ISSN 2304-3415, Russian Open Medical Journal
2022. Volume 11. Issue 4 (December). Article CID e0404
DOI: 10.15275/rusomj.2022.0404

Original article

Carbohydrate metabolism, pancreas functional activity and diet in young residents of two ethnic groups in the North

Inessa V. Averyanova

Arctic Scientific Research Center, Far Eastern Branch of Russian Academy of Sciences, Magadan, Russia
North-Eastern State University, Magadan, Russia

Received 30 March 2022, Revised 16 May 2022, Accepted 20 June 2022

Abstract: *The objective* of this study was to analyze the type and balance of the diet, examine the hormonal regulation of carbohydrate metabolism in order to identify the etiology of hyperglycemic manifestations in young people of two ethnic groups residing in the territory of Magadan Oblast.
Methods — Blood serum carbohydrate parameters were measured using the ion-exchange chromatography, enzymatically enhanced chemiluminescence, and the hexokinase method.
Results — We established that the homeostatic model assessment of insulin resistance (HOMA-IR) index did not exceed the reference limits, which implied that the examined young men of two ethnic groups had no insulin resistance. The indigenous subjects demonstrated statistically significantly higher values of glycosylated hemoglobin, closely approaching the upper limit of the reference range. The blood insulin level in examined young men was lowered towards the lower limit of the reference range. Against the background of detected hyperglycemic manifestations in young men of two studied groups in Magadan Oblast, their dietary intake was characterized by insufficiency and imbalance in both micronutrient and macronutrient compositions. It was established that the observed diet contained an excessive amount of mono- and disaccharides in 49% of Caucasians and 72% of natives, which was 52% and 108% higher, respectively, compared with the reference range against the pronounced deficiency of chromium, copper, and vitamin D.
Conclusion — The results indicated an unbalanced diet with excessive intake of mono- and disaccharides, along with reduced insulin secretion and increased glycosylated hemoglobin, which was more pronounced in the indigenous group, probably causing hyperglycemic manifestations in the carbohydrate metabolism observed in young residents of Magadan Oblast.

Keywords: young Caucasian men, young indigenous men, carbohydrate metabolism, hyperglycemic manifestations, actual diet.

Cite as Averyanova IV. Carbohydrate metabolism, pancreas functional activity and diet in young residents of two ethnic groups in the North. *Russian Open Medical Journal* 2022; 11: e0404.

Correspondence to Inessa V. Averyanova. Phone: +79246911146. E-mail: Inessa1382@mail.ru.

Introduction

Diabetes is currently becoming a non-infectious epidemic, with changes in the age-related incidence towards younger groups [1]. This coincides with the previously obtained results on the carbohydrate metabolism analysis for young residents in Magadan Oblast, whose blood glucose closely approached the upper limit of the reference range for normoglycemia and varied from 5.4 to 5.6 mmol/L. At the same time, in over 25% of young people under study, glucose exceeded the reference range, which undoubtedly constituted a prerequisite and a risk for developing hyperglycemic conditions at older age [2]. Notably, the values of carbohydrate metabolism observed in young males of Magadan Oblast do not agree with those of the European North, where, on the contrary, the tendency to develop hypoglycemic conditions was revealed both in newcomers and long-term residents of the North. The author of this study interprets this finding as a certain feature of the so-called *northern metabolism* [3]. There is still no consensus as to the features of insulin regulation in people residing in the conditions of the North. For instance, it was established that native inhabitants of the North adhering to the conventional protein-lipid type of nutrition, had a specific *economical* type of metabolism with higher cortisol levels against the background of a lower base content of blood insulin [4]. The study by O.N. Poteryaev et al. (2017), on the contrary, reported high insulin content corresponding to the maximum permissible level for this indicator in groups of both indigenous subjects and newcomers to the Yamalo-Nenets Autonomous Okrug [5]. The publications also mentioned the minimization of carbohydrates in the energy metabolism among the native residents of the North caused by a slowdown in the rate of glycolysis and reduced activity of enzymes involved in carbohydrate metabolism [6]. Hence, the objective of our study was to examine the type and balance of nutrition, along with hormonal regulation of carbohydrate metabolism in order to identify the etiology of hyperglycemic symptoms in young male residents of Magadan Oblast.

Table 1. Indicators of the pancreas functional activity and carbohydrate metabolism

Indicators	*Examined subjects*		*Statistical significance*
	Caucasians (n=136)	Indigenous people (n=44)	
HbA1 glycosylated hemoglobin, %	5.21±0.05	5.38±0.06	p=0.045
HOMA-IR, arb. units	1.86±0.16	2.10±0.23	p=0.392
Glucose, mmol/L	5.38±0.06	5.49±0.08	p=0.281
Insulin, mIU/mL	7.59±0.80	8.14±0.86	p=0.643

Table 2. Indicators of macronutrient, micronutrient and vitamin compositions, and energy values of the diets in young males of different ethnic groups living in the North

Indicators	*Examined subjects*		*Statistical significance*
	Caucasian men (n=136)	Indigenous men (n=44)	
Proteins, g	73.1±2.5	74.1±1.8	p=0.712
Animal fats, g	40.2±2.1	34.0±1.5	p=0.036
Vegetable fats, g	40.1±2.4	36.3±1.7	p=0.182
Fats, g	80.2±3.3	70.2±2.2	p=0.005
Fibers, g	5.1±0.3	3.9±0.1	p=0.007
Carbohydrates, g	248.5±8.4	327.1±8.3	p<0.001
Mono-, disaccharides, g	113.4±4.8	154.8±7.2	p<0.001
Copper, µg	1.562.2±104.8	1.730.7±46.1	p=0.142
Chromium, µg	54.5±3.6	46.5±2.8	p=0.081
Vitamin D, µg	2.9±0.4	2.9±0.5	p=0.912
Vitamin E, µg	13.4±0.6	13.9±0.4	p=0.552

Table 3. Frequencies of the deficit, excess, and normal values of the main indicators of macronutrient, micronutrient and vitamin compositions, and energy values of the diets in young males of different ethnic groups living in the North

Indicators	Examined subjects					
	Caucasian men (n=136)			Indigenous men (n=44)		
	Deficit, %	Excess, %	Norm, %	Deficit, %	Excess, %	Norm, %
Proteins, g	67±3	7±2	26±4	67±5	6±3	28±5
Fats, g	78±4*	5±2	17±3	67±5	11±4	22±5
Fibers, g	98±1	1±1	1±1	100±0	0±0	0±0
Mono-, disaccharides, g	12±3	49±5*	39±4*	17±4	72±5	11±4
Carbohydrates, g	79±4*	2±1*	19±4*	56±6	11±4	33±5
Copper, µg	68±4	12±3	20±4	56±6	17±4	28±5
Chromium, µg	84±3	9±3	7±2	83±4	6±3	11±4
Vitamin D, µg	91±3	7±2*	1±1	83±4	17±4	0±0
Vitamin E, mg	36±4*	50±5*	15±3	22±5	67±5	11±4

* indicates statistically significant differences between ethnic groups.

Material and methods

Study participants

The examinees were men aged 17–21 years old. All subjects were permanent residents of Magadan Oblast and by the time of the survey were full-time students with comparable living conditions for more than six months. The examination was conducted in physical education classes before exercises, which implies no chronic disease in the acute stage or complaints about the health condition, which was the direct inclusion criterion for the study. The research was conducted taking the ethnicity into account, with male representatives of the Caucasian population and indigenous young males representing small-numbered peoples of the North (Koryaks, Evens). The mean age was 18.2±0.2 years (n=44) in the indigenous group, and 18.3±0.1 years (n=136) in Caucasian group. The Caucasian subjects were characterized by the following anthropometric characteristics: body mass of 69.4±0.2 kg, body length of 179.1±0.5 cm, chest circumference of 91.5±0.2 cm, BMI of 21.7±0.1 kg/m^2. The anthropometric values established for the indigenous group were, respectively, 61.7±0.9 kg, 170.9±0.7 cm, 87.7±0.6 cm, and 21.1±0.2 kg/m^2. These differences were probably caused by the ethnic nature of the morphotype development.

Blood serum carbohydrate indicators

Venous blood samples were taken from the subjects using vacuum blood collection tubes. The samples were taken on an empty stomach in the laboratory of *Unilab-Khabarovsk LLC*. Automated D10 analyzer (Bio-Rad, USA) was used for the reference method of high-pressure liquid ion exchange chromatography to determine glycosylated hemoglobin (HbA1). The method of enzymatically enhanced chemiluminescence by means of immunochemical analyzer IMMULITE 2000XPi (Siemens, USA) was employed to measure insulin concentration. Glucose analysis was performed using the hexokinase method on the AU 480 biochemical analyzer (Beckman Coulter, USA). The assessment of the insulin resistance was conducted based on the formula proposed by D.R. Matthews, et al. (1985) for calculating the homeostatic model assessment of insulin resistance (HOMA-IR) index: [Insulin (mIU/mL) × Glucose (mmol/L)] / 22.5 [7].

Dietary analysis

The subjects kept food recording notebooks for 5 days, excluding weekends and holidays, to evaluate some parameters of their diets. The diet composition was calculated using the ASPON-nutrition software (Saint Petersburg). Using this software, the macronutrient composition of the diet was analyzed for the following components: proteins (g), fats (including vegetable and animal fats) (g), carbohydrates (g) (with specifying mono- and disaccharides (g), and fiber (g). The obtained data were compared with the standard levels of food intake [8]. The frequencies of deficient or excessive intake of macronutrients and micronutrients were recorded, as well as actual diets, compared with the referent ranges. Additionally, some micronutrients that affect carbohydrate metabolism were analyzed: vitamin D (µg), vitamin E (mg), Cu (copper, µg); Cr (chromium, µg).

Statistical data processing

The collected data were processed using Statistica 7.0 software package. The normality of the distributions of measured variables was verified using the Shapiro-Wilk test. The results of parametric data processing are presented as the mean value (M) and standard deviation of the mean (±m). The statistical significance of differences was calculated via Student's t-test for independent samples. The critical significance level (p) was assumed at 0.05 [9].

Results

Table 1 demonstrates main indicators of functional activity of the pancreas and carbohydrate metabolism. The presented data suggests that young men of both groups are described by statistically significant differences in the values of glycosylated hemoglobin, which were lower in the group of Caucasian males. No intergroup ethnic differences in blood glucose, insulin, or HOMA-IR were detected. *Table* 2 presents macro- and micronutrients, and vitamins, as well as the diet energy value in

young Caucasian vs. indigenous males in Magadan Oblast. Our data implied that young men of both groups exhibited considerable differences in amount of animal fats in their diet, total lipids, and fiber. Notably, the indigenous subjects had smaller values of fiber, while the young Caucasian men had considerably lower levels of carbohydrates, and mono- and disaccharides. *Table* 3 demonstrates the occurrence of deficiency, excess, and normal values of the main indicators of macro- and micronutrients and vitamins, as well as the energy value of the nutrition observed in young Caucasian and indigenous men of Magadan Oblast. The analysis of the results suggests more frequent manifestations of lipid, carbohydrate and vitamin E deficiency in Caucasian subjects.

Discussion

Carbohydrate metabolism and functional activity of the pancreas

The main characteristics of the pancreas functional activity, along with carbohydrate metabolism, presented in *Table* 1 demonstrated statistically significantly higher values of glycosylated hemoglobin in the group of young males from the indigenous population of the North. Herewith, even though within the reference range, the obtained values were close to its upper limit (at a rate of 3-6 %) for all surveyed young males of both ethnic groups under study. The HOMA-IR index values in both groups did not exceed the reference values, thereby implying no insulin resistance experienced by the test subjects. Notably, the fluctuations in the insulin levels in both groups tended to shift towards the lower limit of the reference range despite relatively high blood glucose content registered on empty stomach (5.38–5.49 mmol/L). The data obtained in our study confirmed the previous research results on the rearrangement mechanisms in hormonal regulation of metabolism that people develop in the North, where the leading symptom is a decrease in insulin production, called the *stress diabetes* [4]. This, in particular, is consistent with the reference data, suggesting the development of transient physiological stress diabetes in the conditions of the North, which is characterized by the decreasing threshold of sugar and other low molecular weight compounds reabsorbed in the renal tubules, and also by reduced insulin content [4]. According to some authors, that could be associated with a reduction of the carbohydrate role in the energy metabolism, as well as with the energy metabolism per se: the latter tends to switch from its carbohydrate type to the lipid type [10]. The authors also indicate that due to low insulin levels, cell metabolism switches to ketone/free fatty acids with subsequent reduction of glucose utilization. Instead of the glucose, free fatty acids in the bloodstream become the source of energy [11]. The above analysis of glycosylated hemoglobin, the HOMA-IR index, and the level of insulinemia suggests the absence of hyperinsulinemia and insulin resistance, which could be the cause of high blood glucose levels. In contrast, both studied groups had low values of the HOMA-IR index and blood insulin, which, with the high values of glycemia, is indicative of insufficient functioning of β-cells in the insular apparatus of the pancreas.

Micronutrients in the diet

Analysis of main indicators of the micronutrient status (*Table* 2) demonstrated no significant differences in chromium between the subjects of two ethnic groups. Therewith, mean values of this micronutrient were low in approximately 83-84 % of all test subjects, compared with the recommended standards (45% below the norm in Caucasians and 53% lower in young indigenous men). It is necessary to emphasize the biological role of chromium in the regulation of carbohydrate metabolism, as well as its importance for the blood glucose levels since it is a component of the glucose tolerance factor (GTF) [12].

Our data indicate that chromium deficiency constitutes a prerequisite for type 2 diabetes, which is generally consistent with the high frequency of fasting hyperglycemia in young males under study (over 25% in the sample) [2]. The nutrition analysis demonstrated no significant differences in the copper amount between the groups; a deficiency in this micronutrient was observed in 68% of young Caucasian males and 56% of indigenous men. It is known that copper contributes to the normal functioning and activation of insulin [13].

Vitamin supply

Table 2 demonstrates the amounts of some vitamin intake by young men in our study. No ethnic differences in the concentration of vitamin E have been found between the ethnicity-based groups, but on average, both groups had 34-39% higher vitamin E content than the recommended standards. The excess was observed in 50% of Caucasian subjects and 67% of indigenous men. Apart from its antioxidant effect, vitamin E is also involved in glucose metabolism [14]. Some studies have proven the negative correlation between the concentration of tocopherol in blood plasma and insulin resistance [15, 16]. An important biological role of vitamin D in increasing insulin secretion and insulin sensitivity was established as well [17]. It was confirmed that low levels of vitamin D in the blood increase the risk of diabetes development [17, 19]. Notably, normalization of vitamin D levels in the blood optimizes the plasma concentration of glucose sampled on an empty stomach towards the physiological norm, and also reduces insulin resistance in such patients [20]. This study demonstrated vitamin D deficiency in 91% of Caucasian males and in 83% of the studied natives: the mean was 74% lower in both ethnic groups, compared with the reference range, and no statistically significant intergroup differences were detected.

Macronutrient diet composition

Analysis of the macronutrient supply indicated insufficient protein intake in 67% of young males in both studied groups. The mean amount of observed protein consumption was 26–27% lower than the recommended physiological norm. Similar picture could be observed in the lipid intake: 78% of Caucasians and 67% of the natives demonstrated mean lipid amounts below the reference range. The author established that 79% of Caucasian males and 56% of native men lacked carbohydrates in their diet against the background of an excess of mono- and disaccharides observed in 49% and 72% of them, respectively. At the same time, mean consumption of mono- and disaccharides exceeded the norm by more than 52% in the group of Caucasians and by 108% in the indigenous population of the North. It is known that high consumption of simple sugars is a risk factor for the development of insulin resistance and type 2 diabetes [21].

The energy contribution of proteins, fats, and carbohydrates to the nutrition by the Caucasian subjects demonstrated the following ratio: 15:35:50 (%), which reflects the carbohydrate type of their diet with an increased proportion of mono- and disaccharides up to 22% (while the WHO recommendation is

below 10%). The examinees from the native population of Magadan Oblast had the following macronutrient ratio: 14:28:58 (%), with the share of mono- and disaccharides up to 28%, which defines such diet as a pronounced carbohydrate type. Remarkably, the analyzed diets of young males in both groups were low in fiber (~4-5 g, as seen in *Table* 2, vs. the norm of 25—35 g per day).

Conclusion

Thus, our data confirmed that such factors as unbalanced diets with the increased proportion of mono- and disaccharides, and pronounced deficiency of fiber, vitamin D and chromium, and the reduced concentration of insulin in the blood have been the most substantial prerequisites for high blood glucose content in young men in the city of Magadan. These findings were more distinct in the group of indigenous population in Magadan Oblast, which was expressed in higher levels of glycosylated hemoglobin, along with excess of mono- and disaccharides in their diets by as much as 108%. We are confident in our assumption that this is a consequence of abandoning the traditional lifestyle by this ethnic group.

Funding

Our research was fulfilled at Arctic Scientific Research Center, Far East Branch of the Russian Academy of Sciences, with financial support by the Russian Federation budget within the framework of the project, *Examining intersystem and intrasystem mechanisms for the development of functional and adaptive reserves of a northern type* person at different ontogenetic stages *under discomfort and extreme living conditions with the determination of integral informative indicators of health* (registration No. AAAA-A21-121010690002-2).

Conflict of interest

The author declares no conflicts of interest.

Authorship

Research concept and study design; data collection; statistical data processing; data analysis and interpretation; writing and editing: I.V.A.

Ethical approval

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki for medical research involving human subjects, including research on identifiable human material and data (2013), with the informed consent of voluntary participants. The study protocol was approved by the Bioethics Committee at the Institute of the Biological Problems of the North, Far Eastern Branch of the Russian Academy of Sciences (No. 001/019 of 29 March 2019). Prior to the study, all volunteers gave their written informed consent.

References

1. Ogurtsova K, da Rocha Fernandes JD, Huang Y, Linnenkamp U, Guariguata L, Cho NH, Cavan D, Shaw JE, Makaroff LE. IDF Diabetes Atlas: Global estimates for the prevalence of diabetes for 2015 and 2040. *Diabetes Res Clin Pract* 2017; 128: 40-50. https://doi.org/10.1016/j.diabres.2017.03.024.
2. Averyanova IV, Maksimov AL, Borisenko NS Lipid and carbohydrate metabolisms in indigenous and Caucasian young males living in the Magadan Region. *Vestnik of Northern (Arctic) Federal University. Series "Medical and Biological Sciences"* 2016; (2): 5-15. Russian. https://doi.org/10.17238/issn2308-3174.2016.2.5.
3. Bojko ER Physiological and biochemical grounds for human vital functions in the North. Ekaterinburg: Ural Branch of RAS, 2005; 189. Russian. https://search.rsl.ru/ru/record/01002806123.
4. Panin LE Homeostasis and problems of circumpolar health (methodological aspects of adaptation). *The Bulletin of Siberian Branch of Russian Academy of Medical Sciences* 2010; 3(3): 6-11. Russian. https://www.elibrary.ru/item.asp?id=15112226.
5. Poteryaeva ON, Russkikh GS, Biushkina NG, Rozumenko AA, Zubova AV, Goltsova TV, et al. Analysis of serum insulin, cortisol, and glucose levels in the settlement inhabitants of the yamalo-nenets autonomous okrug. *Human Physiology* 2017; 43(6): 700-704. https://doi.org/10.1134/S0362119717060081.
6. Manchuk VT, Nadtochiy LA. The state and tendencies in the formation of the health in native people of the north and Siberia. *The Bulletin of Siberian Branch of Russian Academy of Medical Sciences* 2010; 30(3): 24-32. Russian. https://www.elibrary.ru/item.asp?id=15112229.
7. Matthews DR, Hosker P, Rudenski AS, Naylor BA, Treacher D, Turner RC. Homeostasis model assessment: Insulin resistance and β-cell function from fasting plasma glucose and insulin concentration in man. *Diabetologia* 1985; 28(7): 412-419. https://doi.org/10.1007/bf00280883.
8. The Norms of Physiological Requirements for Energy and Nutrients in Different Population Cohorts of the Russian Federation. The guidelines. MR 2.3.1.2432-08. Moscow, Russia: Federal Center of Hygiene and Epidemiology of Rospotrebnadzor. 2009; 39 p. Russian. https://fcgie.ru/download/elektronnaya_baza_metod_dokum/mr_2432-08.pdf.
9. Borovikov V. Statistics. The Art of Analyzing Data on a Computer: For Professionals. Moscow: Piter. 2003; 688 p. Russian. https://search.rsl.ru/ru/record/01001860859.
10. Poteryaeva ON, Russkikh GS, Mokrushnikov PV, Osipova LP, Tuzikov FV, Tuzikova NA. Hormonal status, lipid profile and membranes microviscosity of north residents. *Journal of Ural Medical Academic Science* 2014; (2): 149-152. Russian. https://www.elibrary.ru/item.asp?id=21615232.
11. Roden M, Price TB, Perseghin G, Petersen KF, Rothman DL, Cline GW, et al. Mechanism of free fatty acid-induced insulin resistance in humans. *J Clin Invest* 1996; 97(12): 2859-2865. https://doi.org/10.1172/jci118742.
12. Haylock SJ, Buckley PD, Blackwell LF Separation of biologically active chromium-containing complexes from yeast extracts and other sources of glucose tolerance factor (GTF) activity. *J Inorg Biochem* 1983; 18(3): 195-211. https://doi.org/10.1016/0162-0134(83)85002-8.
13. Mahan LK, Escott-Stump S, Raymond JL, eds. Krause's Food & the Nutrition Care Process, 13th ed. St. Louis: Saunders, 2012; 1248 p.
14. Manning PJ, Sutherland WH, Walker RJ. Effect of high-dose vitamin E on insulin resistance and associated parameters in overweight subjects. *Diabetes Care* 2004; 27(9): 2166-2171. https://doi.org/10.2337/diacare.27.9.2166.
15. Asayama K, Kooy NW, Burr IM. Effect of vitamin E deficiency and selenium deficiency on insulin secretory reserve and free radical scavenging systems in islets: Decrease of islet manganosuperoxide dismutase. *J Lab Clin Med* 1986; 107(5): 459-464. https://pubmed.ncbi.nlm.nih.gov/3517203.
16. Facchini F., Humphreys MH, DoNascimento CA, Abbasi F, Reaven GM. Relation between insulin resistance and plasma concentrations of lipid hydroperoxides, carotenoids, and tocopherols. *Am J Clin Nutr* 2000; 72(3): 776-779. https://doi.org/10.1093/ajcn/72.3.776.
17. Sung CC, Liao M., Lu KC, Wu CC Role of vitamin D in insulin resistance. *J Biomed Biotechnol* 2012; 2012: 634195. https://doi.org/10.1155/2012/634195.
18. Afzal S, Bojesen SE, Nordestgaard BG. Low 25-hydroxyvitamin D and risk of type 2 diabetes: A prospective cohort study and meta-analysis. *Clin Chem* 2013; 59(2): 381-391. https://doi.org/10.1373/clinchem.2012.193003.

19. Tsur A, Feldman BS, Feldhammer I, Hoshen MB, Leibowitz G, Balicer RD. Decreased serum concentrations of 25-hydroxycholecalciferol are associated with increased risk of progression to impaired fasting glucose and diabetes. *Diabetes Care* 2013; 36(5): 1361-1367. https://doi.org/10.2337/dc12-1050.
20. Talaei A, Mohamadi M, Adgi Z. The effect of vitamin D on insulin resistance in patients with type 2 diabetes. *Diabetol Metab Synd* 2013; 5(1): 8. https://doi.org/10.1186/1758-5996-5-8.
21. Sloboda Z, Glantz MD, Tarter RE. Revisiting the concepts of risk and protective factors for understanding the aetiology and development of substance use and substance use disorders: Implications for prevention. *Subst Use Misuse* 2012; 47(8-9): 944-962. https://doi.org/10.3109/10826084.2012.663280.

Authors:
Inessa V. Averyanova – DSc, Principal Researcher, Laboratory of Physiology of Extreme Conditions, Arctic Scientific Research Center, Far Eastern Branch of the Russian Academy of Sciences; Associate Professor, Department of the Physical Education, Sport and Basics of Medical Knowledge, North-Eastern State University, Magadan, Russia. https://orcid.org/0000-0002-4511-6782.