HORMONES AND COLD: INTEGRATION OF ENDOCRINOLOGY, MORPHOLOGY, PHYSIOLOGY AND BEHAVIOUR

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Summary

Humans are originally Africans. They are naked and need clothing and buildings to survive in cold conditions as their own body structure and ability to produce heat is limited to cover the loss due to dissipation of the heat. Heat is produced in cold environments by muscles. All their contractions release heat. The muscles start shivering in cold. In addition to that hormones activate metabolism. The latter is also called non-shivering or chemical thermogenesis. It includes mainly thyroid hormones and catecholamines. In adult subjects short-term cold exposures do not activate the thyroid gland but long-term cold exposures lead to increased production and consumption of thyroid hormones. This results in decreased blood levels of thyroid hormones. In newborn babies short-term cold exposure stimulates the pituitary and thyroid gland. Thyroid hormones stimulate many chemical reactions resulting in increased heat production. Cold exposures always lead to release of noradrenalin from the nerve endings of the sympathetic nerve system. Noradrenalin induces the release of free fatty acids, mostly from the brown adipose tissue. Fatty acids serve as energy substrates and interfere with mitochondrial hydrogen ion influx. This produces more heat at the expense of mitochondrial ATP. Brown adipose tissue has rich sympathetic innervation and blood circulation. There is more brown adipose tissue in subjects exposed to work in cold than in sedentary ones and in full term babies that in premature

ones. If the cold exposure causes a frost bite in the peripheral parts of the body, they can be as dangerous as burns.

1. Introduction

Humans are tropical. They have no fur and hair has poor capacity to bind air. Animals having fur (like polar bears and reindeer) or plumage (like owls and ptarmigans) can save warm air around their bodies and survive even in arctic climates. Dry air is an excellent insulator. Water is poor insulator as also wet air. Sea mammals (like seals) have thick lipid layers (see also *General Comparative Physiology*). This helps to maintain the thermal balance even in icy water.

Some humans may have big stores of subcutaneous fat, but the form of human body is such that the dissipation of the heat is always relatively high (Figure 1). The whole body of seals is oval e.g. every different from ours. Some swans can get fixed by their legs in ice, when they sleep in freezing temperatures, but they can completely recover if helped to get free.

Figure 1. Reindeer herd and a Saame working on one animal. Reindeers survive through out the year and find their feed even under snow. The fur provides them proper insulation. Saame people have traditionally received good part of their feed from reindeer and they have used also the skin of the animal in their clothing and shoes. In former times snow used to insulate the Saame accommodation. Their kammis made out of turf were covered by snow in winters. Still now if a storm suddenly erupts, it is best to hind under the snow as the animals do and let the wind to play. Snow contains a lot of insulating air and it keeps the wind away. (Photo provided by Dr. Mauri Nieminen)

The temperatures at which naked humans feel thermal comfort are as high as 25 – 27 º C (see also *Thermoregulation*). The thermal comfort zone is somewhat lower in women, since they carry under their skin more insulating fat than men. This unexpectedly high thermal comfort zone may associate with the development of human species. Most archeological findings demonstrate that the origins of human species are tropical climates, especially in Africa.

Why tropical humans are able to live practically in all the places on earth, in high mountains as well as in Polar Regions, even in the space close to the absolute zero temperature?

Part of the answer is highly developed housing and clothing. They help to keep warm air around the body and break the wind. The technology of the modern times makes live practically easy about where-ever, but the inhabitation of cold arctic areas long before our time needs an explanation.

Ancient humans have used caves, structures build with animal skins, turf and timber as well as even snow as their shelter. Snow is a good insulating material in addition that it breaks the wind.

Humans have used also animal skins as their clothing before they learned to prepare textiles from wool and natural plant fibers. At present artificial fibers are synthesized, which have properties responding to the variations of environmental temperatures by increasing or decreasing the insulation (i.e. capturing various amounts of air and permitting variable amount of ventilation).

The main emphasis of the present review is how humans successfully meet the cold environment as a tropical species. The high temperatures (like in saunas) can be effectively managed with the help of sweating which is very powerful way to dissipate the heat (see also *Thermoregulation)*. Another reason to give main emphasis on cold is the fact that even in equatorial zones the nights are cold especially in high altitudes. Wind increases the coldness of air everywhere. Snow storms are not unknown in temperate zones. Traffic jams and accidents may expose many people to conditions which may cause freezing. Actually many people annually die even nowadays in such situations. Especially elderly people can die due to cold without any accident, when their housing gets cold due to lacking or insufficient heating even in western well-off societies and cities.

2. Why did a tropical man move to cold climate areas?

Arctic oceans are large reservoirs of biomass. During constant light in spring and summer those oceans produce several times more plankton than the equatorial ones. Plankton is the major fish diet, and it brings fish to these waters. Fish is provides food for birds and other animals like whales and seals that follow the fish. Seals make also the life of polar bears possible as they are at the end of the food chain.

The rich fauna of boreal, subarctic (also antarctic) and even arctic areas offered even to primitive man new possibilities. It has not been always easy to obtain food in tropical

areas due to high competition. Primitive man realized that and moved to north, where animals were readily available.

Also after the ice-age periods many big animals such as mammoths grazed in the transition grass lands near the melting ice.

Primitive man was wise enough to use animal sources for food, clothing, housing and transport in order to keep his high thermal comfort zone also in polar climates.

3. Does modern man experience cold?

In advanced countries people may stay day and night in thermally controlled conditions. Heating is necessary at high latitude countries and high altitude regions. The houses are warmed and the indoor temperature stays usually over 20º C during the whole year. But still there are moments when also these people meet the natural conditions and may be exposed to low environmental temperatures. The traffic accidents tend to take place during poor weather conditions on icy roads (Figure 2).

Figure 2. A car has slipped out of the road. When the engine is not working the temperature drops quickly even inside the cabin and is soon the same as in the environment. Most car drivers wear indoor clothing and that clothing does not much help in the maintenance of comfortable body temperature. Traumas usually increase the difficulties as muscle cannot be used as a source internal heating of the body. (Photo provided by Dr. Matti Mattila)

Traffic jams after heavy snow storms are rather frequent even in Central Europe. Therefore warm clothing is most recommendable in cars in winter times. Most people in the world are, however, exposed the natural climates of their living areas. Heat has to be produced for convenience or survival.

What is the situation at low latitude countries? The energy consumption is highest California during summer as the cooling systems are on. If the rooms are not thermostated, the temperature oscillates with the natural climate.

Recent studies have shown that the bedroom temperature during winter nights may decrease close 10º C e.g. in several southern and western European countries. The present author has also a personal experience from southern California, where summers are hot. An apartment was rented, but heating was not connected. In wintertime the bedroom temperature soon fell to the level of outdoor temperature, and cold was experienced through the whole night. Therefore the accidents can mean a serious risk of hypothermia especially at nights in mountain roads and proper care of thermal balance must be taken seriously (Figure 3)

Figure 3. First aid cover used in Northern Europe and designed for the rescue teams in ambulances and rescue helicopters. It is of outmost importance to support the thermal balance of subjects. The material of this cover breaks the wind and prevents the rain and moisture to penetrate. It helps also to control the microbial infections of the traumas. (Photo provided by Ms Jaana Holopainen)

The insufficient thermal efficiency of housing even in southern Europe has been related to winter mortality that is more pronounced in southern than in northern Europe. Cold strain is known to aggravate many cardiovascular risk factors such as increased blood pressure, blood clotting and noradrenalin secretion.

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Bibliography

Cannon B. and Nedergaard J. (2004). Brown adipose tissue: function and physiological significance. *Physiol. Rev.* 84:277-359. [This is an extensive description of brown adipose tissue and explains the effects of noradrenalin and thyroxin in heat production. Other adipose tissue hormones are also presented].

Hassi J., Sikkilä K., Ruokonen A. and Leppäluoto J. (2001).The pituitary - thyroid axis in healthy men living under subarctical climatological conditions. *J. Endocrin.* 169:195-203. [Blood levels of thyroid hormones in outdoor workers in Northern Finland decrease in winter, possibly due to their increased elimination. Dark season may also affect the pituitary-thyroid axis].

Jurkovich G.J. (2007). Environmental cold-induced injury. *Surg. Clin. North Am.* 87(1):247-267, viii. [An overview of hypothermia and outcomes frostbites including].

Leppäluoto J., Pääkkönen T., Korhonen I. and Hassi J. (2005). Pituitary and autonomic responses to cold exposures in man. *Acta Physiol. Scand.* 184:255-264. [This review describes the effects of various cold exposures on pituitary, thyroid and adrenal medullary hormones. In most short-time experiments pituitary and thyroid hormones do not change in adults, but during intensive cooling and in newborns they usually increase. All kinds of cold exposures activate noradrenalin secretion. Interestingly, growth hormone and prolactin levels decrease during cold exposures].

Reed H.L., Silverman E.D., Shakir M.M., Dons R., Burman K.D. and O'Brien J.T. (1990).Changes in serum triiodothyronine kinetics after prolonged Antarctic residence: the polar T_3 syndrome. *J. Clin. Endocrinol. Metab.* 70:965-974. [Overwintering in Antarctica gradually leads to decreased blood thyroid hormone levels. Although release of thyroid hormones from the thyroid gland is increased, the peripheral elimination of thyroid hormones is faster and explaining decreased levels].

The Eurowinter group. (1997). Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet* 349:1341-1346. [This paper describes effects of cold seasons on mortality rates in several European countries and show that mortality rates increase during cold spells. The increase is unexpectedly larger in southern than in northern countries. This is mostly due to low thermal insulation of buildings in southern countries].

Wikipedia, The Free Encyclopedia see Whttp//en.wikipedia.org/wiki/Frostbite [Short description of prevention, first aid and therapy of frost bites].

Biographical Sketch

Prof. Juhani Leppäluoto was born in Helsinki, Finland, in 1939. He has an MD 1966 from the University of Helsinki, and in 1972 he also defended his Dr. Med. Sci. dissertation at the Department of Physiology of this University. He has served as researcher at the Universities of Helsinki and Oulu. He worked for three years in Prof. Roger Guillemin's Laboratory at Salk Institute, USA. He became associate professor in 1974 and Professor of Physiology in the University of Oulu and Chairman of the Department in 1991. He has served also as Director of the International Arctic Research Center. He retired in 2004, but he continues his research. His research interests have been in the area of endocrinology, at first thyroid hormones and then mostly on the seasonal and diurnal variations of melatonin secretion. Cardiac hormones have been other research topics. He has contributed to the development of methods of hormone

analysis. He is currently serving as the President of the Finnish Physiological Society. He has been active in the Board of the Nordic Physiological Society and in the Editorial Board of Acta Physiologica Scandinavica, and Editor in Chief of the International Journal of Circumpolar Health.