Activity of Disaccharidases in Arctic Populations: Evolutionary Aspects

Disaccharidases in Arctic Populations

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Abstract Disorders of dietary sugar assimilation occur more often among native people of the Arctic than in temperate climate inhabitants.

It is hypothesized that the limited variety of natural exogenous sugars in the Arctic, and their low content in the traditional diets of native northerners in accordance with a “protein-lipid” type of metabolism weakened selection, favoring diversity of disaccharidase enzymes. *J Physiol Anthropol Appl Human Sci* 24(4): 473–476, 2005 <http://www.jstage.jst.go.jp/browse/jpa> [DOI: 10.2114/jpa.24.473]

Keywords: arctic, indigenous peoples, aborigines, carbohydrate metabolism, lipid metabolism, disaccharidases lactose, sucrose, trehalose, glucose

Introduction

In numerous publications devoted to nutrition in northern aborigines, researchers have pointed out widespread disorders in the assimilation of some dietary sugars (Ellestad-Sayed and Haworth, 1977; Gudmand-Hoyer et al., 1987, 1988; Kozlov, 1998; Kozlov and Vershubsky, 1999). Frequently these disorders are treated as signs of disease. Disaccharidase malfunction may actually arise as a result of endured diseases, as a consequence of a specific diet, or under the influence of other external factors. However, the main regulator of the functioning of disaccharidases in digestive processes is gene control (Semenza et al., 1999). In this article we consider the frequencies of the primary (genetically attributed) disaccharidase deficiency.

We suppose that integrating data on epidemiology of food carbohydrates’ maldigestion and anthropologic analysis allow us to reveal patterns connected to human adaptation in high latitude regions.

In this article we consider the following questions. Does the

genetically attributed insufficiency of enzymes splitting carbohydrates (disaccharidases) occur more frequently among Arctic aborigines than in populations of a temperate climate? If the difference exists, what are the reasons?

Materials and Methods

To compare frequencies of lactose, sucrose and trehalose maldigestion in northern aborigine and European populations, we used both data of our investigations and from the scientific literature.

The results of our study of lactase deficiency in indigenous populations of the sub-Arctic (Mansi, Khanty, Komi-izhems), and Arctic (Saami, Nenets, Chukchee, Siberian, Eskimo-Yupik) have been published earlier (Kozlov, 1998; Kozlov et al., 1998; Kozlov and Vershubsky, 1999). Molecular genetic data on the frequency of the C/T-13910 loci of the *LAC* (lactase) gene in the Chukchi population come from our unpublished materials.

Our data on the content of glucose in blood serum in groups of Mansi, Khanty, Komi-izhems, Saami, and Nenets have been presented in the following articles: Kozlov and Vershubsky (1999); Kozlov et al. (2003).

We used official statistics to analyze the nutrition of Chukotka aborigines (Podgainy and Zdor, 2001; Ainana et al., 2002). Results are described in the work of Kozlov (2004).

The following considerations were taken into account while choosing data for comparison. Lactase activity has an expressed age relation (Flatz, 1987). Therefore, only adults were included as subjects in analysis of frequencies of genetically attributed (primary) lactose maldigestion. We have not found information on age dynamic of trehalase activity, so we used data on trehalose maldigestion in adults. Sucrase does not manifest an age dynamic (Kilby et al., 1978; Kohlo and Savilahti, 2000), so we pooled children’s and adult’ data on sucrose maldigestion.

Discussion

Frequency of lactose malabsorption (primary hypolactasia) varies in the studied populations from 48% (Saami; the sample includes a big number of half-breeds) up to 98% (Chukchi). In aboriginal populations of Arctic regions of Greenland, Alaska and Canada, primary hypolactasia is found in 63 to 100% (Flatz, 1987; Scrimshaw and Murray, 1988; Kozlov, 1998). In populations of Western and Central Europe, lactose deficiency constitutes from 2% (Danes) to 37% (Hungarians, French, Poles) (Flatz, 1987). The geographical spread of the lactase activity regulating alleles has been described in our publication (Kozlov et al., 1998).

Trehalose maldigestion was registered in 10.5% of Greenland Inuit (Gudmand-Hoyer et al., 1988). Results of enzymatic analysis of intestinal biopsies have shown that trehalase deficiency in various European groups can oscillate from 0.25% to 2% (Bergoz et al., 1982; Murray et al., 2000).

Sucrase deficiency is rare among Europeans, and no differences have been found between populations (Blomme et al., 2003). For example, an examination of 204 Danes has not revealed a single case. Only one child of 188 Finnish children had suppressed sucrase activity (Kohlo and Savilahti, 2000). In aboriginal populations of high latitude regions, on the other hand, sucrase deficiency occurs frequently. It was recorded in 5% of Greenland Eskimo and in 6.9% of Northern Manitoba Indians (Ellestad-Sayed and Haworth, 1977; Gudmand-Hoyer et al., 1987).

Interpopulation differences in disaccharidase deficiency are brought together in Table 1. The numbers testify that food carbohydrate maldigestion in groups of native northerners occurs more frequently than among those originating in temperate climates.

Mechanisms of gaining energy for tissue (cell) aerobic respiration differs in human organisms adapted to arctic and temperate climates.

For the residents of non-arctic regions, carbohydrates are the main source of energy. Assimilation of food carbohydrates proceeds in two stages. First, food sugars, mostly disaccharides, must be decomposed into monosaccharides capable of penetrating the intestine wall. The decomposition is provided by an enzyme (disaccharidase) specific for every food sugar. The final stage of food carbohydrates assimilation is monosaccharide metabolism. Concentration of monosaccharides in blood serum depends on the quantity of carbohydrate consumption and the rate of its utilization. If consumption of food sugars is very high, the number of monosaccharide intolerances increases.

In the Arctic, there is a specific situation formed by ecological conditions. A native northerner on a traditional diet uses mainly lipids and derivatives of protein metabolism, rather than carbohydrates, for gaining energy. The traditional diet differs from the "European" one in having a very high rate of animal proteins and lipids in it (the influence of ecological and economic factors on the diet of native northerners has been

Table 1 Disaccharidase deficiency in native Arctic and European populations

Disaccharide	Maldigestion, %	
	Indigenous Arctic populations	European populations
Lactose	48–100	2–37
Trehalose	10.5	0.25–2
Sucrose	5–6.9	0.5 (?)

Table 2 Caloric intake (%) of proteins, fats and carbohydrates in the diet of Greenland Inuit in 1908, Siberian Yupik in 2000, and Europeans

Ethnic group and year of investigation	Proteins	Fats	Carbohydrates
Inuit, NW Greenland, 1908 ¹	44	47	8
Siberian Eskimo (Yupik), 2000 ²	23	44	33
Europeans (recommended)	15	30	55

Sources: ¹ Krogh and Krogh, 1913; ² Kozlov, 2004

analyzed earlier: Kozlov, 2004). For example, in the contemporary, partly "westernized", diet of Siberian Eskimo (Yupik), proteins and fats supply 1.5 times as much energy as they do in the diet of Europeans. Essential differences in the ratio of the main nutrients in the diet of the "traditional" Greenland Inuit (Eskimo) and the "westernized" Siberian Yupik in comparison with Europeans are clearly seen in Table 2.

In northern people, both dietary fats and endogenous glucose, synthesized from food proteins (amino acids), partake in the processes of providing energy (tissue respiration). The necessary quantity of endogenous glucose is produced by the liver from amino acids, entering with food proteins. Therefore, the glucose concentration in the blood serum of northerners is not high normally. In the subjects studied (18–55 years old, n=422), blood serum glucose concentration averaged 4.47 mmol/l (SD=0.87). The value practically coincides with the median of the trait's normal variation: from 3.3 to 5.5 mmol/l. Deviations of population averages are from 4.38 (Saami) to 4.77 (Nenets) mmol/l. Our data agree with the data of other studies (reviews: Shephard and Rode, 1996; Kozlov and Vershubsky, 1999).

Disorders of glucose metabolism are also rare in the northern aborigines having close to a traditional style of life. We found glucose intolerance in 4.9% of cases, and diabetes mellitus in 0.5% (combining 5.4%). That is 2–4 times less than in European populations (review: Kozlov and Vershubsky, 1999).

The share of energy supplied by exogenous sugars (disaccharides entering with food) in traditional "arctic" diets is insignificant. Even at the end of the 1980s, daily consumption of sugar in Chukotka natives, considerably "westernized" by the time, averaged 67.2 g in males, and 48.8 g in females (Shubnikov, 1991). It is half that of Europeans (Birch et al., 1977), and Russians (Kozlov, 2002).

We suppose that the limited variety of natural exogenous sugars in the Arctic, and their low content in the traditional diets of native northerners in accordance with a “protein-lipid” type of metabolism, weakened the selection aimed at maintaining the diversity of disaccharidase enzymes.

The weakening of selection may be aggravated by cultural-genetic coevolution. Tundra dwellers, Nenets in particular, traditionally do not eat mushrooms, regarding them as a food for reindeer, not for humans (Yoshida, 1997). Possibly, the tradition of refusal of such a protein-rich food source could be conditioned by relatively widespread trehalose maldigestion in high latitude populations. Trehalose is a sugar contained in mushrooms, and trehalase deficiency could cause a stomachache after eating mushrooms (Arola, 1999).

This situation is similar to the rejection of whole milk as a food. A person with lactase deficiency could suffer dyspepsia after drinking milk. There are no dishes with whole milk in the traditional diets of Arctic natives, for it contains a considerable quantity of lactose. Some popular publications mention Saami using reindeer whole milk. However, as our study has shown, this notion rather ought to be regarded as one of the numerous myths on the “food of exotic peoples” (Kozlov and Lisitsyn, 1997).

Conclusion

For dwellers of the tropics and the temperate climate zone, carbohydrates are the main source of energy supplying tissue (cell) respiration. The traditional food of the peoples there contains various food sugars (sucrose, fructose, trehalose, glucose, maltose). The initial diversity should have contributed to the selection supporting the activity of a big number of disaccharidase enzymes.

The traditional diet of Arctic natives on the other hand includes a very scanty set of food sugars. The function of the main energy source in the high latitude populations for ecological reasons has passed to lipids and endogenous glucose, synthesized from proteins. This matter weakened the selection which support the diversity of carbohydrate-utilizing enzymes.

The results of the analysis have practical implications. Due to the fact that the selection aimed at maintaining the variety of disaccharidases in Arctic populations is weakened, we can expect the genetically attributed maldigestion of various disaccharides among modern northerners to be widespread. Meanwhile, undergoing “westernization” of the traditional Arctic diets is accompanied with an intensive rise in the consumption of sweets. Therefore, medical practitioners in indigenous communities should be ready for an increasing number of cases of disaccharidose maldigestion among their wards.

Acknowledgements This work is supported by grant of the Russian Foundation for Basic Researches 05-06-80427-a.

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Received: February 28, 2005

Accepted: March 23, 2005

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