Andrew J. Young, Ph.D., '74

Floyd D. Gottwald Jr., '43 Visiting Professor of Leadership and Ethics

# Human Performance Challenges in Extreme Environments: How Leaders Can Make a Difference

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## About the Gottwald Visiting Professorship

Each year, VMI selects a distinguished scholar as the Floyd D. Gottwald Jr. '43 Visiting Professor in Leadership and Ethics. The Gottwald chair is sponsored by the Center for Leadership and Ethics and provides perspectives on leadership and ethics from across the disciplines. The chair is embedded in one or more of VMI's 15 academic departments. Cadets and colleagues gain from the visiting professor's lifetime achievements in research and field work.

This year's Gottwald Visiting Professor is Dr. Andrew Young.

# Human Performance Challenges in Extreme Environments: How Leaders Can Make a Difference

Andrew J. Young, Ph.D., '74

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*Floyd D. Gottwald Jr., '43*
*Visiting Professor of Leadership and Ethics*

Before beginning, I want to thank the VMI administration and especially Colonel Jim Turner for inviting me to spend this year at VMI as the Gottwald Visiting Professor. I also want to thank the Gottwald family whose generosity made my visiting professorship possible.

After I graduated from VMI and completed graduate school training in physiology, the Army assigned me to the military's medical research laboratory in Massachusetts, which develops procedures, products and policies to sustain the individual warfighter's physiological readiness to perform military missions under stressful conditions. I spent almost my entire 38-year career as a scientist working at that laboratory, studying how extreme environments and operational conditions affect human health and performance capability, and so I'm going to address those effects and how to mitigate them.

## Warfighting is an Outdoor Activity

For the most part, warfighting is not an indoor activity. Combat operations and training take place 24/7, year-round and anywhere on earth, often in very hot or cold weather and sometimes at very high altitudes above sea level, and some of you will be leading teams in those harsh conditions very soon. Now, many young officers think that as long as they are physically fit, tough and determined, they can drive on under any conditions and get the job done. However, no matter how tough and determined you are, the environment can impact your team's performance, and if you, their leader, understand what's causing those effects, you will be better able to get your team to its objective, healthy and fit enough to complete your assigned mission. For those of you who won't be leading military teams when you leave VMI, these lessons may be applied to performing any kind of work, sports or physical activity outdoors in harsh climates.

## High Altitudes

U.S. Forces have been engaged in Afghanistan for over 13 years, and Afghanistan has a very harsh climate: incredibly hot summers in the northern valleys, bitterly cold winters in the highlands, and high altitudes throughout the entire country. Many of the U.S. combat operations in Afghanistan have taken place at very high altitudes. For example, Operation Anaconda was conducted to capture or destroy Taliban and Al Queda fighters using the mountains of Eastern Afghanistan as a stronghold. On the first day of the operation, two battalions from the 101st ABN Division and one battalion from the 10th MTN Division air assaulted into the eastern part of the Shahikot valley. They immediately became engaged in intense combat that


***Source: CMH Pub 70-83-1: The U.S. Army in Afghanistan: Operation ENDURING FREEDOM. Courtesy of the U.S. Army Center for Military History.***

continued all day and for several days following, all in very rough terrain at altitudes ranging from 8,000 to 9,000 feet.

Early morning of the second day of Operation Anaconda, a SEAL team was sent to the 11,000-foot summit of Takur Ghar, a mountain overlooking the Shahikot Valley, to provide reconnaissance and control air support for the battle in the Valley. As they were landing, they came under fire and one SEAL fell from the damaged helicopter as they maneuvered to escape the area. The rest of the SEAL team were picked up by another helicopter and returned to the summit to rescue their teammate. Immediately upon approach, they, too, came under heavy fire and had to withdraw to just below the summit.

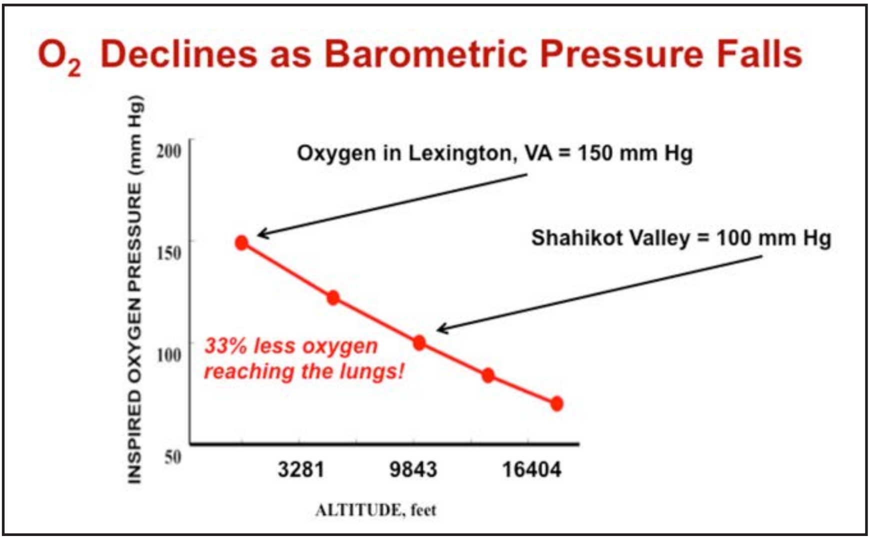
A team of U.S. Army Rangers sent to assist the SEALs arrived at the summit of Takur Ghar at about 0600, but their helicopter was shot down, killing a crewman. Four Rangers were shot and killed exiting the helicopter, and almost all of the other Rangers were wounded as they ran for cover and began an intense firefight. A second team of Rangers arrived 20 minutes later, but the helicopter had to insert these Rangers about 700 yards below the summit of Takur Ghar. The leader of that team radioed the other Rangers that they would reach the summit of Takur Ghar in 45 minutes to join the fight. However, it took them almost two and half hours to hike up and join the fight on the summit. The fighting lasted several more hours, and then the Rangers and

SEALs had to wait rest of the day at about 11,000 feet altitude and in very cold weather, until 2015 that night when helicopters could safely evacuate them. The media stories about the battle, as well as official after-action and lessons-learned reports, make it clear that the extreme high altitude conditions impacted performance of the warfighters during Operation Anaconda.

As we climb from sea level to higher altitude, barometric pressure declines. Barometric pressure is the pressure exerted by the atmosphere due the weight of the air above, and as we climb higher into the atmosphere, there is less air above, so less weight and less barometric pressure. Here in Lexington we are about 1,000 feet above sea level, and barometric pressure is about 3% less than at sea level. However, at 11,000 feet, the summit of Takur Ghar in Afghanistan, the barometric pressure is 34% less than at sea level.

As barometric pressure falls, so do the pressures of all of the individual gases making up the atmosphere, including oxygen. The air breathed by soldiers of the 101st Airborne and 10th Mountain division battalions in the Shahikot Valley during Operation Anaconda had about 35% less oxygen than the air we are breathing here in Lexington today, and the air on the top of Takur Ghar had even less. So as a result, when we are at high altitude, our blood contains much less oxygen than at sea level. The problem is that the muscles need the same amount of oxygen to do their work at high altitude as at sea level, so the lungs and especially the heart have to work much harder during heavy physical labor and exercise at high altitude than at sea level.

Because of the increased strain on the heart and lungs and other effects of oxygen deprivation, our ability perform strenuous work or exercise is greatly




*Source: Dr. Andrew Young.*

degraded at high altitude compared to at sea level, and we can see this in the after-action interviews of soldiers who fought in Operation Anaconda. It took much, much longer for units to move by foot and reach their objectives in the Shahikot Valley and on Takur Ghar than they expected based on their experience during sea-level training and operations.

Besides degrading work performance, oxygen deprivation at high altitude can actually make people sick. The two most common illnesses caused by oxygen deprivation at altitudes where military operations are likely to take place are acute mountain sickness or AMS and high altitude pulmonary edema or HAPE. AMS is the most common altitude sickness, affecting about 25% of all persons ascending to 8,000 feet altitude, and 75% of those ascending above 10,000 feet. The symptoms begin after about 3 hours at high altitude, and peak at about 24 hours, and are similar to severe flu or hangover – potentially incapacitating headache, vomiting, and dizziness. Reports indicate a large number of soldiers experienced AMS during Operation Anaconda.

HAPE, which begins as a hacking cough, that eventually leads to coughing up blood and causes the lungs to fill with fluid, is not as common as AMS, but more serious and fatal unless the patient is quickly evacuated to lower altitude. Reports from soldiers who fought on the summit of Takur Ghar suggest that some of them may have been experiencing HAPE.

Even if you don't experience altitude illness, lack of oxygen and fluid accumulation in the brain will degrade your vision, cognitive function and ability to detect and track targets. The dry air at high altitude will dehydrate you and your team, and your bodies will burn more carbohydrates at high altitude, further limiting your endurance. All of those effects degrade the team's military performance and decision making in the high mountains.

If you stay at high altitude for a while, you begin developing acclimatization, a collection of adaptations that tend to compensate for the effects of oxygen deprivation. Within a day or so, brain function begins improving and symptoms of acute mountain sickness usually abate after two or three days of acclimatization. Endurance and work capacity begin improving after about a week, and the longer you stay at high altitude, the better acclimatized you and your team will become.

Even with full acclimatization, performance does not fully recover back to sea-level capability, as shown in this graph, which depicts the 2-mile run time for eight members of a Special Forces A-team, first at sea level and then at the top of Pikes Peak, Colorado, at 14,110 feet altitude, on the third day after they arrived and again after they had lived and acclimatized up there for two weeks.

The best way to acclimatize to altitude is to climb just high enough each day to acclimatize, but not so high or fast that you get AMS. When that's not possible because of your mission, or for your team members that know they are susceptible, the medics have drugs that can reduce symptoms of mountain sickness, but those drugs won't restore your physical stamina at altitude.

## Extreme Cold

It was also cold up in the mountains, and historically, cold exposure-related injuries have had major effects on military campaigns and battles. For example, during the Korean War, 12,000 Marines and soldiers experienced cold injuries, mostly frostbite, during the 17-day Chosin Reservoir Battle, and 30% of the British marines and soldiers who fought in the 24-day Falkland Islands War experienced cold injuries, in this case mostly trench foot.

There are three types of cold injuries: 1) frostbite, in which body tissues become frozen, thereby damaging the cells; 2) hypothermia, in which the body loses so much heat that deep body temperature falls, causing the heart, brain and nervous system all to malfunction; and 3) trench foot, in which prolonged exposure of skin, usually of the feet, to nonfreezing cold and wet conditions causes the skin and underlying tissues to die. Frostbite can only occur when temperatures are below freezing, but hypothermia and trench foot can develop at cool, non-freezing temperatures, especially in rain or when walking through wet terrain.

In previous wars, soldiers and Marines oftentimes didn't have adequate cold weather clothing. The good news is that both the Army and the Marines now have excellent, high-tech cold weather protective clothing and boot systems. Designed to fully integrate with the ACUs or MCCUUs, they provide much better protection from even the most extreme conditions. During Operation Anaconda, cold weather clothing had been issued, and there were no cold injuries.

However, cold injuries can occur even when air temperatures aren't extremely cold. Water conducts heat better than air, so body heat loss is faster in rainy conditions or during immersion in water, compared to dry air of the same temperature. Thus, wet conditions greatly increase the risk of hypothermia.

In February of 1995, four soldiers at the U.S. Army Ranger School died of hypothermia during a training exercise one night in the swamps of north Florida, and north Florida isn't known for extremely cold weather, even during winter. My research team was asked to help identify factors that contributed to this terrible accident.

Ranger School is a grueling 60-day infantry-training program, where students work extremely hard for many hours a day with limited sleep. At the

## Gen 3 Extended Cold Weather Clothing System


*Source: U.S. Army Program Executive Office Soldier.*

time I was studying these men, their daily rations during field training were limited to only 1 MRE per day. As a result, most of them had lost almost all of their body fat by the end of the course, going into the swamp operations phase of training.

On the morning of the exercise, the instructors thought that, even though water temperature was cold and close to the Ranger School safety limits, the exercise could go on because the water in the swamp was only knee deep. They also expected the Ranger students to be immersed for much less time than five-hour safety limit allowed by SOP for knee deep water at 52o F. However, the instructors had measured the swamp water depth on the day before the training exercise and didn't realize that heavy rain upriver to the north was causing the river to flood and water temperatures to fall.

The three student companies began paddling their boats down river at about 1100. The instructor with the first company moving down the river was the most experienced, and he recognized that the water was too deep, so he directed his company to continue down river and not disembark until they reached a point where they could move to the objective by walking on dry land. This company experienced no hypothermia casualties.

*Source: official digital archive of Fort Benning and the Maneuver Center of Excellence.*

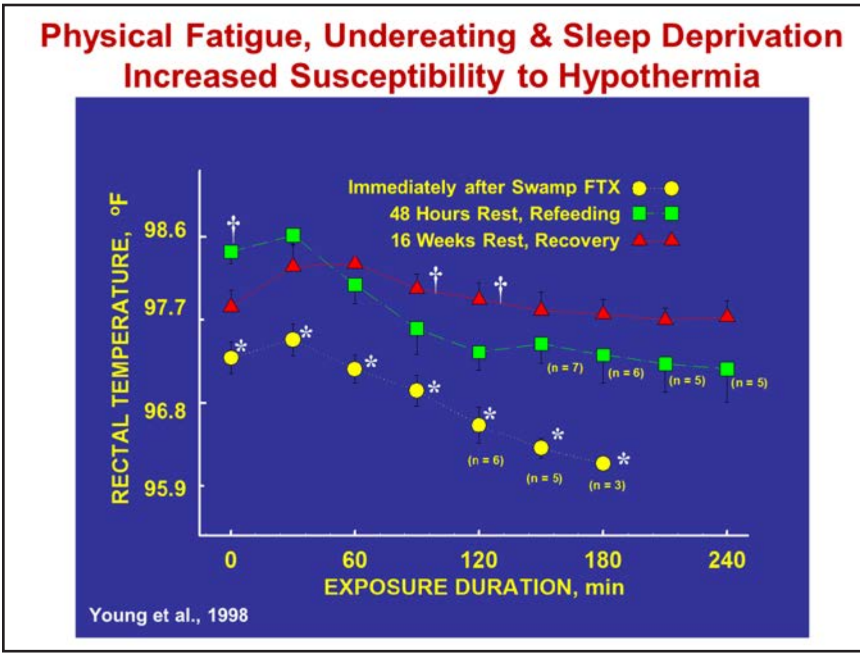
The other two companies disembarked the Ranger students in the swamp, and things quickly deteriorated. The water was colder and much deeper than expected, and there was a strong current running. At times, the men had to swim from tree to tree in water that was over their heads. They were moving very slowly, and after about two hours, men began showing symptoms of hypothermia: sluggishness and confusion. A medivac was called, and movement was slowed further while the first three casualties were lifted out of the swamp.

The platoons continued moving slowly through the swamp toward the objective, but it was now dark and foggy and they began to spread out as groups got separated and stragglers slowed and stopped walking. Most of the students were showing signs of hypothermia, and the cadre were confused and hypothermic themselves. Soldiers had to be pulled along by their buddies. It wasn't until about 2130 hours that most of the men reached dry land, after almost eight hours in the swamp. Casualty collection points were established, first aid started, and several more soldiers were medivaced by ground. However, one student remained missing. His body wasn't found until the next morning, in the water not far from dry land. All told, four Ranger students died of hypothermia that night.

Hypothermia affects brain and nerve functions, and that's why hypothermia victims often display mental confusion, loss of situational awareness, and apathy, all of which appear to have contributed to poor performance during the training accident that night.

After the accident, I investigated how the severe physical demands, food restriction, weight loss and sleep deprivation that Ranger students endured during the 60-day training program affected their ability to regulate body temperature. I recruited a group of Ranger School students who were at the same point of training as the students in the class that experienced the hypothermia accident to participate in my experiments. I picked them up as they finished the swamp FTX at the end of Ranger School, and took them to a nearby laboratory chamber where they sat in cold air for four hours while I measured their body temperatures, metabolic rate and a variety of other things. After they finished the test, I let them eat and sleep for the next two days in first-class hotel near the lab, and then they repeated the test. Then they went home and recovered from Ranger School and regained their body fat for 16 weeks before coming back to the lab for a final test.

The graph shows their deep body temperatures during the three trials, and you can see that the body temperatures fall much faster and lower during the trial conducted less than 2 hours after the FTX, when they hadn't rested, slept or eaten for days, and their body fat was almost completely burned away, compared to the other two trials when they had rested and eaten and, in the third trial, regained their body fat.




*Source: Young, A.J., W.E. Castellani, C. O'Brien, R.L. Shippee, P. Tikuisis, L.G. Meyer, L.A. Blanchard, J.E. Kain, B.S. Cadarette, and M.N. Sawka. Exertional fatigue, sleep loss and negative energy balance increase susceptibility to hypothermia.* **Journal of Applied Physiology** *85: 1210-1217, 1998.*

So clearly, the physical stress, food and sleep deprivation, and depletion of their body fat over the course of the 60-day Ranger School training program had degraded their body's ability to regulate its temperature, and they were highly susceptible to hypothermia during the swamp training phase of Ranger School.

Based on these and other findings, recommendations were made to change the water immersion safety limits used by the Ranger School in planning swamp movements. We also recommended that the Ranger students be given more food to mitigate the body weight loss somewhat, so now the students are provided 2 MREs each day they are in the field.

## Extreme Heat

Hot weather is probably the most commonly experienced environmental extreme, and historically, heat stroke and heat exhaustion have been a serious military problem, as indicated by journal entries of soldiers who fought in the Battle of Monmouth during the American War for Independence, a day when the temperatures reportedly reached 100 oF. Both the British and Continental armies experienced a large number of heat stroke fatalities during that battle, and the outcome of the battle was influenced by the extremely hot weather.

Here is a more contemporary description of the heat stress experience of our deployed military personnel in Iraq. Each year for the past decade about 350 military personnel have had to be medically treated for heat stroke, a potentially fatal injury, and another 2,000 are treated for heat exhaustion and other types of heat injuries. And those numbers are only those admitted to medical treatment facilities in the continental U.S., not the heat injuries treated in theater or by unit medical personnel outside of medical treatment facilities.

During the Iraq war, the Marines of the 1st Battalion, 4th Marine Regiment, and soldiers of the 1st Battalion, 5th Cavalry Regiment, and 2nd Battalion, 7th Calvary Regiment, fought Iraqi insurgents from Muqtada al-Sadr's Mahdi Army in Najaf, a city of about a half a million people, located in central Iraq, south of Bagdad. The battle for control of this city was intense urban combat fought during the absolute peak of the Iraqi summer.

The high temperature in Najaf during August averages 108 oF, but during the battle in August of 2004, mid-day temperatures reached 125 oF or higher.

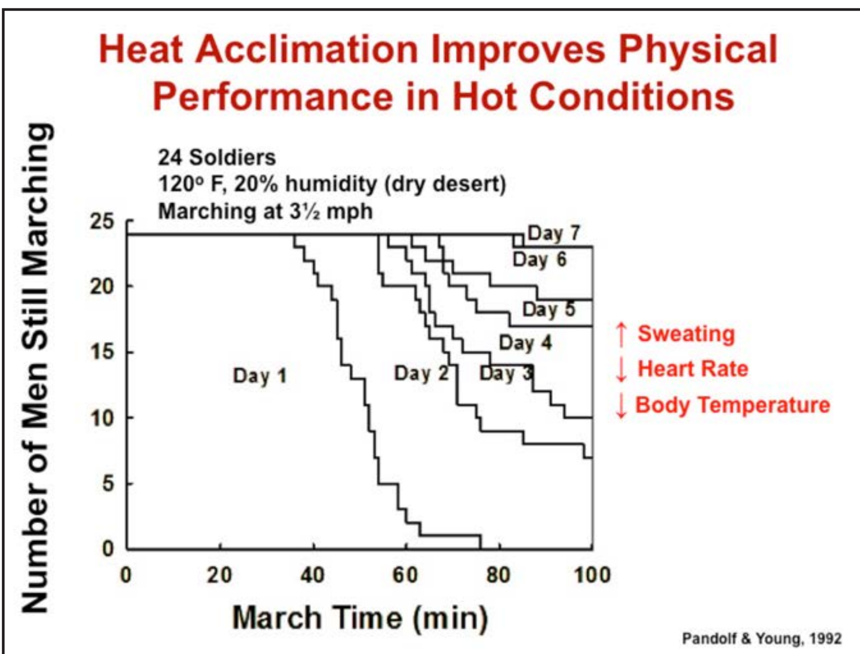
The incredible heat stress during the battle made it extremely difficult for the Marines and soldiers to stay hydrated, and there were large numbers of heat casualties evacuated from the fight.

When we are working or exercising, the muscles create lots of heat, and the body has to get rid of that heat, or else body temperature rises excessively, eventually leading to heat exhaustion or heat stroke. The body has two primary means of dumping excess heat. One is by is by heat conduction from the skin to the environment. However, when the ambient air temperature is higher than body temperature, this doesn't work. The other mechanism is by evaporation of sweat on the skin surface, which cools the body. But when heavy military clothing and body armor cover most of the skin, that mechanism is almost entirely blocked.

Furthermore, the body armor worn by soldiers and Marines is very heavy and they carry very heavy loads, which means that the muscles must work harder than usual just to move around, and this adds to the amount of body heat being produced while they are working. As the heat builds and body temperature rises, the blood pools in the skin, and the heart must work harder move blood around the body. All of these effects of heat stress cause people to fatigue much sooner than during cool conditions, and if body temperature continues rising, collapse due to heat exhaustion can occur and heat stroke can develop with body organ damage due to high temperatures and inflammation.

Heat acclimatization greatly improves our body's ability to dissipate excess heat. Acclimatization develops when we repeatedly exercise hard enough to sweat profusely in hot conditions over a number of days.

The following graph depicts an experiment that we did at the Army laboratory in Massachusetts, and it shows how the development of heat acclimatization improves performance. Twenty-four soldiers attempted to march for 100 minutes in 120° F each day for 10 days. As the march continued, medical staff pulled men as their body temperatures rose and reached our safety limits. As you see, on the first day, the first soldier was pulled after only 40 minutes and everyone hit the upper limit of body temperature before completing 75 minutes of marching. The next day, the first guy didn't hit the limit until an hour of marching, and seven of the guys made it to the 100-minute finish line without hitting the high temperature limit. Each day thereafter, more and more of the guys were able to make it to the end of the march until by the eighth day, all 24 men completed the march without hitting the upper limit for body temperature. Heart rate during exercise becomes lower, following a similar pattern during heat acclimatization, while sweating is increased so that improved sweating helps cool the body and lower body temperatures and heart rates during exercise, all of which allow endurance and performance to improve.

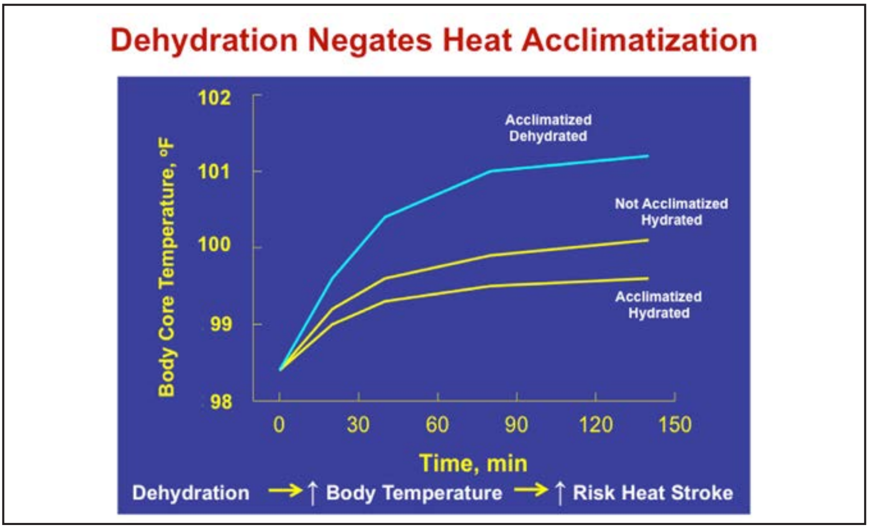



*Source: Pandolf, K.B. and A.J. Young. Environmental extremes and performance. Endurance in Sports. R.J. Shephard and P.O. Astrand (eds.), Oxford: Blackwell Scientific: 272-284, 1992.*

*U.S. Army Pvt. Derek Hayes, a mortarman from Charlie Company, 1st Battalion, 27th Infantry Regiment, 2nd Stryker Brigade Combat Team, 25th Infantry Division, patrols Tarmiya, Iraq, Feb. 17, 2008. Source: U.S. Air Force.*

Dehydration works in the opposite way as heat acclimatization, reducing sweating and causing heat rate and body temperature to rise excessively during exercise, so dehydration increases the risk of heat stroke.

So how much do you have to drink to stay hydrated? The simple answer is that you have to drink enough to match the amount of sweat you lose. However, that's not always possible, especially in really extreme heat conditions, when sweating during heavy work can be so high that your stomach can't empty that amount of water into your body even if you could drink it. In those situations, you have to make sure you drink enough during the rest break after work, especially at meals, to make up the deficit. One thing to keep in mind is that under severe heat stress conditions, when sweating is high and large amounts of water are being consumed, it is important that you are also eating food so that you don't become electrolyte depleted. Sports beverages can be a good approach when you must go long periods without a regular meal.




*Source: Sawka, M.N. and K.B. Pandolf.* **Physical Exercise in Hot Climates: Physiology, Performance, and Biomedical Issues. Textbook of Military Medicine, Medical Aspects of Harsh Environments, Vol. 1.** *K. B. Pandolf and R.E. Burr, Washington, D.C.: Office of the Surgeon General, Department of the Army, and Borden Institute: 87-133, 2001.*

## What Leaders Can Do

So what can leaders do to make a difference when they and their teams must perform in extremely harsh environments? Most importantly, you need to understand how the environment stresses you and your team members, and you need to warn them about what to expect and what to watch out for. You need to plan for a period of degraded performance and give newly arrived folks some time to acclimatize to the new extreme environment. You may need to adjust how your team approaches its tasks during that period to spread the workload out differently. In any new, stressful environment, push your team, but don't break them.

It boils down to taking care of the people you lead and keeping them healthy and fit enough so that when they arrive at the objective, they can do the mission you are assigned.

# Acknowledgements

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The opinions or assertions contained herein are the private views of the author(s) and are not to be construed as official or reflecting the views of the Army or the Department of Defense. The investigators have adhered to the policies for protection of human subjects as prescribed DOD Instruction 3216.02, and the research was conducted in adherence with the provisions of 32 CFR Part 219.


Dedicated to:

- Captain Milton Palmer, 2nd Lieutenant Curt Sansoucie
- 2nd Lieutenant Spencer Dodge, Sergeant Norman Tillman

U.S. Army Ranger School Class 3-95

# Brief Biography of Dr. Andrew J. Young

Dr. Young is an alumnus of VMI, Class of 1974, and has an extensive background in physiology and military nutrition. He recently retired as chief of the military nutrition division at the U.S. Army Research Institute of Environmental Medicine in Natick, Massachusetts, but continues to serve as a senior program advisor and consultant to that Institute in the area of military operational physiology and nutrition. He has written more than 130 articles reporting his research concerning the biological basis for, and strategies to mitigate, performance degradations in people exposed to stressors such as intense physical exertion, sleep restriction, nutritional deprivation, and exposure to extremes of heat, cold, and high altitude.

Dr. Young is a fellow of the American College of Sports Medicine, the immediate past editor-in-chief of the American College Sports Medicine's flagship scientific journal, Medicine and Science in Sports and Exercise, and a member of the American Physiological Society.

After graduating with a bachelor's degree in biology from VMI, Young commissioned in the U.S. Army. He served first at the U.S. Army Research Institute of Environmental Medicine and then at the Walter Reed Army Institute of Research. After his retirement from the Army, he continued as a civilian employee at the Research Institute. In 1977, Young earned a doctorate in physiology at North Carolina State University.

This year, we have been pleased to have Dr. Young teach in both our biology and physical education departments as part of their exercise science program. In the fall he taught a course in Human Performance and Environmental Physiology, and this spring he taught a course titled Sports and Military Nutrition.

# The VMI Center for Leadership and Ethics

The primary mission of the Center for Leadership and Ethics is to enhance the cadet experience here at VMI. Our staff assists VMI departments and external organizations in developing and offering relevant, dynamic events on a variety of topics. We provide programs that support VMI's system of leadership training and challenge cadets and our society with conferences on topics of national and international importance.

## UPCOMING SCHEDULE OF EVENTS:

### Academic Year 2015-2016: 'Living in the Age of Machines'

• Oct. 6-7, 2015 – Hands-On STEM: Technology and Project Based Learning

• Dec. 11-12, 2015 – Biennial Seiziémistes of the Mid-Atlantic Conference

• Mar. 7-8, 2016 – 6th Annual Leadership Conference: 'Ethical Dilemmas in the Digital Age'

• Apr. 5-7, 2016 – 27th Annual Environment Virginia Symposium

• Apr. 8-9, 2016 – Virginia State Science & Engineering Fair

• May 28, 2016 – 16th Biennial Stonewall Jackson Symposium

• June 5-7 – "Inverse Problems" Mathematics Conference

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