Session No. 682

Climatology vs. Physiology: Climate Change and Aging Workforce Adaptability

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Introduction

Regardless of whether the influences are man-made or due to predictable geological vicissitudes, according to the National Oceanographic and Atmospheric Administration (NOAA) and the National Atmospheric and Space Administration (NASA), we are assured to be in a period of global temperature change that is trending upward for our foreseeable future. The drivers influencing this change are immaterial to our discussion and better left to those with particular interests or positions to promote or protect. Since this trend is expected for the foreseeable future, taking measures to understand basic human physiology can better prepare us to prevent injuries, illnesses and incidents that an exposed workforce could encounter. While doing so allows our efforts to rest on the solid ethical foundation of preventing pain and suffering to those who count on us for protection, we can also reap the obvious benefits of saving our industries countless amounts of wasted expenditure reacting to immutable factors that simply could have been avoided.

To wit, climate data as presented by NOAA in Exhibit 1 and NASA in Exhibit 2 suggests we will be exposing our workforce to increasing heat in all non-climate controlled environments.[1, 2]

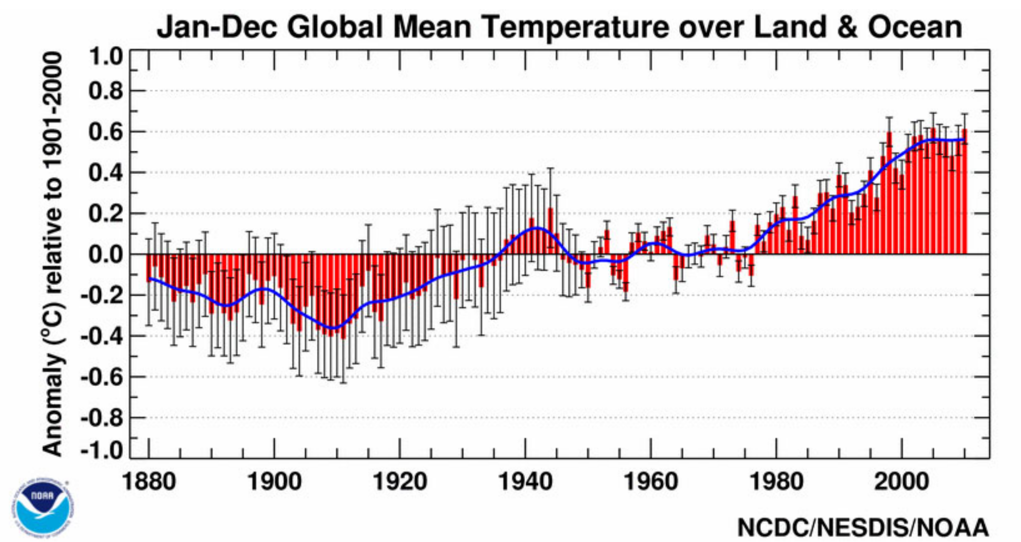


Exhibit 1. NOAA Global surface temperatures have increased about 0.74°C (plus or minus 0.18°C) since the late-19th century, and the linear trend for the past 50 years of 0.13°C (plus or minus 0.03°C) per decade is nearly twice that for the past 100 years. The recent warmth has been greatest over North America and Eurasia between 40 and 70°N. Lastly, seven of the eight warmest years on record have occurred since 2001 and the 10 warmest years have all occurred since 1995.

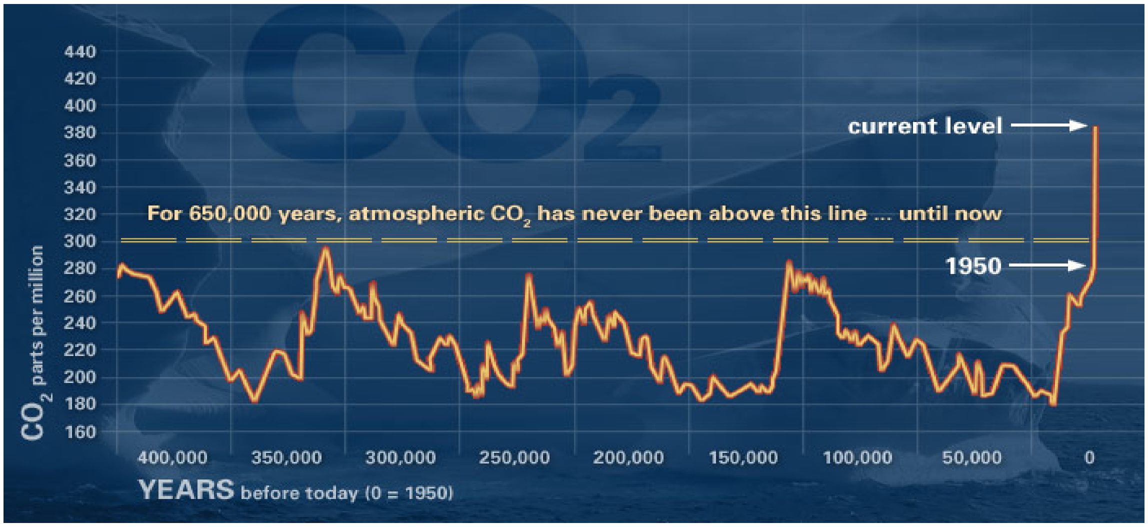


Exhibit 2. NASA. All three major global surface temperature reconstructions show that Earth has warmed since 1880. Most of this warming has occurred since the 1970s, with the 20 warmest years having occurred since 1981 and with all 10 of the warmest years occurring in the past 12 years. Certain facts about Earth's climate are not in dispute: The heat-trapping nature of carbon dioxide and other gases was demonstrated in the mid-19th century. Increased levels of greenhouse gases must cause the Earth to warm in response.

What concerns us in environmental health and safety is that these atmospheric phenomena are occurring at a critical time in US (and world) workforce evolution. The US Department of Labor, Bureau of Labor Statistics warns us in Exhibit 3 that the US workforce is aging and will continue to age well into the middle of this century. Members of the Baby-Boom Generation (born 1946 to 1964) are entering into their 50's, 60's and 70's. Many members of this generation will continue to work for myriad reasons. Within the perspective of the present global economic climate combined with hindsight and fall-out from investments in the tech-bubble of the 1990's and housing-bubble of the 2000's, many will do so out of necessity. [3]

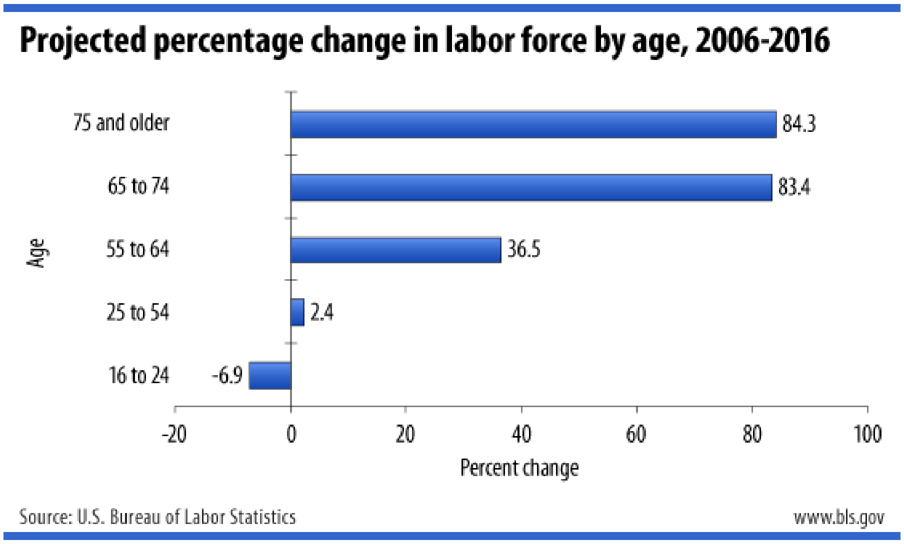


Exhibit 3. US Bureau of Labor Statistics data show that the total labor force is projected to increase by 8.5 percent during the period 2006-2016. When analyzed by age categories, workers age 55-64 are expected to climb by 36.5 percent. Workers between the ages of 65 and 74 and those aged 75 and up are predicted to soar by more than 80 percent. By 2016, workers age 65 and over are expected to account for 6.1% of the total labor force, up sharply from their 2006 share of 3.6 percent.

Challenges

The scientific medical literature is replete with references on how temperature (especially heat) regulation begins its decline in later life. When compared with the performance and tolerance of younger adults during heat stress, older workers typically respond with attenuated individual sweat gland outputs, decreased skin blood flows, reduced cardiac outputs and smaller redistributions of blood flow from visceral circulation where core temperature can contribute to an overheating feedback loop. This is understood to exist under the best of conditions, before chronic illness, pharmacological interventions and their potentially detrimental influences are factored in. Resultant areas of concern are both immediate and long-standing. Of immediate bearing is increased exposure to heat illness in aging workers, which can constitute an uptick in medical emergencies with grave consequences. Of equal and lasting concern is the increased exposure to both acute and cumulative musculoskeletal disorders (MSD's). A lack of knowledge in basic structural physiology can unwittingly expose the aging workforce to stressors that may increase MSD's, along with concomitant pain-and-suffering and costly consequence to business operations. We intend to bridge that gap. [4]

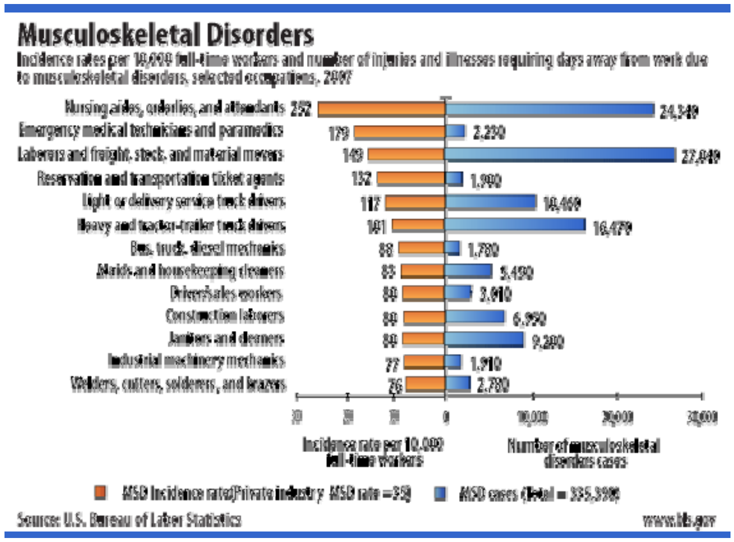


Exhibit 4. US Bureau of Labor Statistics - Musculoskeletal Disorders (MSDs) requiring days away from work. These disorders are often referred to as "ergonomic injuries" and are injuries or illnesses affecting the connective tissues of the body such as muscles, nerves, tendons, joints, cartilage, or spinal discs – examples are sprains and strains from lifting, hernias, and carpal tunnel syndrome. The overall private industry rate for MSDs was 35 per 10,000 full-time workers.

With MSD's demonstrating a 35 per 10,000 full-time workers private industry rate in 2007 as illustrated in Exhibit 4 by the US Bureau of Labor Statistics, the combination of climate change, aging workforce thermoregulatory decline, and age-related soft tissue changes, it doesn't take an over-active imagination to predict a steadily rising MSD incidence rate in the future if appropriate measures of education, awareness and action aren't pursued.[5]

Attention to, and understanding of both expected and preventable physiological decline is crucial to prescient Safety Professionals. Forestalling heat-related illness and the manifestations of impairment brought about by both unhealthy aging and declining heat-regulatory mechanisms are critical. For our discussion, it is particularly difficult to pinpoint a specific age where a person is considered 'elderly'. Aging does not occur uniformly across the population. People can differ dramatically in physiological age, even though they may be the same chronological age. Throw disease or de-conditioning into the discussion, and the view gets even murkier. While we all inevitably age, how we age can be greatly affected by diet, hydration, stress-management, leisure activity and exercise. Decline does not have to be significant in rate and magnitude. Specific physiological variables to watch for include slower reactions times, lower muscular strength, lower muscular flexibility, longer recovery times to exertion, etc. These are to be expected up to a point. Knowing the general effects of aging on physiological function can help a planner portend inherent changes and make adjustments to keep the workforce productive in the decades to come.[6]

Human Thermoregulatory Physiology

Homeostasis (Latin for 'the same place') demands a high degree of efficiency in humans, especially when it comes to the maintenance of body temperature. Cellular activity depends on chemical reactions, which are mediated by enzymatic influences. This highly precise system can be directly affected by fluctuations in body temperature.

In our normal resting state, we produce heat at a basal metabolic rate (BMR) through essential body activities including a beating heart and a contracting diaphragm. When we engage in activity, the heat produced by metabolism raises blood temperature. Even blood leaving an active brain is warmer than blood entering it. Skeletal muscles heat blood considerably during manual work. This warmed blood is directed to our organs of heat loss, mainly our lungs and our skin.

Convection and radiation work to cool our bodies. But by far, our prevalent cooling mechanism is evaporation, especially when ambient temperature exceeds that of the body (97F – 99F). Our evaporative cooling system relies on deep, warmed blood being shunted to the surface near our skin. This redirection is closely regulated by the sympathetic ('fight or flight') division of the autonomic nervous system. It stands to reason that when we find ourselves in high-temperature environments, we perceive it as uncomfortable, or 'hot-and-bothered' as they say. Sympathetic division dominance of the autonomic nervous system is characterized by a lack of 'ease'. It is closely related to perceived stress, irritation, etc. Simply put, our bodies keep us from this hyper-irritated state by these five physical mechanisms:

- First, contact with a cold object, like a wet shirt can utilize **conduction** to transfer the heat from the overheated body to the cool shirt.
- Second, cool air can move across the body from a fan, providing **convection**, which draws heat off and away from the body, transferring it without contact.
- Third, the vaporization of water on the bodies surface is the transformation of liquid to a gas which draws off heat through **evaporation**, a process that liberates heat.
- Fourth, cooler air can be inspired, through **respiration**, and our hot exhaled breath releases heat this continual drawing in of cooler air and expiration of hot air transfers body heat outside us.
- Fifth, we can transfer heat from actual **radiation**, where cooler objects close to (but not touching) our bodies heat up to closely match the temperature of our bodies.

Centrally located, not far behind our eyes sits the hypothalamus, where a group of nerves sensitive to the arterial blood that passes them resides. This internal 'thermostat' detects arterial blood temperature changes and alerts the rest of the body. This is followed by a vasodilatation, or expanding of the blood vessels closest to the skin. We feel hot. We may remove clothing, or get into the shade, or seek air-conditioned environs. Our eccrine (sweat producing) glands are activated, and the sweat is drawn out onto the hairs on our skin, so that more surface area is exposed and evaporation is more efficient. Locally, the hormone bradykinin is released, inducing increased vasodilatation and greater heat loss through evaporation. If external environmental temperature is higher than our body temperature, four of the five mechanisms for releasing heat energy from us will be thwarted. Only evaporation of sweat, which itself is then dependent on relative humidity being low enough, will be left to do the job.[6, 7, 8]

Working in Hot Environments

When our work environment challenges our capacity to release heat through the five methods just mentioned, our physiology cycles through successive systems to manage it. First, the skin's blood vessels dilate to increase blood flow to the surface and increase sweat production, radiation and convection. This is done at the expense of blood flow normally destined to other organs. Cardiac output and heart rate then increases to elevate circulation. Respiratory rate follows suit to aid in heat dispersion so long as ambient temperature does not exceed core temperature. Unabated, the 2.0 to 2.5 million eccrine (water-producing) sweat glands dump between 2 to 8 liters of water within 24 hours. Along with the water loss (if we're un-acclimatized), most of us give up 2 grams of sodium chloride with each liter of water lost. The good new is our bodies learn how to conserve these valuable electrolytes as acclimatization develops over time. So the need for replenishment of electrolytes actually diminishes in conditioned, 'seasoned' workers. [6, 7, 8]

Sweating is a great thermoregulatory tool when relative humidity is low, since we can dump up to 600 kcal of heat with each liter that vaporizes off of us. The trouble begins when humidity rises. No heat loss will result from sweat that simply drips off of us or saturates our clothes. The threshold of concern is when work environments exceed 87 degrees F (or 31 degrees C). Below this temperature, we can normally manage two-thirds of our heat loss needs through radiation and convection. We just give off heat. The last third of heat lost can be evaporated from our skins sweat and our lungs when we exhale. A small remaining amount of heat is let go through expelling our urine and waste. However, when our work environment exceeds 87 degrees F and approaches our skin temperature, the two-thirds of our heat loss through radiation and convection is markedly impeded. Evaporation is the last guardian standing between us and overheating. Evaporation cools the blood in the capillaries at the skins surface, which is reliant on the amount of body surface exposed to the air, the type of clothing worn, the relative humidity in the work environment and the rate of air passing over the exposed skin.

When our environment is hot AND humid, even moderate exertion can cause a rapid rise in body temperature. This can overwhelm our regulatory system. Heat stroke is more prevalent in older individuals with chronic disease. Older workers who are less able to adapt to high external temperatures can be at greater risk for heat exhaustion. Those with heat exhaustion will complain of weakness, headache, nausea, and vomiting followed by acute hypotension and collapse. They are generally depleted of salt and fluid due to prolonged sweating combined with a lack of proper fluid and salt intake. Fluid and electrolyte balance needs to be corrected in order to prevent or treat this condition.

Elevated workplace heat means a reduced thermal gradient between a workers skin, core and the surrounding atmosphere. Thus, there is a built-in resistance to heat dissipation. If that weren't bad enough, we know intuitively that heat can actually be gained when ambient temperature is greater than skin temperature. Factor in high relative humidity, and the barrier to heat loss is strengthened further as the evaporative vapor pressure gradient between the work environment and sweat on the skin is diminished. Combine these subsiding thermal and vapor pressure gradients in hot, humid work environs and increased load on a worker's circulatory, cardiac and sweating mechanisms result.

Skeletal muscles are like engines that generate heat. Just like any engine, that heat must be dispersed. If not, serious internal injury results. But high ambient heat combined with humidity leaves no where for the muscular heat to go. Guidelines for competitive exercise, industrial and military populations can be applied to work environments to help prevent damaging elevations in core temperature and control the effects of dehydration. [6, 7, 8]

Acclimatization

Our bodies can adapt to heat in high temperatures, up to a point. This was first discovered in our military, when gradual tolerance to hot environments meant work could be performed without the initial exhaustion first observed. Neural, hormonal and cardiovascular physiology can modify just as they do with physical training effect. Once acclimatized, less discomfort is reported. Pulse and respiratory rates don't rise as readily or as rapidly. Sudden postural changes (sitting-to-standing rapidly) and exertion are met with increasing cardiovascular stability (less 'faintness'). Both skin and core temperatures stay close to normal while sweating actually begins sooner and at lower temperatures after work exposure in heat. Sweat production increases along with cooling efficiency.

Opinions vary as to how long acclimatization takes, from anywhere between one week and two months, depending on the source cited. What is agreed upon is that the more physically conditioned the worker, the better their ability to adapt. Once acclimatization is achieved it can be easily sustained for weeks with just short periods of exposure. In as little as 6 weeks of exposure to exertion in the heat, our acclimatized worker can produce over twice the volume of sweat of an un-acclimatized coworker. When tested under high heat and humidity conditions, physically fit workers require less acclimatization time than unfit ones. For safety's sake, it makes sense to build work tolerance exposure in heat to that of the less fit workers, so as not to increase the likelihood of heat exposure syndromes.

Sweating is initiated in untrained and un-acclimatized workers at higher core temperatures, meaning their body-cooling evaporative response mechanism lags behind actual need. When the workforce is adequately trained and acclimatized, their sweat rate increases and onset of sweating occurs sooner (at lower core temperatures). Training in hot environments has been shown to produce between half and two-thirds the physiological adjustment attributable to heat acclimatization, so simple exposure to heat is not sufficient to influence the change [6, 7, 8, 9]

Human Hydrodynamic Physiology

About 60 % of body weight is water. About 70% of skeletal muscle is, too. This makes water the most critical of all nutrients for consistent worker performance. Even the most sedentary worker loses 2 to 2.5 liters of water a day through their skin, lungs, urine and waste. A conditioned athletic worker can lose that much in an hour in just sweat alone. If hydration is inadequate, a 2 – 3% (4-6 lbs in a 200 lb worker) loss in body weight can be expected, which will inevitably fatigue and adversely affect work performance and output.

Heat illness exposure is compounded by high humidity in hot work environments if exposure and exertion lasts longer than one hour. This is especially so for un-acclimatized or older workers. Those who are on blood pressure medications such as diuretics are especially vulnerable since balancing hydration becomes skewed toward fluid elimination. While water loss is of greatest concern, electrolyte loss should not be overlooked. Losses in sodium, potassium, chloride, magnesium and calcium are most frequently observed in un-acclimatized workers. Salt tablets are rarely used nowadays because if not carefully regulated, they can draw fluid into the intestine and away from the very skeletal muscle that needs it at the most crucial time. Water replacement is primary during extended physical activity, especially when exposure exceeds 90 minutes. At this point, electrolyte replacement is important as is some carbohydrate replacement. Hydration products containing glucose polymers (maltodextrins) are considered favorable due to their complex, long glucose chain structures, which mediate absorption over a longer period, thus delaying fatigue. [6, 7, 8, 9]

Finding an appropriate carbohydrate concentration can be a challenge. General non-glucose polymer concentrations are recommended not to exceed 2.5 percent. Glucose polymer concentrations shouldn't exceed 7 percent. Higher concentrations of either carbohydrate have been shown to impede adequate water absorption through the intestinal wall. The result of this poor absorption rate can be cramps, nausea and vomiting due to fluid shifting back into the intestine via osmosis, as the body tries to dilute a too high carbohydrate concentration. Sweat contains more water than salt so it is hypotonic to blood. This makes the interstitial fluid surrounding the cells within the body become hypertonic to each cell’s interior. The consequence is an attempt at maintaining osmotic equilibrium by drawing more water from each cell’s interior out into the interstitial fluid. Meanwhile, blood volume continues to diminish due to water lost as sweat. Higher concentrations of electrolytes remain in the blood. This high concentrate interferes with heart rhythm, precipitating ventricular fibrillation and eventual heart failure. Finally, sweating discontinues because blood volume has dropped to a critical level. Older workers who sweat without replacing water can experience a critical physiological threshold.

If high work exertion exposure with high heat and humidity exceeds an hour, then electrolyte replacement solutions are worthy of consideration. However, most prepared drinks are too sugary, which impedes their emptying from our stomachs, indirectly delaying their absorption. No more than 2.5 mg / 100 ml of sugar is recommended. That’s about 6 grams in an eight ounce cup or 12 grams in a pint. This is enough sugar and carbohydrate for the prevention of exhaustion for exposure that lasts longer than one hour. Under ideal conditions, we humans can survive without food for up to 2 months, yet we can only survive without water for about 2 weeks. Essential nutrients for living will only function in an aqueous environment, so it stands to reason that water is the most important single element in our diet. Recall that we need 2 liters (or quarts) of water each day for normal replenishment. Prolonged exertion in hot work conditions can cause 2 liters of fluid loss per hour.

A fit, athletic 200 lb worker who is exerting himself continually under hot environmental conditions can potentially lose 4 liters of fluid between breaks (say, 2 hours). This amount of fluid lost is approximately 8 pints, meaning 8 lbs of fluid could potentially be lost in just those two hours in a workday. This equates to a 4% loss in body weight from fluid in our 200 lb worker. This is a serious performance depleting and potentially life-threatening percentage of fluid lost. Here’s why: A 2 – 3% loss has been shown scientifically to cause performance decline. When a 4 – 5% loss in body weight is recorded, blood is now less capable of carrying nutrients to tissue, and its ability to remove heat from heat generating muscles and organs is compromised, so body heating is not mitigated. If the water loss isn’t replaced, a cascade ensues progressing from heat exhaustion, to potential heat stroke and even death. While key electrolytes like sodium, chloride, potassium and magnesium are lost through sweat, how much an individual needs to replace is difficult if not impossible to gauge. This is because needs vary within each individual from day-to-day and over whole populations. Plus, it’s all relative to a workers (or workforces) amount of acclimatization and physical conditioning. The interesting juxtaposition that flies in the face of the sports-drink industries advertising is that well-conditioned athletes actually give up fewer electrolytes through sweat than poorly conditioned ones. So the need for that sports-drink replenishment is actually diminished.

All this indicates we can make up most of our electrolyte demands with balanced meals. Diets rich in fruits and vegetables meet most if not all potassium needs for us. Our primarily important nutrient to replenish is and always has been simply, water. If any extra table salt is used for taste in our diets, copious amounts of water is recommended. If hydration through plain water replenishment isn’t heeded, sodium can be drawn from our body’s cells and dehydration can be exacerbated. As we’ve seen, it’s water loss that is of greater concern than electrolyte loss, which has been over played by a sports-drink industry bent on selling more product. It’s adequate hydration (through water) that prevents abnormal rises in body temperature. Just an average adult worker exerting his or herself in a neutral work environment will need to replenish around 2.5 liters of water each day. Realize this water comes from everything we consume, including our food.

Considering exertion demands of some jobs, even under ideal climatic conditions, a worker or workforce should be conscientious about consuming fluids before, during and after their shifts to ensure adequate hydration levels from day to day.

So, can't we rely on thirst tell us when to drink? The short answer is 'No'. Thirst is unreliable and often kicks in late, when up to 2 percent of body weight is already lost. For our 200 lb warehouse worker, that can be 4 lbs lost before they even realize they may be thirsty. Worse yet, our thirst response is satiated when only half of our bodies needs are met, leaving us dehydrated and no longer knowing it (again) ensuring that the inadequate hydration cycle will repeat itself, over and over. [6, 7, 8, 9]

The Role of Diet in Physiology:

Most of the water available to us comes from water in foods and the water freed from their metabolic breakdown. For instance, the reason fruits and vegetables are such a great choice for diet is because 90% of their composition is water. Plus, when our bodies break down our protein, carbohydrates and fats for energy, water is released for immediate use. For example carbohydrates are stored for later use in skeletal muscle in the form of glycogen. But it takes 3 grams of water to store 1 gram of glycogen, so this water is released in our bodies when the glycogen is broken down for energy use.

Regular old table salt (sodium and chloride) makes for the highest percentage of nutrients lost in our sweat. The other electrolytes include potassium, magnesium and calcium. The loss of electrolytes from urine actually diminishes during periods of strenuous exertion in an attempt to preserve them. In the case of potassium, a diet adequate in fruits (especially citrus) and vegetables will replace most lost potassium. Research shows that an adequate diet provides adequate electrolytes. Replacing these electrolytes during physical exertion has shown to be of little value since electrolyte concentrations actually increase in the body due to body water loss as sweat. Even marathon runners who eat an adequate diet and hydrate with water maintain adequate electrolyte balance. In truth, most of us in the U.S. consume somewhere between 3 and 5 times the amount of sodium we need per day in our highly salty, packaged and preserved North American diets. Even then, most of us sprinkle table salt on top of that (!). So making a case for us needing more salts through sports drinks is dicey, at best.

And the need for electrolyte replenishment swings wildly. Measures of electrolytes present in sweat can swing from lows to highs in multiples of 6 to 9 in their concentration. Most typically mixed diets provide the sodium, chloride and potassium to fulfill daily requirements, so deficiencies are unlikely even with the most profuse sweaters, provided they are conditioned.

To ensure hydration gains and sustainability, workers should be encouraged to avoid high-protein supplements, caffeinated beverages (and drugs), alcoholic beverages and anything else that elevates urine output. Adherence to this principle will help support maintained replenishment between shift days worked. And not to pick on sports-drinks again, but those containing high amounts of salt and sugar tend to delay their emptying from the stomach to the intestines, where fluid absorption actually takes place. Most agree water is the best fluid our workers can drink. Salt-laden, hypertonic sports-drinks are better avoided since their sodium content has been shown to actually aggravate dehydration in some cases. [6, 7, 8, 9, 10]

Human Connective Tissue Physiology

Fluid outside our body's cells (interstitial fluid) bathes these cells in an aqueous environment. Eighty percent is dedicated to maintaining this environment, while the remaining 20% of it is blood plasma which serves as a transport system for red and white blood cells. Oxygen, nutrients, wastes, and metabolic by-products are exchanged between the two as blood travels the capillaries of our body. Efficient exchange of these elements is reliant on near identical solute concentrations between the fluid inside and outside the cell walls (with the exception of proteins). The major molecular component of our bodies is water, about 60 percent of our body weight. Two thirds of that water is found within our cells (intracellular).

We generally classify connective tissues as muscle, tendon, ligament, cartilage and bone. They all have a common structural makeup of cells and an extra-cellular matrix. Cartilage, ligament and tendon have relatively few cells suspended in their matrix, so they have to rely on migratory cells for their repair. This slows healing when injury occurs. Conversely, muscle and bone have abundant reparative cells on hand, making for more readily rapid repair. What determines the form and function of these disparate tissues are the composition of their extra-cellular matrix, which is a bio-chemically active saline gel. Rich in important macromolecules, this bio-active, responsive gel matrix contains collagen, proteoglycans, elastin, fibrin, and hyaluronic acid. This matrix can coax cells to change their patterns of protein synthesis, in response to bearing loads and repetitive use. The most abundant macromolecule suspended in this matrix is the protein collagen, which is stiff, helical, and insoluble. Think of it as scaffolding that connective tissue relies on for structural support. It makes up to 90 percent of tendon, ligament and bone's dry weight. In fact, with increased mineralization, it can be thought of as the 'backbone' for bone, itself.

The second most abundant macromolecules to be found in our saline, extra-cellular matrix are proteoglycans, which are noted for their water-binding ability. They join with hyaluronic acid to form large molecular aggregates and they serve as electromagnetic sponges that give cartilage its visco-elastic capacity and it's resistance to compression. [6, 7, 8, 9, 10]

When Connective Tissue Ages:

Connective tissue needs a vascular supply to heal. Without it, inflammation (the first stage of healing) never happens. Some of the most troublesome areas of our bodies are so because of tenuous blood supply. The Achilles tendon and the rotator cuff come to mind. They are prone to intermittent blood support by factors such as excessive compression, torsion, traction, or postural impingement. The result is an accumulative deprivation of oxygen and nutrients, and this diminishment then leads to chronic, degenerative cellular change as a result of insufficient healing capacity.

Insufficient capacity to heal, combined with decreased basal function and tolerance due to aging, can detrimentally affect the connective tissue's ability to adapt and recover from environmental stressors. As collagen ages, it goes through a process called *maturational stabilization*, where molecular binding progresses by reducing any available cross-links still present in the tissue. A wavy, undulating structural property found in tendons and ligaments called 'crimp' which acts as a buffering shock absorber by allowing elongation is lost and along with it, a certain capacity to resist damage. Water content is also lost through aging and with it, so is additional resilience and tolerance to deformation. The end connective tissue product is less compliant and less resistant to tension, thus making it more vulnerable to injury.

The most consistent structural change seen in aging populations is degenerative joint disease (DJD), otherwise known as osteoarthritis (OA). It's the persistent wearing-away of the weight-bearing surfaces in our joints. The hard, hyaline (glass-like) cartilage wears away and the bone under the cartilage (subchondral) hardens. This results in a tell-tale narrowing of the joint space and a simultaneous spreading of bone growth outside of the joint margins to increase the weight-bearing surface. With the glassy hyaline cartilage gone, the joint surfaces are as rough as a poorly paved road. They produce a grinding sensation (called crepitus) and often produce aching pain. Overgrowth of bone at the joint margins combined with the pain of movement to impair range of motion. Reluctance to move and diminishment in activity, causes muscle weakness. The muscle weakness, pain with movement, diminished activity and poor range of motion decreases one's metabolism, which too often causes body weight gain. Excess weight puts even more demand on the denuded weight-bearing surfaces of the affected joints, and the situation not only perpetuates, it accelerates. Given that, aging workers should be advised on appropriate footwear for cushioning and stability during work. Sorbothane inserts, anti-fatigue matting and mobile, strap-on anti-fatigue cushioning is often recommended to mitigate trauma to weight-bearing joints. Optimal performance relies on optimal range of motion. Measurable reduction in skeletal flexibility is evident by the third decade in life. It can progress unabated without attention and effort to control or reverse this trend. Loss of flexibility in effect steadily reduces an individual's sphere of ability and activity. A productive life is sacrificed. Next a community life goes, until even self care within the home becomes problematic. All of this can be directly avoided or delayed with appropriate attention and commitment to an active lifestyle.

Mitigating Influences of Aging:

Our muscles have viscoelastic properties meaning changes in their length are proportional to the force applied to them. These properties allow the muscles to decrease or release tension within them at a given length. Knowing these principles, flexibility can be preserved and even restored with the application of stretching at low tension over longer duration or more frequent periods. Scientific literature suggests the effects of flexibility training is transient, thus it should be practiced daily to reap its benefits. Static stretching is considered superior since it involves slowly stretching muscle to the perceivable end of range (a pain-free 'tightness' sensation), then maintaining that positional stretch for 15-30 seconds. The literature shows little improvement after 30 seconds of tension. Repeating each stretch two to four times is considered adequate to achieve desired results, based on the literature. This keeps the time invested short and the need for assistance low, making a stretch break ideal for the work environment. Meanwhile, nothing is lost in the stretch efficacy. Instruction in stretching should emphasize performance in a slow, controlled and graduated manner, progressing to greater ranges over time with no particular 'goal' in mind, other than the experience of the stretching activity at the moment it is being performed. [6, 7, 8, 9, 10]

General guidelines for appropriate workforce stretching include:

- A warm-up to elevate muscle temperature is ideal. For example, marching in place for 2-3 minutes.
- Emphasize the tightest joints and work on the muscles involved in a static stretch format.
- Stretch to the sensation end-point of 'tightness' that is just short of discomfort. Stay in pain-free range.
- Attempt to perform the routine daily, but try not to fall below 2-3 times per week.
- Sustained each stretch for 15 – 30 seconds or 2-3 deep, slow, quiet, even breaths.
- Repeat each stretch 2 – 4 times when possible.

Human Heat Exposure Syndromes

Heat Cramps

While the precise mechanism of cramping is speculative, it is suggested that simple muscle fatigue, electrolyte imbalance and/or dehydration are suspect. The literature suggests the most effective management of cramping is through preventive measures such as a regular stretching program and adequate electrolyte intake during prolonged physical activity or heat exposure. Salt and water balance ensures proper muscle contraction and relaxation. Loss of both salt and water in muscle through excessive perspiration is considered a contributor to heat cramps. Imbalances in electrolyte are also suspected. Heat cramps from profuse perspiration occur most often at the start of warm weather season due to poor acclimatization. Workers complain of cramps in the legs, abdomen or arms. There is a lack of injury reported presently or in the past, however a history of heat cramps is often reported. Rest and assisted passive stretching are performed and a dilute sports drink may help symptoms pass. Prevention requires adequate pre-hydration, sustained hydration, and re-hydration along with graduated conditioning and exposure acclimatization to reduce incidence.

Heat Exhaustion

Sustained heat exposure can overwhelm cardiovascular reactivity and stress the circulatory system. Compensatory blood flow from deep organs to the skin may be inadequate to provide or sustain core cooling. Even fit workers can be overcome by excessive heat environments. Blood flow to muscles and the brain becomes inadequate as the skins demand for capillary filling for cooling increases in an attempt to radiate heat outward. When vascular response is inadequate to meet these conflicting demands, heat exhaustion develops. This situation is slow to progress and easy to overlook as it advances toward collapse of the peripheral vascular system and a ‘shock’ syndrome. Once its taken hold, it is then easy to spot. Shock-like symptoms include a worker complaining of weakness, dizziness, lost appetite, nausea or even an urge to void their bowels. They’ll outwardly show signs of pallor (paleness), sweating diffusely, vomiting or fainting.

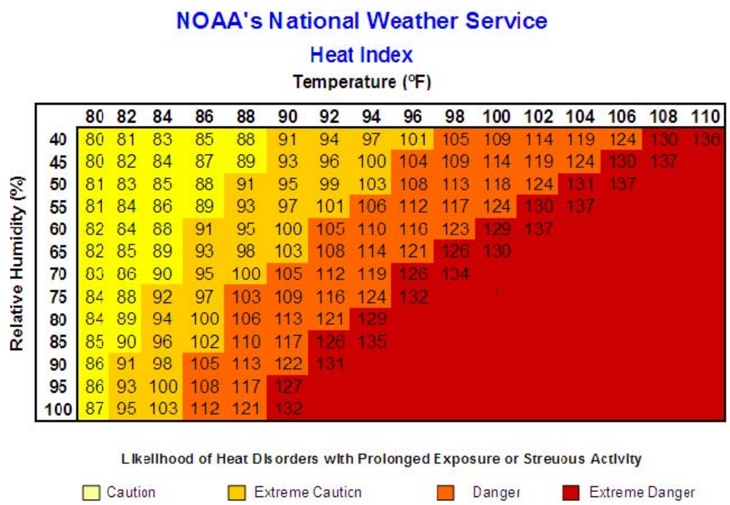
Heat exhaustion can result from either salt depletion or water depletion. Each type has unique characteristics. Generally, poorly conditioned or less acclimatized workers will be more apt to suffer from the salt depletion variety of heat exhaustion. Water depletion heat exhaustion is more often seen with well conditioned (even athletic) and well acclimatized workers. High heat and humidity conditions contribute to high fluid loss through sweating. Blood volume is consequently lost in this fluid draining process. A worker may appear ashen or even gray colored. If it is a poorly conditioned or un-acclimatized individual, their skin will feel cold and clammy to the touch. Suspect salt depletion in this case. If the worker appears otherwise, fit, well conditioned and acclimatized, the skin will feel hot and dry. This is a sign of water depletion and may advance to heat stroke if action isn’t immediate.

Don’t expect vital signs or even body temperature to be other than normal or below normal. A high concentration of blood electrolytes caused by the loss of water through sweating causes a hypertonic state. This is one of the reasons that salt tablet intake has fallen out of favor. Misjudging at this juncture can have dire consequences. Both varieties are potentially serious, but the water depletion (hot, dry skin) is emergent if it is allowed to progress. Immediate intervention is key. Replenishing electrolytes and fluid means this is actually a very good time to utilize sports drinks. Having the worker lie down in a cool room can also offset the affects of low blood volume shock. Rest reduces demands on the overtaxed circulatory system. An old adage for treating shock applies: “If the face is red, raise the head. If the face is pale, raise the tail (feet).” The situation is often reversed if proper attention is applied promptly. Knowing if the worker has contributing conditions such as cardiovascular disease or recent vomiting and/or diarrhea can help determine if additional treatment is necessary.

Paying special attention to poorly conditioned, un-acclimatized, or overeager workers, especially at the beginning of their exposure to high heat work environments is worth the extra effort. They cannot always be counted on to report symptoms of heat illness for fear of losing face or favor. The best practice is to screen all newer hires for any history of heat illness and advise those closest to them to watch for any signs of irregularity. They should not return to their work until all symptoms have disappeared and they are sufficiently well hydrated.

Heat Stroke

The most serious of all three is heat stroke. At this point, every mechanism to reduce core temperature has failed. Hyperpyrexia is the medical term used when core temperature exceeds 105 degrees F (40-41 degrees C). It's second only to head injuries as the cause of fatalities in football. It's problematic for distance runners in hot environments and wrestlers who dehydrate to 'make weight' [class]. It has a high mortality rate and is a true medical emergency. Worker death follows cellular death in the central nervous system. Even some survivors suffer permanent nerve damage. It can be predicted when prolonged, physical work is expected of a worker who is either poorly acclimatized or sweat cannot evaporate adequately (often high humidity and no moving air). The working muscles generate heat that overwhelms self-regulation. Initially, high rates of heat production becomes unsustainable for an indefinite or prolonged period. When sweat rate taps out (called anhidrosis), core temperatures spikes as evaporative-cooling stops. Each degree (F) of core temperature raised ups metabolism 7 percent and a progressive, self-supportive feedback loop is born. [6, 7, 8, 9, 10]


NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	126	130					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Streuous Activity

Caution Extreme Caution Danger Extreme Danger

Exhibit 5. NOAA's National Weather Service Heat Index - Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Remember, heat illness is cumulative. Heat stroke is most likely when ambient temperature exceeds 95 degrees F (35 degrees C) for a couple of days with humidity in the 50 – 75% range as demonstrated in Exhibit 5. The heat regulatory mechanism fails from exertion-related fluid loss. To protect the body from further dehydration, the central sweating response shuts down. Metabolic activity builds up even more core heat. Core body temperature rises. Meanwhile, the skin remains dry. Higher core temperatures create increased cellular metabolism in the central nervous system, generating even more heat until cellular damage occurs. [11]

A heat stroke candidate may be irritable, aggressive, or emotionally unstable to the point of hysteria. If vital signs can be taken at this stage, the pulse will be rapid and strong. These initial findings then progress to apathy, disorientation, or a failure to respond to questions. They may be characterized by a glassy stare or an unsteady gait. The final stage is characterized by hot, dry skin, collapse and unconsciousness. Tissue damaged by body heat causes vasomotor collapse and falling blood pressure accompany a rapid, but now weakening pulse. Emergency care to reduce body heat as rapidly as possible must be initiated. A target of below 100 degrees F (38 degrees C) is sought. Cool water soaks, cool wet sheets or compresses, fans to move maximal air and emergency evacuation to a hospital is imperative. Intravenous fluids may be initiated to treat for shock, but cooling the body is still the highest priority to limit cell death. Air conditioned surroundings help in minor cases. [6, 7, 11]

Aging Workforce Management

Obviously, climatic conditions affect exposure to the syndromes just outlined. Match up heat and humidity, and you've got the basic formula. This makes the work factors within our control so critical. Acclimatization must be gradual and work coaching should not be overlooked. Clothing color matters in outdoor work. When time-of-day can be addressed, it is worthy of consideration. Earlier start and quit times are effective. Night work is also a viable option in hot climates. Lastly, work intensity cannot be ignored.

To foster involvement from the workforce, best practices indicate that workers should be encouraged to weigh themselves at the time clock before and after their shifts to quantify accurately how much fluid needs to be replaced prior to the next shift worked. Workers proven to lose 3 percent of body weight or greater should be encouraged to hydrate frequently during their shift and to re-hydrate after their shift prior to working again. Free intake of fluid must be encouraged if not mandated, though never in large amounts at one time. Water should be replaced at rate of 'A-pint-A-Pound'…for every pound of body weight lost, a pint of water will be needed to replenish it to achieve normal hydration. Ten to twelve ounces every half hour can usually forestall water weight loss. Ideally, hydration should include taking in one pint of water about 3 hours prior to work, then a second pint one hour before work. Once onsite, weighing-in should be done at the time clock, with regular weigh-ins at break rooms, followed-by a weigh-out back at the time clock. This way, freely maintaining proper hydration can occur on the fly, as more frequent, smaller amounts of fluid are consumed over the course of the shift. Recording weight during very hot months is also a viable consideration. Research supports the fact that well-hydrated individuals achieve better physical conditioning faster than poorly hydrated people. Remember, since thirst is an unreliable indicator of sufficient fluid replacement, body-weight measurement (which mainly reflects water loss) is the easiest way to keep track of demands. Body weight taken at a scale located near time clocks, break rooms or bathrooms is useful to detect excessive water deficits. Keeping regular records over time can alert staff to progressive, day-to-day dehydration. Remember, a 3% deficit in water weight that is not made up by the following days shift could be cause for concern. This would be illustrated as a normally 200 lb worker showing up the next day weighing-in at 190 lbs.

The best hydration policy is to formally schedule frequent water breaks and to also encourage each worker to drink at their own discretion. Frequent drinking of small amounts is proven to be ideal. Drinks with high sugar contents (sodas, most sports drinks, juices) significantly retard appropriate voiding from the stomach, making dissipation to tissues inefficient. The ideal drink should have no more than 2.5% sugars (approximately 6 g / 8 oz serving, or 9 g / 12 oz serving) (Costill and Saltin). This is especially significant in exposures to heat and exertion lasting greater than one hour as the lagging absorption rate could result in greater hydration deficits. If workforce members insist on high sugar drinks, attempt to encourage a 2-to-1 ratio of water to the drink. For instance, ask them to consume 24 oz of water for each 12 oz sugar drink they consume. This is far from optimal, but it may improve absorption rates by improved emptying from the stomach. We can tolerate small amounts of sugars in drinks for replenishment, since they can prolong exertion by staving-off and thus sparing glycogen use. But if the concentration of glucose (sugars) is too high, the fluid itself will impede its own absorption by reducing gastric emptying into the intestine, where fluid transfer takes place. Following an industrial athlete model, a fluid and electrolyte replacement recommendation should look like:

Before exertion in high heat/humidity work environments:

- Record body weight.
- Drink 2-3 cups of water 1 to 2 hours preceding the shift or heat exposure.

During work in hot/humid environments:

- Record body weight during breaks to monitor loss.
- Drink .5 to 1.5 cups of cool (absorbs faster) water every 15-20 minutes, thirsty or not.
- If cramps occur, employ sports drinks in lieu of water or add 1/3 tsp salt per liter of water.

After the work or the shift is complete:

- Record body weight and compare to beginning of shift.
- Drink 2 cups of water (16 oz) for every pound lost. [6, 7, 8, 9, 10]

Work Force Management Recommendations

1. Acclimatize your workforce . Build exposure to the heat up gradually shifting the ratio of rest toward greater exposure and exertion in a graded manner. Especially focus on new hires.
2. Consider keeping a scale by the time clock and break rooms. Recommend work force weigh themselves when they clock-in, at each break, and at clock-out. Clock-in weight minus the most recent reading equals weight lost to sweating. This is the amount of fluid needed to be replaced, and…
3. Consider documenting weight loss with weight charts at weigh-ins and re-hydrate at a rate of 2 cups of water/fluid to each pound of weight lost.
4. Encourage adherence to a pre-shift hydration plan, a shift-long hydration plan, and a post-shift hydration plan. The ‘plan’ simply recommends frequently drinking small amounts of water/fluid before, during and after shift work.
5. Consider encouraging a two parts water, to one part sport drink ratio. For instance, each 12 oz bottle of sports drink should be followed with two 12 oz bottles of water. Should fluid loss demand it, the cycle can repeat itself over the course of the entire shift, taking care to ingest small amounts frequently.
6. Recommend work force monitors urine color and clarity during bathroom breaks, striving for clear, non-colored urine output before the shift, throughout the shift and after the shift.
7. Consider purchasing a portable weather station for the worksite or rely on web pages and update staff on plant-wide communication (email, web page, public address, newsletter, etc.) during especially high heat index days (temp x relative humidity).
8. If uniforms are used, consider seasonal changes to lighter density, breathable fabrics that can ‘throw-off’ head allowing for appropriate exposure when applicable. If street clothes are the norm, encourage the same principles so long that dress-code requirements are encouraged.

9. Educate work force on heat illness danger signs and encourage self-responsibility to avoid trouble before it starts. Encourage reporting of muscle cramps, fatigue, coordination loss or light-headedness to supervisors without fear of reprisal.
10. Develop an emergency action plan for heat related illness conditions. Practice Emergency Responder protocols to ensure rapid response should the need arise.

Implementing these measures in a structured way, combined with consistent stretch breaks using appropriate breath sequencing will foster positive nutrient transfer while maintaining viscoelastic connective tissue properties in aging tissues. This avoids several potential problems in a simple, consistent exposure management system. Heat-related emergencies will be avoided. Age-related musculoskeletal disorders will be forestalled. An aging workforce can remain confident it will be able to prolong productive lifestyles for years to come. And informed, engaged safety professionals can be confident that every action was taken to keep the workforce and business operations protected well into the future.

Endnotes

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