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# WORKING IN A HOT ENVIRONMENT - PERSPIRATION LOSS - A DRINK FOR PERSONS WORKING UNDER HOT CONDITIONS, PART 2

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16. Abstract

Losses of various nutrients through sweat of persons working under hot conditions are considered and on the basis of these considerations a supplemental drink is formulated for such persons consisting of 1 liter of water per hour containing salt, potassium chloride, iron, thiamine and ascorbic acid.

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WORKING IN A HOT ENVIRONMENT - PERSPIRATION LOSS - A DRINK FOR PERSONS WORKING UNDER HOT CONDITIONS, PART 2[1]

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Calcium /1900*

Sweat clacium losses as a result of working in a hot environment are stated to be 230 to 330 g per day. These are still considerable amounts with a daily intake of 800 mg (desirable amount given by the Food and Nutrition Board).

Nevertheless, there are no acute calcium deficiency states similar to acute sodium and potassium deficiency states. Of the some 1200 g of calcium in the adult human body, 99% is contained in the bones and teeth. They form a calcium reserve which the organism first falls back of in times of shortage and which it then again replenishes during times of better supply. Short term periods of insufficient calcium intake are overcome in this way without the appearance of specific damage due to calcium deficiency. At the present time it is not known to what extent high levels of sweat calcium losses can be compensated for by a reduced excretion of calcium through the intestines. The intestines are the main excretory organ; the excretion of calcium by the kidneys is only around 100 to 400 mg per day.

Thus the intake of calcium with drinks formulated for people working under hot conditions is not necessary. On top of this, in contrast to the absorption of sodium,potassium and chloride, the absorption of calcium in the intestines is a very complex event. The course of this event is determined by the binding of the ingested calcium, the presence or absence of calcium-precipitating and calcium-deionizing substances, the

1. Part 1 in No. 10, p. 1690 (1976).
* Numbers in the margin indicate pagination in the foreign text.

hydrogen concentration in the intestines at the time, the presence of vitamin D and endogenous factors such as the calcium saturation state of the organism.

**Iron** /1902

In the case of iron the situation is different than in the case of calcium. The iron content of a healthy, sufficiently nourished adult human is 4 to 5 g. Most of this amount (76%) is contained in hemoglobin and myoglobin. An iron deficiency after iron reserves have been exhausted -- about 16% of the total iron content is in the form of hemosiderin and ferritin -- is clinically manifested as anemia with a loss of physical and mental capabilities and general weakness. Findings in recent years have led to the surprising discovery that iron deficiency is a worldwide phenomenon, not only in developing countries but also in highly developed industrial countries. "It is widespread in the USA and in the entire world"[34].

The fact that when working under hot conditions 1.2 mg, indeed 6 to 10 mg, of iron per day can be secreted through perspiration [49] should not be ignored as being insignificant with respect to the generally short supply of iron. The desirable iron intake -- 10 mg per day for men and 18 mg per day for women [6] -- is not attained in the usual diet, and according to the 1972 nutrition report of the German Society for Nutrition [2], the iron intake with food in West Germany has dropped from 20 mg in the years 1909 to 1913 to 15.7 mg per person per day in the years 1969 to 1970. In this regard, an efficient drink for persons working in a hot environment should contain iron. If we consider that a person working in a hot environment drinks 6 to 8 liters, then 1 mg of iron per liter would be adequate.

In this connection, the form in which the iron is added to the drink is of crucial importance. Iron is absorbed in the small intestine in the form of ferrous iron. The gastric acid releases the iron from its bindings in foods in the form of the ferric ion. The ferric iron is then reduced to ferrous iron. Reducing agents, above all ascorbic acid, therefore improve the utilization of the iron in the food [3]. For this reason, many iron preparations made by the pharmaceutical industry contain ascorbic acid.

## Phosphate

In our usual diet there is no lack of phosphates. There are also no indications that significant amounts of phosphate are lost when working under hot conditions. Nevertheless, if phosphate additives are occassionally recommended for persons /1903
working under hot conditions, the idea here is that these may increase the person's efficiency. This opinion, which was first discussed about 50 years ago, is still not based on practical experience, but only on biochemical considerations.

"G. Embden, to whom we are indebted for the first decisive experiments on the role of phosphate in the intermediate metabolism of carbohydrates, was so impressed by the importance of phosphate for muscle activity that he recommended an increased intake of phosphate by consuming more phosphate preparations (for example, Recresal, a registrered trade name for $Na_2HPO_4$) to increase efficiency. Later studies, however, were unable to confirm that phosphate increased efficiency.... Nevertheless, the effect of Embden's suggestion was that many people consumed and additional 5 to 7 g of phosphate (equivalent to 1.0 to 1.5 g P) per day over many years, and in so doing it turned out that such an increased phosphate intake is certainly not harmful" [22].

## Proteins

Nitrogen-containing end products of protein metabolism, above all urea, are excreted in the sweat of persons working under hot conditions. According to data of various investigators, the secretion of nitrogen in the sweat of physically inactive people is between 112 and 1060 mg per day, and for persons working under hot conditions it is between 602 and 1260 mg per 7 hours. On the basis of latest studies, Weiner et al. [47] think that with moderately heavy work in a hot climate and with a normal diet the sweat nitrogen loss does not exceed 1 g per day, and with a nitrogen-deficient diet it does not exceed 0.5 g per day. It remains to be seen to what extent the increased secretion of nitrogen through the skin is compensated for by decreased nitrogen excretion by the kidneys (see note at end of article).

An insufficient protein supply does not make itself immediately felt whenever the balance becomes negative, but only when a deficiency condition has developed as a result of continuous protein undernourishment. Thus a drink formulated for persons working under hot conditions which is drunk during work or immediately afterwards does not need to serve as a source of protein. The protein deficiency, if such a deficiency actually exists, can more easily be made up for by the diet: by a
protein-rich meal at the end of the working period or by pro- /1904
protein-rich snacks. Along the same lines, Weiner et al. [47]. have stated: in the case of physical work in the tropics protein additives are not necessary in order to replace sweat losses.

## Sugar

Muscular endurance is closely related to the muscular supply of carbohydrates (glycogen). As a result of intense physical work the carbohydrate reserves are quickly depleted [1]. These can be replenished by a diet of foods rich in carbohydrates -- foods made from flour, bread, potatoes.

This fact is only relevant to the diet of a person working under hot conditions, and not to the formulation of a supplemental drink for such persons. Only water soluble carbohydrates could be added to such a drink, i.e. disaccharides and monosaccharides such as raw sugar, lactose, glucose, fructose. Carbohydrates administered in this form 30 to 60 minutes prior to atheletic performances lasting more than 30 minutes have a decisive efficiency-increasing effect. Carbohydrate intake during the physical demand is "necessary only when the demand lasts longer than 70 minutes. Oligosaccharides in an amount of 0.25 g per kg of body weight have proved successful. The administration of this amount can be repeated after another 45 minutes" [30].

If the carbohydrate additions are to have an efficiency-increasing effect, then they must be given in relatively large amounts. An amount of 0.25 g per kg of body weight results in 17 to 18 g for a man weight 70 kg at 45-minute intervals. However, a drink containing 17 to 18 g of sugar per liter tastes very sweet and because of this particular taste it is hardly suitable for weeks and months at a time as a daily supplemental drink for persons working under hot conditions.

On top of this there is another point: large amounts of sugar can drastically reduce a person's efficiency as a result of reactive hypoglycemia. This is an undesirable effect for persons working under hot conditions who, in contrast to many atheletes, are expected to maintain uniform efficiency for hours at a stretch.

Therefore it is appropriate not to add sugars to an efficient supplemental drink for persons working under hot conditions and carbohydrate-rich snacks will enable and promote the filling of carbohydrate reserves.

## Ascorbic Acid



No significant amounts of ascorbic acid are lost with the sweat of a person working under hot conditions. Neither are there any indications that the metabolism of ascorbic acid is higher than average in persons working under hot conditions.

The addition of ascorbic acid to a supplemental drink, however, helps in the performance of a very crucial active ion. As we have said, a person working under hot conditions loses a good deal of iron with his sweat. An efficient supplemental beverage must replace this loss. The assimilation of iron in the small intestine is a complex event in the course of which the iron ingested with food and drink must be incorporated into the ferritin of the intestinal mucosa. This incorporation requires the participation of adenosine triphosphate and ascorbic acid. Moreover, ascorbic acid is important for the reduction of trivalent ferric iron in the stomach. Only bivalent ferrous iron can be absorbed in the intestine. Thus in each case the utilization of the iron contained in food and drink is improved by the administration of ascorbic acid, and under certain circumstances the utilization of this iron is even only made possible by the administration of ascorbic acid. To some extent, depending on its ascorbic acid content, orange juice also improves iron absorption.

In this way, adding ascorbic acid to a supplemental beverage helps in the utilization of the added iron and it ensures the supply of iron. This purpose should be fulfilled by 25 mg per liter.

## Thiamine (Vitamin $B_1$)

Apart from the fact that an efficient supplemental beverage should offer replacement for substances which are secreted with sweat and whose absence can lead to undesirable deficiency symptoms, the question arises as whether other viewpoints can or should be important for the formulation of an efficient supplemental beverage.

The thiamine demand increases with increasing energy transformation. Therefore, 0.5 mg of thimaine is considered adequate for each 1,000 calories of energy transformation [6]. If this view is assumed to be correct, then an additional 0.5 mg of thimaine must be given to a person working under hot conditions per each 1000 work calories expended.-- this is not because of the heat, but because of the work. If the energy demand of a hard working, 70-kg man reaches 7.5 to 12.0 kcal per minute, /1910
then this amounts to 2700 to 4320 kcal in 6 hours, thus 1.4 to 2.2 mg of additional thiamine. Thus if the amount drunk is 6 liters for 6 hours of heavy work under hot conditions, then the supplemental beverage would have to contain 0.33 mg of thiamine per liter to cover the additional demand for 2 mg of thiamine.

With their energy demand, persons working under hot conditions are in the habit of eating foods which contain above average amounts of fat. However: "Although it has been shown that fat in the diet to a certain extent 'saves' vitamins, there is little reason to believe that the recommendation should take into account the variations in carbohydrate and fat content of the food" [6].

Odor and Taste Substances

Over a long period of time no one can eat a food which is tasteless and odorless -- no matter how full of value it might be in terms of proteins, vitamins and trace elements. And in the long run a person working under hot conditions will not drink a tasteless beverage, no matter how specifically tailored it is to his special requirements.

It has already been mentioned that beverages with a pronounced peculiar flavor are not accepted in the long run.

The growing popularity of alcohol-free and alcoholic beverages with a bitter taste characteristic is interesting from the physiological standpoint. Collectively referred to as "bitters," bitter drugs have been used as pharmaceutical ingredients for thousands of years, e.g. wormwood, gentian, angostura, galingale, hops, cinchona bark. Even in the German Pharmacopeia (DAB VII), in the age of synthetic drugs, these are still designated as bitters. These drugs owe their popularity to a "tonic" effect, i.e. a strengthening effect which has not yet been clarified with modern pharmacological methods. It would have to be tested whether beverages with a bitter taste are accepted by persons working under hot conditions.

In the formulation of an efficient supplemental beverage for persons working under hot conditions it is perhaps also appropriate to remember the practical experience that many people think that sour beverages are especially good thirst quenchers.

## Drink Temperature /1912

Countless regulations indicate how hot and how cold drinks should be when taken. This requirement is misleading because it suggests that the temperature data are based on the findings of physiological or psychological studies and thus are something like a physiological standard. In actuality they only indicate how hot or cold a drink must be to give it the best flavor, or more precisely, so that it tastes best to the majority of people of a certain group. Experience shows us that certain perfumes and flavoring agents produce a better sensory effect at lower temperatures and others at higher temperatures. So far the subjective-sensory (degustatory) test is the only method for determining the optimum temperature for a food and drink with respect to their enjoyment value.

Sensory sensations are the decisive factor in judging between agreeable and disagreeable. Agreeable means a refreshing, lively, pleasant taste. A disagreeable drink is one which produces unpleasant sensations during or after the drinking of it, e.g. intense hot and cold sensations, pressure, choking, pain. In contrast to what lay persons believe, however, a pain between the navel and breastbone need not emanate from an organ between the navel and breastbone, and whenever the ingenuous lay person speaks of "a feeling of coldness at the inlet of the stomach" and "a feeling of heat at the stomach outlet", then it is explanatory to say that certain feelings are interpreted as a feeling of coldness or warmth, but are not experienced as such -- apart from the fact that a person receives the most surprising information as to where the stomach inlet and stomach outlet are actually located.

It is conceivable that intense temperature stimuli could injure the temperature-sensitive sense organs (thermoreceptors). Actually at the present time there are no indications that cold or heat stimuli harm thermoreceptors.

In the German literature, following an old tradition, cold drinks are still found among the causes of acute and chronic gastritis. A curious fact in this connection is that the same authors, who consider cold drinks to be pathogenic in regard to gastritis, use these drinks therapeutically in order to cure the gastritis of ulcer patients. Clinical evidence for the creation /1913 of a stomach ulcer or gastritis due to extreme cold and hot stimuli has never been published. Therefore in scientific medicine, cold and hot gastritis and gastritis in general today still play a very modest role. "An illness of highest clinical value and important social significance has become a pathological mucosa condition, which to be sure is found in two-thirds of a random patient population, but with which no subjective complaints can be correlated.... Neither nicotine nor alcohol nor the inability to chew are causes of chronic inflamation of the gastric mucosa" [5].

After a person eats a portion of ice cream or a bottle of ice cold cola the temperature of the stomach contents drops to 15°C and after 30 minutes the temperature of the contents has returned to its initial value. After a person drinks hot water with a temperature of 50°C the temperature of the stomach contents climbs to 46°C and after 20 minutes returns to the initial level [29]. If drunk all at once, 250 ml of cold meat broth (+1.7°C) drops the stomach's temperature to 21°to 24°C. In its passage through the mouth, throat and esophagus the drink warms up more than 20°C. Thirty to fourty minutes after drinking the temperature returns to the initial level. When drunk at 63°C, the same amount of the same drink cools off very rapidly. When it enters the stomach the temperature has already dropped to 41° to 43°C, and 15 to 20 minutes later it has again reached the initial level [7].

Thus ice cold drinks are already about 20°C warmer before they come into contact with the gastric mucosa, and hot drinks have already cooled by about 20°C -- an impressive performance by the upper digestive tract. It has never been shown to be likely and from the outset was considered unlikely that the gastric mucosa is injured by the short term effect of temperatures between 20° and 40°C.

Cold drinks, however, activate the motoricity of the stomach. The stomach begins to empty immediately after drinking and this proceeds rapidly. The cold drink passes very rapidly through the small intestine. As the temperature of the stomach content increasingly approaches the body temperature. The intensity of stomach motoricity also decreases, and if after 30 to 40 minutes the temperature of the drink has become "normal" then the motoricity has also become "normal" [7].

Hot drinks at first leave the stomach abnormally slowly, but then they continue in the usual manner and at the usual rate [7]. /1914

The increase in motoricity due to cold drinks and the rapid passage through the small intestine has been connected with the fact that many people react to a cold drink with diarrhea. A matter to consider in this connection is that the urgent need to defecate and diarrhea are symptoms of the large intestine and not the small intestine and that they occur immediately after drinking, i.e. at a time in which the cold drink has certainly not yet reached the large intestine. Presumably what is involved in the case of "cold diarrhea" is a gastrocolic reflex similar to the urge to defecate after food has been consumed.

The secretion of gastric juices is temporarily throttled by a cold drink. However, even before the temperature of the stomach contents has returned to its initial level the throttling effect has been overcome. Hot drinks do not effect the secretion of gastric juices [7].

On the basis of currently available clinical and experimental observations the question as to the usefulness or harm of cold drinks can be clearly answered. Cold drinks are refreshing and stimulating. The optimum temperature in terms of taste for many national drinks is around +10°C and below. When large amounts of cold drinks are drunk very rapidly they may cause unpleasant sensations behind the breastbone and in the upper abdomen, also along with the urge to defecate. However cold drinks never cause pathological changes in the mouth, esophagus, stomach and intestines. Therefore it is not obvious why a healthy person should be offered ice cold drinks and why he should be offered hot tea. Quite without our help he will make sure that the cold does not "hurt his teeth" and that he does not burn his mouth.

In terms of a supplemental drink for persons working under hot conditions this leads to the following conclusion: it should be left up to the worker how hot or how cold he likes his drink.

<u>Guidelines for Formulating and Efficient Beverage for Persons Working Under Hot Conditions</u>

Quantity: 1 liter per hour

Ingredients: table salt 1.0 g per liter; potassium chloride /1916
< 0.32 g per liter; iron 0.001 g per liter; thiamine 0.0003 g per liter and ascorbic acid 0.025 g per liter.

The flavoring and temperature selection of the drink can be selected to suit the desires of the consumer.

<u>Correction Note</u>

In recent studies it has been found by P.Ch. Hao, Ch.-Ch. Lo and W.T. Ho that in a hot environment 11.9 mg of nitrogen per kilogram of body weight is secreted through the skin, and 3.5 mg per kg in a cool environment. The amount of nitrogen excreted by the kidneys was correspondingly 69.7 mg/kg and 82.2 mg/kg. ("Protein requirements of men in a hot climate; decreased urinary nitrogen losses concomitant with increased sweat nitrogen losses during exposure to high environment temperature," <u>Amer. J. clin. Nutr</u>. <u>28</u>, p.494 (1975.)

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