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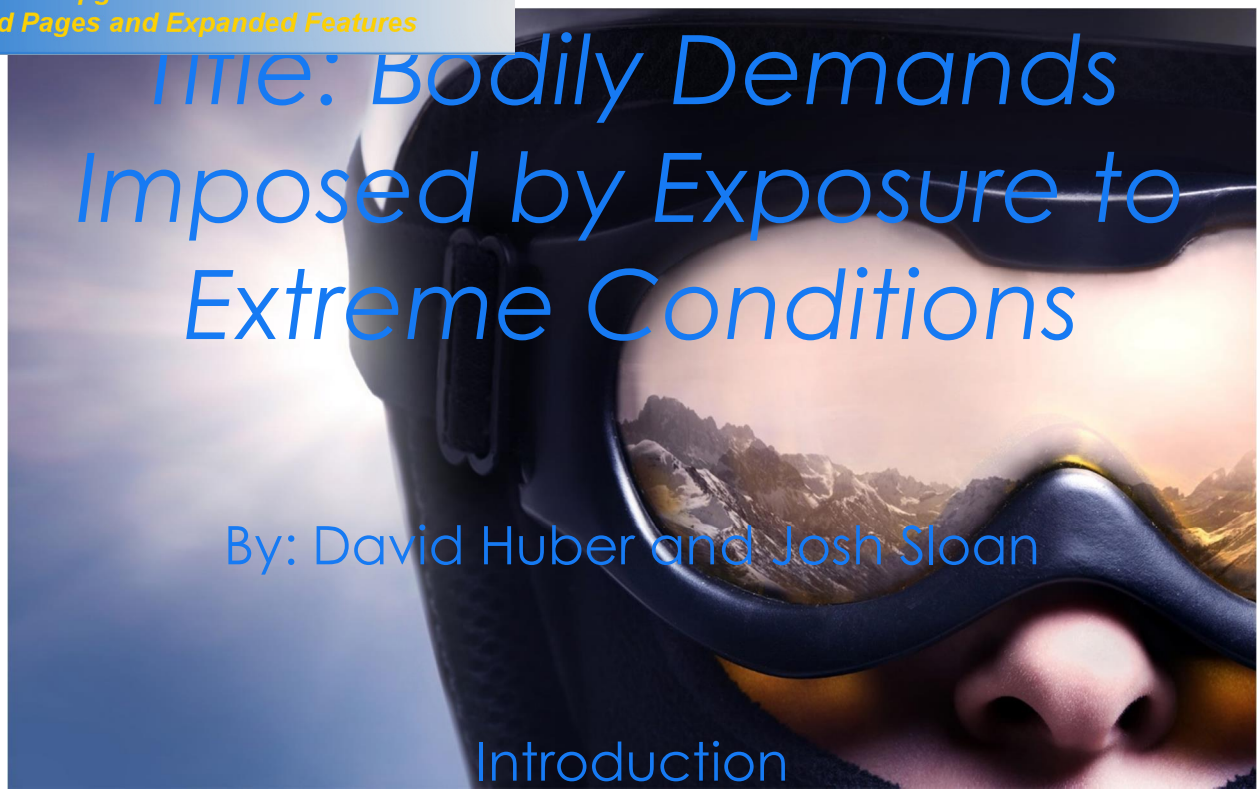

Title: Bodily Demands Imposed by Exposure to Extreme Conditions

By: David Huber and Josh Sloan

Introduction

On the adventurous person's bucket list is the task of climbing a mountain. Why? Successfully climbing a mountain is an accomplishment that is generally accepted as reserved to only those whom are physically fit. If the exercise alone was the accomplishment, why isn't performing a million steps on a Stair Master popular on bucket lists? There is a key characteristic that separates climbing a mountain from other exercises, and that is exposure. Exposure comes in many forms: heat, cold, wind, altitude, precipitation, and humidity. Exposure during exercise places more demand on the body in order to maintain homeostasis. This higher demand makes exercise harder. Climbing a mountain makes the bucket list because it provides an environment that exposes the body to many conditions that further challenge the adventurer. This chapter identifies what these conditions may be and explains how they impact exercise. Then, this chapter identifies ways to limit degradation of performance.

Altitude

As a person climbs a mountain during journey the air gets thinner as the elevation increases. This is important to be aware of because altitude provides an additional physiological challenge when winter camping. Two studies on altitude describe the process the digestive system goes through when digesting

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e impairment of performance and low oxygen cheson, Decombaz, Fern, Cerretelli, 1992) determined that high altitude can lead to malnutrition because of the body's inability to adapt. (*Martin, Levett, Grocott, and Montgomery, 2010*) looked at the changes in performance in people not native to high elevations. This is due to the body trying to adjust to the oxygen level. Certain body function such as ventilation, cardiac function, hemoglobin levels, muscle metabolism, and VO2 max are effected and must adjust to maintain proper survival conditions. Knowing how to prepare for these adjustments is important to know when journeying into high altitude locations. Changes of diet, energy expenditure, and other adjustments may need to be made in order to promote healthy survival while hiking or camping in a mountainous area. The following sections make suggestions for adjustments in further detail.

Exercise in the Cold

The previous section of this chapter touched on the ways the cold temperature impacts a person's energy expenditure. This section will further explore the process the body goes through while exercising in the cold. There are many research articles that look at certain aspects that the cold induces during exercise. These articles introduce topics such as, nutrient metabolism, muscle glycogen levels, protein synthesis, sodium concentration, and immune function. The articles also touch on the intensity of the exercise and how it effects the body's ability to adjust. There is even evidence supporting an advantage of using a walking stick while bearing weight when hiking in strenuous conditions. The idea of all the research journals in this section is to get a general understanding of what the body goes through during exercise. All of this will be explained in this section.

Nutrient metabolism is supplying the body and being able to use those nutrients in order to gain the highest performance in cold conditions. This can be seen in the metabolism of fats and carbohydrates. *Exercise in the cold* and *Cold exposure and exercise metabolism* looked into the

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olize energy and work at a high level. These f exercise, energy cost, amount of clothing, shivering, hormone adaptations, and fluid cycles (Adams, Jett, and Stamford, 2006). During exercise in the cold, research has shown that the body needs to work harder to complete the same intensity of exercise than in higher temperatures (See Energy Expenditure section). Not only that, but this nutrient metabolism is dependent upon the duration of being exposed to the cold both during rest and exercise. Thermoregulation also plays in a part in the efficiency of exercise and the energy expended. As (Adams, Jett, and Stamford, 2006) states, insulation and clothing are another important factor when determining the effects of exercise. These elements give a good overall picture of the things that the body needs to adjust to in order maintain homeostasis in the cold.

Muscle Glycogen and protein synthesis are discussed in *Effects of post-exercise recovery in a cold environment on muscle glycogen, PGC-1alpha, and downstream transcription factors* and *Protein turnover rates of two human subjects during an unassisted crossing of Antarctica*. These studies showed that the recovery from exercise is different for the body in colder environments in their respective areas. Cold temperatures were believed to have an effect on nuclear respiratory factor 1 (NRF1), nuclear respiratory factor 2 (NRF2), and mitochondrial transcription factor A (Tfam) which are transcription factors on mRNA (*Slivka, Heesch, Dumke, Cuddy, Hailes, Ruby, 2013*). The results of the study were that "ERRa and NRF2 mRNA transcription were reduced with cold exposure and NRF1 and TFAM were unaffected." This means that cold environments could actually hinder the production of the mitochondria. The research about protein synthesis followed two men on a journey across Antartica. The men were on a strict diet and yet due to the amount of energy exertion, lost weight. However, even though there was weight loss, illness, and unfavorable circumstances, the study showed that there was still a sustainable amount of protein synthesis during the trip (*Stroud, Jackson, Waterlow, 1996)*. Even with these results from the studies, adjustments can be made to diet and energy intake in order to maintain homeostasis in cold environments.

The articles, *Hyponatremia in a cold weather ultraendurance race* and *Change in serum sodium concentration during a cold weather ultradistance*

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s during extreme endurance races exposed to sured the weight, body fat, and urine concentrations of the long distant runners. The results of both of the studies showed that too much water or not enough sodium was an issue. This resulted in the runners, more often than not, suffering from hyponatremia after the race. The purpose of the research is to understand and find a healthy balance between salt and water consumption during cold temperature exercise.

The immune function research is a study about saliva and bicyclists in cold weather. The study, *Salivary IgA response to prolonged exercise in a cold environment in trained cyclists* looked into amount of immunoglobulin A (IgA) that the body produces in the saliva during and after exercise. IgA helps protect the lungs from respiratory tract infections. There are theories that exercising in the cold may bring illness. The results of the study showed that exercise in the cold may not have as much effect on illness as previously thought because the levels of IgA were not drastically effected.

Finally, there is research that supports the use of a walking stick that helps support the strenuous exercise of hiking. The claim is that using a walking stick helps with balance while hiking and bearing weight (Jacobson, Caldwell, Kulling, 1997). The study said that using two walking sticks is the most beneficial. Since the body does not have to focus as much on balancing over the rough terrain, the body works more efficiently and can safe need energy for later in the journey.

Thermoregulation

Heat regulation is a vital component to maintaining homeostasis. If body temperature drops below 95 degrees Fahrenheit, hypothermia ensues. That is only 3.6 degrees lower than resting body temperature. Hypothermia causes organ, muscle, and nervous system dysfunction and can lead to death. Exposure to a variety of conditions may hinder thermoregulation and propagate hypothermia. Exercise itself is thought of as one of these conditions (*Castellani et al*, 2001). A study performed on 13 men was used to validate this notion by exposing them to five degree Celsius temperatures for six hours after having their clothes saturated with water. This happened for 8 days. The last seven days for experimental groups (10 of the 13 individuals) involved four hours of various

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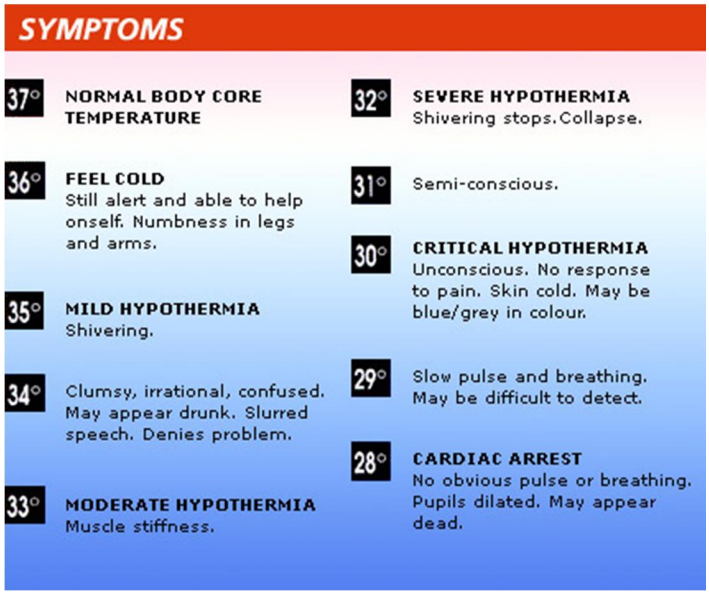
of 70% repetition max weight lifting, four 20 cling, and treadmill) prior to the exposure duration. On two of the experiment days, an additional bout of exercise was added pre-exposure. Temperature change ratios as well as maximum temperatures were taken both rectally and dermally. The test subjects made to exercise showed a faster drop in internal temperature and a decrease in venous ability for constriction which suggests that the body is undergoing thermoregulatory fatigue(*Castellani et al, 2001)*. This means that the body can no longer properly control temperature. Later, (*Castellani et al, 2003)* conducted an experiment on 10 U.S. Army Rangers (fit, mid-twenty year old males). The subjects were made to carry out eighty-four hours of operations where exertional fatigue, sleep deprivation, and energy deficits create a high stressor environment. Post operations, the subjects were subsequently exposed to 10 degree Celsius temperatures for 2.5 hours. Subjects wore minimal clothing and were made to sit and perform minimal action. This cold air test was preformed again after a week of rest as a control. Blood samples were taken before, during, and after exposure and examined for plasma glucose and norepinephrine content. Metabolic heat production was calculated with the plasma glucose and used as an indirect measurement of shiver response. The control trial was shown to have an earlier metabolic response (induced at a higher core temperature) to the environmental stimuli, suggesting that the shivering response to cold is blunted temporally in fatigued individuals. The experimental trial also had a much stronger metabolic response nearing the end of the trial (at 2.5 hours), which could be the bodies attempt to maintain core temperature at



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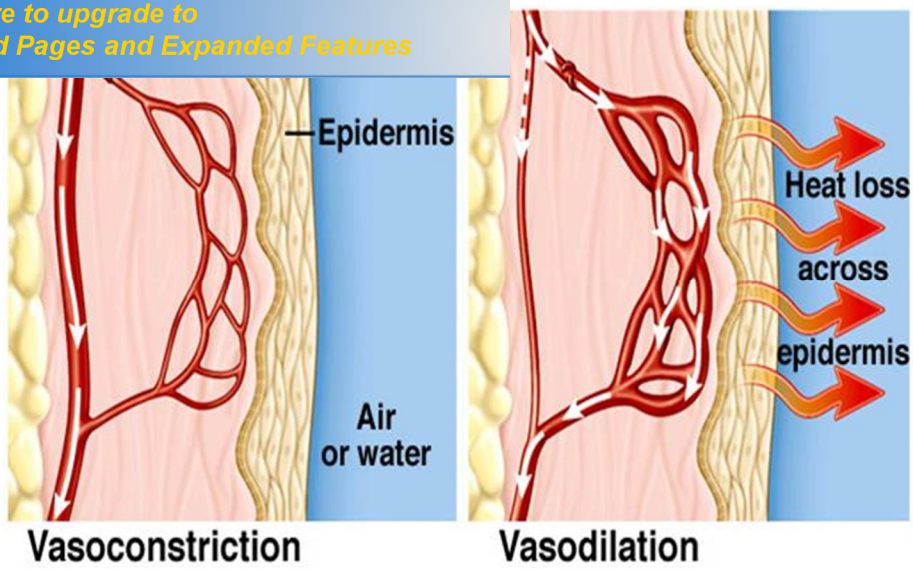

homeostasis. Mean skin temperature was used to assess vasoconstriction. Skin response was higher in the experimental trial which is believed to have been due to a higher temperature gradient early on between core and superficial tissue (*Castellani et al*, 2003). What does this mean? Vasoconstriction cuts off blood, nutrients, and heat from distal appendages in an attempt to conserve core temperature. In doing so, it causes the peripheral tissue to lose function and, in extreme conditions, can cause cellular death or necrosis. This study suggests that fatigued individuals homeostatic response might work contour to its normal response initially. This might happen because either fatigued individuals have a dysfunctional thermoregulatory response or because they dissipate heat faster in superficial tissue, which their body counteracts.

Another study used nine male subjects in their mid-twenties and of average height/weight/body fat to give evidence that dehydration can lead to vasoconstriction (*O'Brien, C., Young, A. J., & Sawka, M. N.*, 1998). Each subject was induced to three conditions over a 5 week period (hypohydration, euhydration, and hyperhydration) via diet and exercise adherence. After obtaining each individual state, the subject was exposed to a 7 degree Celsius environment for two hours. Subjects showed no variance in core temperature drop across all three trials (approximately .3 C). Through indirect measurement (body weight, caloric expenditure, O2 uptake, blood sample analysis, and urine analysis), this study inferred that vasoconstriction rate was higher for subjects during the dehydration phase as was caloric expenditure. The authors of this study hypothesize that if the study were done at lower temperatures or over a longer period of time, there would be a significant decline in core temperature sooner for those that are in a hypohydrated state.

Exercise, dehydration, low temperatures, precipitation, sleep deprivation, and a negative energy balance are all things you have the chance of experiencing as a winter athlete, whether you are skiing for a day or are

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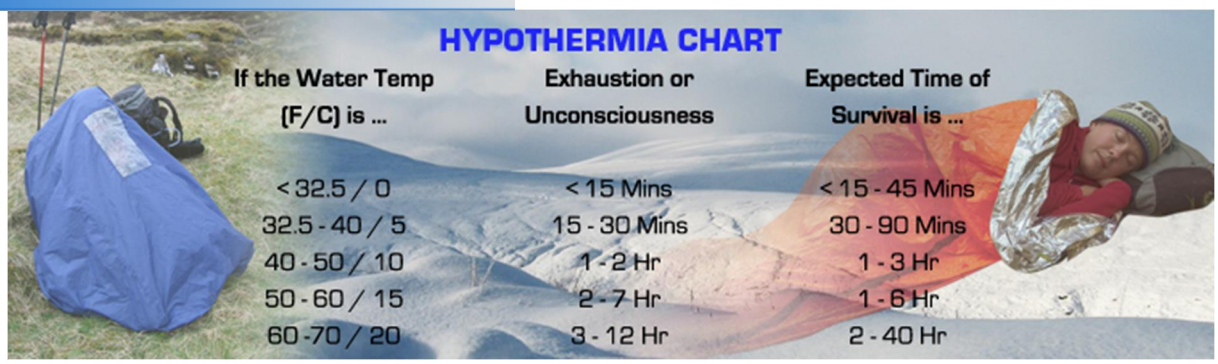
These conditions can affect thermoregulation,



Energy Expenditure

With every activity whether someone is going snowboarding or hiking/camping during the winter, there is always a maximum quantity of goods that can be brought along. This becomes an important facet to planning an activity when talking about nutrition. Packing the right kind of food and enough of it can affect performance and well-being. One study looked at diets altering carbohydrate intake coupled with exercise in cold and hot weather to figure out if diet effects performance and if temperature effects use (*Pitsiladis, Y. P., & Maughan, R. J.,*1999). The subject pool was 6 cyclists. The two diets were a low(10% of intake) and a high (80% of intake) carbohydrate intake. The two temperatures that were used for testing were ten and thirty degrees Celsius. Each trial lasted 8 days: day one-bike until exhaustion, day two and three- rest, day four- consume one of the above diets and perform a 70%VO2 max biking session in one of the above temperatures, days five through eight- repeat days one through four with the other diet. With the examination of oxygen uptake and blood metabolite concentration, this study found that carbohydrate oxidation was higher for trials with a high carbohydrate diet regardless of temperature. What is interesting though is that the trial of high carb and low temp showed the metabolic use of over twice the amount of any other trial. What could be both a cause and effect to this was "time until exhaustion". During the high carb high temperature trial, subjects reached exhaustion between two and three times quicker than the high carbohydrate low temperature trial. This suggests that the higher temperatures prevented the athletes from exercising long enough to deplete their glycogen stores. On the contrary, it seemed that athletes were able to perform exercise for the full duration required to deplete glycogen stores when exercising at ten degrees

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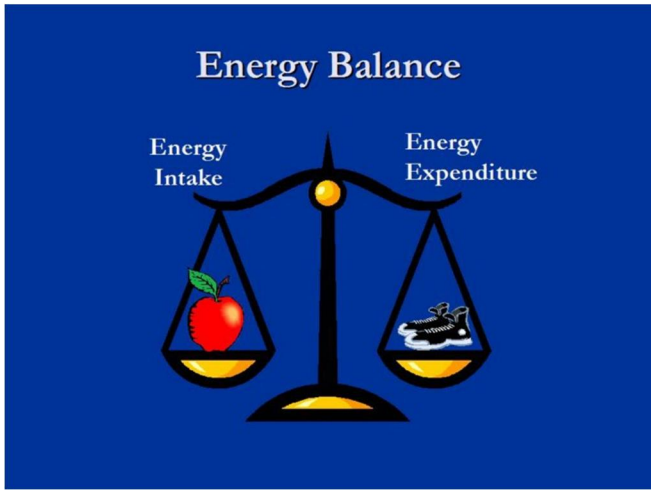
y to high carbohydrate diets, on average, re increase in performance time. That is almost twice the time until exhaustion. This seems to indicate that available carbohydrate (glycogen storage) is the limiting factor on performance while cycling at ten degrees Celsius (*Pitsiladis, Y. P., & Maughan, R. J.,* 1999). That the human body is able to perform more prolonged exercise and deplete energy stores more completely while in the cold before the onset of fatigue should be taken into consideration by winter athletes. Glycogen stores need to be replaced by carbohydrate adequately, which might be hindered if the athlete gauges energy use with perceived exertion because it takes longer to become fatigued the colder it is. Another factor to take in to consideration regarding energy store replenishment is how much a decrease in temperature effects basic metabolism in the human body. A study published in the *British Journal of Nutrition* (*Dauncey, M.,*1981) looked at the difference in energy expenditure between subjects in a twenty-two and twenty-eighty degree environment. Just a six degree drop in temperature showed significant results. Nine women with the average age of thirty-four spent sixty hours in a whole body calorimeter- thirty hours at twenty-two degrees Celsius and thirty hours at twenty-eight degrees. These two sessions were spaced a month apart. The order of sessions was reversed for half the group. Subjects were allowed to perform routine daily actions in the whole body calorimeter to simulate everyday life. Ambient temp, resting metabolism, and energy expenditure were calculated for every trial, day and night. The results of this study showed a seven percent increase in heat production at the lower temperature as well as a six percent increase in heat loss (*Dauncey, M.*,1981). While this may seem like an insignificant difference in energy expenditure, it must be taken in to consideration that the temperature difference was minimal. Temperatures experienced during winter sports and activities are considerably lower than twenty-two degrees Celsius (71.6 F). Caloric expenditure may greatly increase with decreases in temperature.



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e energy input and output was able to be ecific mountaineering expedition. This makes for a great example of the rigors involved in long winter sport events/endeavors. It was as follows: four male British soldiers spent six weeks traveling through the Alaskan mountains. Over this time period, the group had to transport one thousand pounds of equipment across twenty miles of terrain and travel approximately six thousand feet vertically (from an elevation of 5,000-6,000feet to an elevation of 11,000-13,000ft). the average temperature during bouts of exercise was twenty three degrees Fahrenheit. Average caloric intake Varied from 3500-4000 calories depending on the individual. Average fluid consumption per day was four pints. Vitamin/mineral supplements were provided and rationed for the party. In a given day, average time spent performing major physical exercise, minor physical exercise, and resting was 5.5,10.25, and 8.25 hours respectively. Between the beginning and end of the expedition weight change was not significant (*Kinloch, J.*, 1959). This suggest that energy input and output remained relatively balanced throughout the expedition. The average weight of the party members was 70 kg with an average age of 27 and average height of 177cm. Using the BMR formula for men [66 + (13.7 x weight in kilos) + (5 x height in cm) - (6.8 x age in years)] and the Harris-Benedict Formula, mountaineering has an activity factor of 2.2. This is the equivalent of being extremely active every day for the entire six week trip and is above almost every other exercise. It seems logical to suspect that the cold temperature (alongside other environmental factors) is what increased the strenuousness of the expedition. A concurring study looked at energy requirements of military personnel (*Tharion, W. J., Lieberman, H. R., Montain, S. J., Young, A. J., Baker-Fulco, C. J., DeLany, J. P., & Hoyt, R. W.*, 2005).

This study looked into the nutrition and energy requirements of the military. The majority of the study was based on men. However, there were women involve in the study as well. The study researched different environments the military men and women were in and the types of energy exertion they were under. The outcomes were different for men then for women. The study supported that energy requirement were higher during combat or training situations. The study stated that "compared to temperate conditions, total energy expenditures did not appear to be influenced by hot weather, but

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or high altitude conditions." Both U.S. and
increase in energy expenditure when comparing across desert and temperate climates. Even higher energy expenditures were observed when two Norwegian SEALS crossed the Arctic Ocean over the North Pole (*Tharion, W. J., Lieberman, H. R., Montain, S. J., Young, A. J., Baker-Fulco, C. J., DeLany, J. P., & Hoyt, R. W.*, 2005). This means that cold weather demands more out of the body then in average or hot climate conditions.

Dietary Preparation

Dietary preparation explores the need to consume adequate nutrition with the knowledge of going into a situation that makes it more difficult for the body to maintain homeostasis. The research shows that the body needs certain nutrients to be increased during exposure to the cold, elevation, or a combination of both. Each article researches using primarily sports and exercise in adverse environments. *Nutritional strategies for football: counteracting heat, cold, high altitude, and jet lag* and *Nutrition for winter sports* discusses different ways that coaches can prepare for adverse game locations by altering the athlete's diet. This can be translated to exercise rather than sports. The exercise intensity is the important factor. Whether camping or playing sports, the human body will adjust the same if the intensity of exercise is the same. While exposed to extreme and adverse conditions, it is important to plan as best as possible for the changes in diet the body will need in order to survive and be healthy. Now that there is a better understanding of what cold temperatures and exercise can do to the body, there are foods that would be a solid choice for these circumstances. A proper meal according to (Kinloch, 1959) might look like this:

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ry ration from a 2 × 8 man-day standard ration pack ation pack and (B) extra luxury items for the whole expedition

A (all values in oz.)

	Type A	Type B	Type C	Type D	Emergency ration
Pemmican	2	—	—	—	—
Corned beef	—	3	—	—	—
Stewed steak	—	—	4	—	—
Luncheon meat	—	—	—	2	—
Sardines	1⅛	—	—	1⅛	—
Cheese	—	2	2	—	—
Porridge oats	3	—	3	3	1½
Grapenuts	—	1¼	—	—	—
Nut pemmican	—	—	—	—	2
Soup	—	—	—	—	½
Mint cake (Kendal)	—	—	—	—	2
Cake (fruit)	2	—	—	2	—
Steamed pudding	—	2½	2½	—	—
Glucose tablets (Horlick's Energade)	—	—	—	—	¾
Orangeade powder (Army)	—	—	—	—	2
Sugar	4				4
Condensed milk	1⅛				—
Tea	¼				—
Butter	1⅞				—
Biscuits (Army)	3				—
Biscuits (sweet)	2				—
Chocolate	4				2
Sweets	2				—
Fudge (Horlick's)	—				2

B (except soup, all values in lb.; total weight 60 lb.)

Soup	16 (packets)	Preserves (various)	2
Meat bars	1½	Fudge	2
Dried vegetable	1	Sugar	2
Dried potato	4	Vita-Wheat	8
Baked beans	4	Beverages (various)	6
Rice	2	Tablets (Horlick's and Ovaltine)	4
Nut pemmican	3	Peanut butter	2
Dried fruit	6	W.D. butter concentrate	3
Tinned fruit	6	Salt	2

This is the food inventory list from the excursion this group did while mountain climbing in Alaska. The list of food is from 1959 but it provides a good idea of the types of food that can be taken on such a trip.

Nutrition is not the only factor that must be taken into account when partaking on an excursion such as hiking and camping in extreme conditions of mountainous areas. The other factor that must be accounted for is the amount of food that can be brought. A camper can only bring the food that they can carry. This is why many times meals must be light weight and dried or preserved in order to make it on the journey. This most of the time means that meals may not be quite as balanced as they normally might be. Food could also be provided by hunting, fishing, or gathering. This should not be relied upon since during a cold season food in the wilderness may be scarce. It would be better to bring the food that is necessary rather than not and be caught unprepared.

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Conclusion

No matter what hobby you choose to pursue as a winter athlete, there are many things you can do to make sure you remain safe and healthy throughout the experience. For these activities, wearing insulated clothing that protects your skin from wind and keeps out the cold and wetness is always a must to prevent hypothermia. Keeping adequate fluids around is also important to prevent dehydration from the dry atmosphere and from physical exertion. Always have enough food close by to replace the calories you burn. It is always a good idea to have extra high energy foods, extra water, and heat packs just in case of an emergency. For activities that last less than a day, restoring your electrolytes with beverages that have sodium, potassium, and calcium can help with performance. Regulating your vitamins and minerals isn't an immediate concern to a single day sport but should be taken into consideration for routine exercise and for long term health. When going on multiple day excursions, packing efficiently becomes more important. Take in to account how many calories you will be burning a day and pack more than you need just in case. If you feel like you have too much food to carry, consider more calorie dense foods such as fats. Here, vitamin and mineral supplements become a viable option to cut pack weight while maintaining healthy requirements. Be sure to track how much of each nutrient you are getting and attempt to ingest close to your daily value instead of overdosing. Between your fluid, food, heating, and insulating supplies, your load can get quite heavy depending on how long you plan on being out and what you intend to be doing. There are many ways to help manage this load, whether it is buying an ergonomically efficient backpack (better weight displacement and back support) or using a walking stick or a sled.

Every achievement, including climbing a mountain, can be accomplished as long as you do it in a safe and effective way. Take every environmental condition in to consideration during your planning phase because they affect your body as much as the exercise alone does (if not more). Winter sports are a great way to stay in shape and enjoy the outdoors as long as you do not forget that they can quickly become hazardous or even life threatening.

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