matter beneath the cerebral cortex that transfers signals between parts of the brain. Damage to this area causes widespread and irreversible problems.

ACUTE MOUNTAIN SICKNESS

When one ascends too high too fast, acute mountain sickness is common above 9,000 ft (2743 m) with symptoms of severe headache, nausea, vomiting, interrupted sleep pattern, loss of appetite and weakness. Climbers should immediately descend until the symptoms are gone. If the ascent is continued without acclimatization, the condition may well develop into what is known as high altitude cerebral edema.[13]

Treatment for acute mountain sickness is rest, fluids, and mild analgesics that will not mask worsening symptoms (acetaminophen, aspirin, or ibuprofen.) Recovery is rapid with descent. If resting at altitude, improvement usually occurs in one or two days, but may take as long as three or four days.[14]

HIGH ALTITUDE CEREBRAL EDEMA

A condition called high altitude cerebral edema is present when the symptoms of acute mountain sickness are compounded by loss of coordination, and decreasing levels of consciousness including disorientation, loss of memory, hallucinations, irrational behavior, and coma. High altitude cerebral edema almost always occurs because ascent is attempted when the climber is symptomatic with acute mountain sickness. It is therefore considered preventable except when climbers are stranded for long periods above 26,246 ft (8000 m). and the situation is compounded by the lack of bottled oxygen.

The person with this condition is often confused and may not recognize the need to descend. Others may not be aware of a problem until their companion collapses or they note atypical behavior such as unsteady gait, lack of awareness of surroundings, and irrational actions. Oxygen administration and medications may temporarily alleviate symptoms and facilitate descent--the absolutely imperative life-saving measure.

The mechanism of acute mountain sickness and high altitude cerebral edema are not completely understood, although the symptoms have been traditionally assigned to leakage of fluid from cerebral vessels to cause swelling, however, the actual pathophysiology may be more complicated. Damian Bailey M.D. and his associates have published works implicating the role of hypoxia in stimulating cerebral oxidative-nitrative stress[15] and have also found in acute mountain sickness only "minor vasogenic edema" (minor brain swelling from leakage of the cerebral vessels), suggesting that the symptoms are not explained by cerebral edema.[16] It will be interesting to see studies that follow.

HIGH ALTITUDE PULMONARY EDEMA

Acute mountain sickness can be complicated by pulmonary edema, a life-threatening development after rapid ascent to altitudes above 8,250 ft. (2500 m). The mechanisms of this acute breathing distress is multifaceted.[17] Essentially, excess fluid develops in the lungs, either in the lung tissue itself or in the alveoli In either case, the exchange of oxygen and carbon dioxide across the alveolar membrane is compromised and the person cannot get enough oxygen to function normally.

Symptoms

All symptoms are worse at night when recumbent.

- Difficulty or uncharacteristic slowness in walking
- Congestion and a chesty cough, possibly accompanied first by a clear phlegm and later by blood
- Extreme fatigue/weakness
- Gurgling sound whilst breathing. If you place an ear to the victim's chest, you may hear crackling or gurgling noises.
- Poor judgment

- Breathlessness during rest--easier breathing sitting up
- Rapid heart rate (90 to 100 beats/min at rest)
- Blue/grey lips or fingernails (cyanosis)
- Fever of up to 101.3° F (38.5° C)
- Profuse perspiration
- Confusion→Collapse→Coma→Death

Treatment---Immediate descent

Immediate descent is imperative but if left too long is hindered by the person's exhausted state, confusion, and the worsening condition with exertion. Unless oxygen is available, delay may be fatal. If it is necessary and even possible to carry the person, keep him or her, as much as possible, in a seated position to ease respirations. Obviously, immediate descent with the first symptoms, while the individual is still able to climb down on his own, saves lives, not only that of the victim, but also of the would-be rescuers, who place their own lives at risk for a rescue at such high altitudes.

THE "DEATH ZONE"

It is well known that the hypoxia affecting climbers at altitudes above 7000 meters (22,966 ft) nears the limit of human tolerance. Dr. Mike Grocott and his associates of the *Caudwell Xtreme Everest Research Group*[18] have taken blood samples from 10 climbers to and from the summit of Mt. Everest and found that the hemoglobin concentration increased such that the oxygen content of arterial blood was maintained at or above sea-level values until the climbers reached an elevation of 7100 m (23,294 ft).

Mountaineers have learned by bitter experience that the "death zone" begins at approximately 7,000 meters---close to the altitude at which the oxygen content of arterial blood begins to fall. In Dr. Grocott's study, at 8400 meters the mean arterial oxygen content was 26% lower than that at 7100 meters. There was also an increased difference between the concentration of oxygen in the alveoli and the arterial blood. This was thought to represent either preclinical pulmonary edema (before symptoms are observed) or to a functional limitation in pulmonary diffusion.[18] Whichever the case, experienced mountaineers know the importance of descending to a camp below the "death zone" as quickly as possible after summating.

Elevations of camps on the southern approach to Mt. Everest

- Base Camp - 17,500ft (5,400m)
- Camp 1 - 20,000ft (6,100m)
- Camp 2 - 21,300ft (6,500m)
- Camp 3 - 24,000ft (7,400m)
- Camp 4 - 26,000ft (8,000m)
- Summit - 29,035ft (8,850)

THE EYES AT ALTITUDE

In 2009, Dr. Martina M Bosch and her research team measured intraocular pressure of 25 healthy mountaineers at ascending altitudes as they climbed Mt Muztagh Ata in the Pamir mountains of central Asia. They found that climbs to very high altitudes were safe for the eyes with regard to intraocular pressure changes. [19] [20]

Something beautiful for your eyes---Mt Muztagh Ata in thin clouds with its summit at 24,751ft (7544 m). Lake Karakul and the foothills are in the foreground.

THE THREE GOLDEN RULES OF ALTITUDE SICKNESS

With thanks to Dr. David Shlim: CIWEC Travel Medicine Center in Kathmandu, Nepal.

Golden Rule I: If you feel unwell at altitude--it is altitude illness until proven otherwise.

Golden Rule II: Never ascend with symptoms of acute mountain sickness.

Golden Rule III: If you are getting worse or have symptoms of high altitude cerebral or pulmonary edema, go down at once.

ANATOLI BOUKREEV

I would like to finish with a tribute to a great mountaineer, Anatoli Boukreev, who was undeservedly and thoroughly trashed in Jon Krakauer's book, *"Into Thin Air"*. Anatoli's own story has been told in two books, *"The Climb" and "Above the Clouds"*.

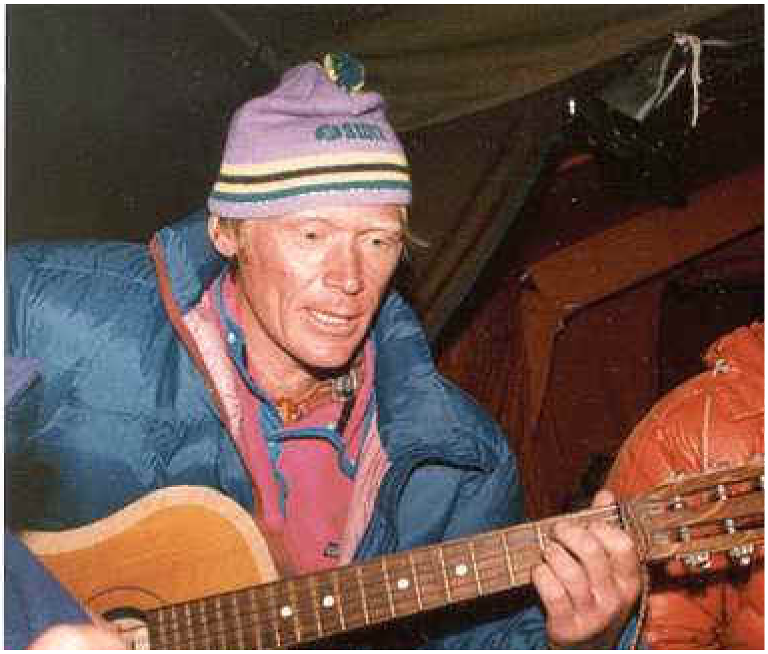
I'm not sure if the journalist, Jon Krakauer, ever actually understood what happened that day in May 1996, stranded as he was in the "death zone" and possibly compromised by his own exhaustion, critical hypoxia, hypothermia, mental impairment, relative inexperience and inability to fully comprehend Anatoli's halting English. Nor did he have a clue as to Anatoli's deep sense of responsibility, or the in-depth experience and reasoning of a brilliant man with an extraordinary higher education in physics and extreme altitude mountaineering. Jon Krakauer dares to second guess such a man.

On May 10, 1996, two commercial expeditions, each headed by professional mountaineers, attempted to climb Mt. Everest. Crowded conditions on the last steppes to the summit caused critical delays at extreme altitude. Uncharacteristically poor judgment on the part of the expedition leaders, flesh-freezing cold, and a sudden ferocious storm with knife biting jet stream wind left climbers stranded in the dark at extreme high altitude. Eight people died, including the two expedition leaders, most without adequate strength to save themselves. Without Anatoli Boukreev's brave rescues, it would have been eleven and he risked adding to that number.

Anatoli had gone from tent to tent begging for help and alerting others to the peril of four of their climbers. No one was able to help--not even the Sherpas, who were themselves tapped out, in their tents on oxygen. Desperate to find the lost climbers--knowing that they would die in the extreme altitude and cold without help, Anatoli gathered two oxygen bottles and a thermos of hot tea for the victims and stepped out alone into the heart of the blinding storm in the dark and knowing that he had little strength left. After two attempts, unable to see beyond his hand, he finally found three climbers, left oxygen with two of then, brought one to camp and returned for the remaining two before he collapsed.

For his heroic actions that day on Mt. Everest and after a thorough study of all records and accounts, the American Alpine Club awarded Anatoli Boukreev its highest honor, the David A Sowles Memorial Award. Hopefully, the life of this remarkable man will not be defined by the thoughtless and ignorant words from a self-serving journalist on assignment from Outside magazine looking for print.

"Mountains are cathedrals: grand and pure, the houses of my religion. I go to them as humans go to worship. From their lofty summits, I view my past, dream of the future, and with unusual acuity I am allowed to experience the present moment. My strength renewed, my vision cleared, in the mountains I celebrate creation. On each journey I am reborn." *-Anatoli Boukreev*



Anatoli Boukreev 1958-1997

Legendary Climber Killed on Annapurna

Anatoli Boukreev, 39, an elite but virtually unknown Russian climber who moved into the media spotlight in the wake of the tragic Mount Everest climb of May 1996, died Christmas Day 1997 on Annapurna when a cornice of ice collapsed, sending an avalanche of ice blocks and snow to sweep him away. He is mourned and missed by many--those who loved him and called him friend; those who climbed with him and counted on his extraordinary strength, sense of responsibility, honesty, and mountaineering expertise; and those who were close to him through his journals. He was a good man and a true hero.

References

[1] Napier PJ: **Medical and physiological considerations for a high-altitude MMA site**, MMA memo No. 162, J.B. West,. School of Med, UCSD, Oct 10, 1996.

[2] Hallagan LF, Pigman EC: **Altitude: Acclimatization to intermediate altitudes**, Encyclopedia of Sprots Med & Science, 13 July 1998.

[3] Holt D: **Altitude training, running & racing: red blood cell production and mitochondria enhancement**, home.sprynet.com/~holtrun/altitude.htm

[4] Eckert DJ, Jordan AS, Merchia P, Malhotra A: **Central sleep apnea: Pathophysiology and treatment.** Chest. 2007 Feb;131(2):595-607.

[5] Netzer N, Schuschnik M, Matthys H, et al: **Sleep and respiration at an altitude of 6,400 m (Aconcagua, Argentina],** *Pneumologie*. 1997 Aug;51 Suppl 3:729-35.

[6] Küpper T, Schöffl V, Netzer N.: **Cheyne stokes breathing at high altitude: a helpful response or a troublemaker?** *Sleep Breath*. 2008 May;12(2):123-7.

[7] Heil N: **Dark Summit**, Henry Holt and Company, NY, 2008. p. 239.

[8] Boukreev, Anatoli: **Above the Clouds; The Diaries of a High-Altitude Mountaineer**, St. Martin's Press, NY, 2001.

[9] Rippetoe M, Kilgore L: **Practical programming for strength training**, second edition, The Aasgaard Company, Wichita Falls, TX 2009.

[10] Fayed N, Diaz L, Dávila J, Medrano J: **Hematological indices, mountain sickness and MRI brain abnormalities in professional and amateur mountain climbers after altitude exposure.** *Neurol Res*. 2009 May 6.

[11] Fayed N, Modrego PJ, Morales H: **Evidence of brain damage after high-altitude climbing by means of magnetic resonance imaging.** *Am J Med*. 2006Feb;119(2):168.

[12] Fields D: **Are the mountains killing your brain?** "*OUTSIDE"* online.

[13] Maggiorini M, Bühler B, Walter M, Oelz O: **Prevalence of acute mountain sickness in the Swiss Alps.** *BMJ*. 1990 Oct 13;301(6756):853-5.

[14] Dietz TE: **An altitude tutorial,** International Society for Mountain Medicine, Nepal. 29 Jan 2006.

[15] Bailey DM, Taudorf S, Berg RMG, et al: **Increased cerebral output of free radicals during hypoxia; implications for acute mountain sickness?** AJP, Sept 2, 2009

[16] Bailey DM, Bärtsch P, Knauth M, Baumgartner RW: **Emerging concepts in acute mountain sickness and high-altitude cerebral edema: from the molecular to the morphological.** *Cell Mol Life Sci*. 2009 Sep 10

[17] Stream JO, Grissom CK: **Update on high-altitude pulmonary edema: pathogenesis, prevention, and treatment.** *Wilderness Environ Med*. 2008 Winter;19(4):293-303.

[18] Grocott MP, Martin DS, Levett DZ, et al; Caudwell Xtreme Everest Research Group: **Arterial blood gases and oxygen content in climbers on Mount Everest.** *N Engl J Med*. 2009 Jan 8;360(2):140-9.

[19] Bosch MM, Merz TM, Barthelmes D, et al: **New insights into ocular blood flow at very high altitudes.** *J Appl Physiol*. 2009 Feb;106(2):454-60.

[20] Bosch MM, Barthelmes D, Merz TM, et al: **Intraocular Pressure During a Very High Altitude Climb.** *Invest Ophthalmol Vis Sci*. 2009 Oct 29

mc:02/22/2010