IS THE INCREASE IN THE INCIDENCE OF TYPE 2 DIABETES IN YAKUTIA DUE TO A DECREASE IN COLD EXPOSURE OR DIETARY CHANGES?

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Annotation. In Yakutia for 30 thousand years people live, and for centuries they were constantly fighting with the cold for survival [5, 6]. The Situation began to change only in the second half of the twentieth century. In 20-ies of the last century, a campaign for the reconstruction of traditional Yakut home began. As a result of the transition from Balagan (Yurts) to houses with stove heating, and then to centralized and gas heating, the temperature inside residential buildings has significantly increased. A fairly extensive literature has now accumulated linking rising residential temperatures with obesity-related morbidity.

In order to determine the role of climate warming, an increase in the average temperature in the houses of the region, and changes in the diet on the incidence of type 2 diabetes, we built a multiple regression equation with 10 factors over 20 years (1994-2013). The following factors were included in the multiple regression model: the average annual temperature in Yakutsk, the average temperature of houses in the region during the heating period, the consumption of vegetables, fruits, sugar, proteins, fats, carbohydrates per year per person, and the daily calorie content of the diet.

The conducted studies made it possible to find out that there are positive linear statistically significant pair correlations between the incidence of DM2 and the consumption of fruits and berries, the average housing temperature, the consumption of vegetables and melons, and the calorie content of the diet, but when analyzing multiple regression, the role of each factor in the development of DM2 turns out to be statistically unreliable, except the level of consumption of fruits and berries (at $p > 0.05$). It should be noted that a sharp increase in the incidence of DM2 in the population of Yakutia (including indigenous people) is associated with many factors, but the role of increased consumption of fruits and berries in its development should be considered causal, probably due to the lack of adaptation of the body of northerners to intake of large amounts of fructose, with a high level of fat intake.

Keywords: diabetes mellitus type 2, multiple regression analysis, dependent variables, independent variables, housing temperature, consumption of fruits, vegetables, proteins, fats, carbohydrates, dietary calories.

Introduction. Yakutia is located in the north-eastern part of Siberia. It is included in the Far Eastern Federal District of the Russian Federation and covers an area of 3.1 million square km. More than 40% of the country lies within the Arctic Circle, and more than 50% within a mean of annual temperature isotherm -10 °C, and almost all the territory within the isotherm of mean annual temperature -5 °C. Steady daily temperature is below 0 °C and lasts for 8 months.

Yakutia is cold pole of the Northern Hemisphere. In the Northern Hemisphere, in Verkhoyansk it was recorded the lowest temperature in the world equal to -67,8 °C by the exiled revolutionary, on January 15, 1885 by S.F. Kovalik, a native of Poltava province, a candidate of Mathematical Sciences. It was used a special alcohol thermometer weather station, which was built by A. Bunge, doctor of medicine in Verkhoyansk in 1884. In 1986, these data have been officially registered in the main physical Observatory of Russia as an absolute minimum on the globe in the Northern Hemisphere [1].

Cold is the main problem of the northern territories, limiting the activity of human body and human activities in the North [2, 3, 4]. In defence of cold, the body invented the complex system of thermoregulation. To the human body, the optimum temperature is 36,7 °C, the minimum deviation from which leads to undesirable consequences.

In Yakutia for 30 thousand years people live, and for centuries they were constantly fighting with the cold for survival [5, 6]. Situation began to change only in the second half of the twentieth century. In 20-ies of the last century, a campaign for the reconstruction of traditional Yakut home began. According to the conclusion of the Commission of Academy of Science of the USSR in study of Yakut ASSR «Living conditions – yurta with khoton - is one of the main negative health circumstances» [7]. According to the plan of the Commission of Academy of Science the new construction and reconstruction of, 45903 conventional dwellings and outbuildings would be held in Yakutia [7]. It should be noted that the temperature in a traditional home in the winter time can range from 15 °C to 0 °C. On this occasion P.N. Sokolnikov and colleagues wrote in 1913: "From a hygienic point of view, the Yurt with Khoton and the glitter and glow of fireside evenings and chill in the morning does not hold water" [8].

The final conversion of traditional dwelling in livestock regions of Yakutia only ended by the end of the 50s of the last centuries. The transition of villagers from Yurts on log houses with wooden floors, glass windows and furnace heating raised thermal comfort at homes during the winter. Depending on the ambient temperature, the temperature in log houses with stove heating ranges from 15 °C to + 23 °C. At the beginning of 1999 gasification of rural settlements of Yakutia started. By the beginning of gasification in 1998 in rural areas, only 26.9% of the housing stock had central heating, and 73.1% of the housing countryside had furnace heating [9]. A fairly extensive literature has now accumulated linking rising residential temperatures with obesity-related morbidity [10].

In Yakutia, since 2000, obesity and related morbidity began to grow: metabolic syndrome, diseases of the circulatory system (BSC) of atherosclerotic genesis and especially type 2 diabetes mellitus. According to N.S. Yagya in 1988 the incidence of the region's population with diabetes was 0.1 per 1,000 of population [11], in 2013 it rose to 3.2 per 1,000 population or by 32 times. K.R. Sedov, well-known researcher in health status of the Arctic latitudes, Academician of AMS USSR in 60-70 years reported that there was no diabetes among the indigenous inhabitants of the North [12].

Methods and results. We measured the temperature inside a private residential building with gas heating during the heating season in Yakutsk from September 15, 2021 to May 15, 2022 in the morning. The average temperature was determined by

Table 1. Is there an association with the incidence of diabetes and housing temperature?

Period	Type of home heating	Mean t° of housing	Incidence rate of diabetes
before 1950	Balagan (yurt)	12,5 °C*	Extremely rare, and not found in some populations [11]
until 1991	House with furnance heating	19 °C*	0,1 per 1000 population [12]
after 1991	House with central and gas heating	24,1 °C**	up to 3.5 per 1000 population

 * Expert opinion; ** own data (average t° measurement value of a private house with gas heating from September 15 to May 15. Measurement data in Supplementary Materials).

summing all measurements by their number. The average temperature inside residential buildings before 1950 and before 1991 was determined by expert assessment, taking into account existing literary sources (Table 1).

In order to determine the role of climate warming, an increase in the average temperature in the houses of the region, and changes in the diet on the incidence of type 2 diabetes, we built a multiple regression equation with 10 factors over 20 years (1994-2013). The following factors were included in the multiple re-gression model: the average annual temperature in Yakutsk, the average temperature of houses in the region during the heating period, the consumption of vegetables, fruits, sugar, proteins, fats, carbohydrates per year per person, and the daily calorie content of the diet (Table 2). The calculation was made using the online calculator https://math.semestr.ru (accessed 06.06.2022).

The final multiple regression model we built consisted of the dependent variable y and five independent variables: x_2, x_6, x_7, x_8, x_{10} (see Table 3). As a result of the anal-ysis, from the initial model, consisting of 10 independent variables, 5 of them with a low partial F-test were excluded as not playing a significant role in the development of T2DM (for more details, see Supplementary material).

According to the obtained data, pairwise correlation coefficients were significant between the incidence of type 2 diabetes mellitus and the level of consumption of fruits and berries (Fig. 1) and the average temperature of houses (Fig. 2).

Table 2. Data of analyzed variables

Year	y	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
1994	0,4	-9.6	22,2	61	81	291	2143	44	18	23	6
1995	0,5	-7.6	22,2	55	67	264	1890	43	20	22	5
1996	0,6	-8.8	22,3	56	67	270	1916	35	17	19	5
1997	0,6	-8.1	22,4	52	70	265	1905	38	17	24	7
1998	0,6	-8.7	22,4	61	77	315	2203	42	13	20	11
1999	0,5	-8.9	22,3	69	99	367	2645	54	16	36	17
2000	0,5	-9.1	22,5	65	88	316	2305	48	18	20	12
2001	0,8	-8.7	22,4	66	83	347	2402	41	20	22	12
2002	0,9	-7.6	22,4	69	93	355	2543	48	29	24	13
2003	1,1	-8.0	22,4	69	93	360	2557	49	29	23	11
2004	1,3	-9.8	22,5	70	97	367	2627	54	30	26	13
2005	1,6	-7.7	22,7	74	100	368	2672	58	49	31	12
2006	2,1	-8.8	22,6	71	97	345	2544	51	45	30	12
2007	1,8	-7.3	22,7	68	90	306	2314	46	47	24	10
2008	1,8	-7.2	22,7	71	92	319	2399	48	50	25	10
2009	2,2	-7.7	22,7	72	96	317	2430	48	49	26	11
2010	3	-7.7	22,7	77	105	341	2626	60	64	28	11
2011	2,8	-7.3	22,8	77	103	337	2593	67	62	28	11
2012	2,8	-7.8	22,8	77	103	337	2594	62	60	29	11
2013	3,2	-7.4	22,8	79	106	334	2618	60	60	29	11

y – incidence of type 2 diabetes mellitus (DM2) per 1000 population;

x_1 – average annual temperature in Yakutsk, in °C;

x_2 – average temperature of houses during the heating season (calculated on the basis of empirical and expert estimates and statistical data on the housing conditions of the population, depending on the heating of housing with stove and central (gas) heating. Calculation methods in Supplementary materials) °C;

x_3 – proteins in the diet, g;

x_4 – carbohydrates in the diet, g;

x_5 – fats in the diet, g;

x_6 – caloric content of the diet, in kcal;

x_7 – consumption of vegetables and melons, in g;

x_8 – consumption of fruits and berries, in g.;

x_9 – consumption of sugar and confectionery products, in g;

x_{10} – consumption of vegetable oil and other fats, in g.

Table 3. Matrix of paired correlation coefficients R with 5 independent variables

-	y	x_1	x_2	x_3	x_4	x_5
y	1	**0.9056**	0.6002	0.7704	**0.9692**	0.2083
x_1	**0.9056**	1	0.6029	0.7131	**0.9191**	0.3171
x_2	0.6002	0.6029	1	0.8161	0.6082	0.8264
x_3	0.7704	0.7131	0.8161	1	0.7783	0.5164
x_4	**0.9692**	**0.9191**	0.6082	0.7783	1	0.1899
x_5	0.2083	0.3171	0.8264	0.5164	0.1899	1

y – incidence of type 2 diabetes mellitus (DM2) per 1000 population;
x_1 – average temperature of houses during the heating season in °C;
x_2 – caloric content of the diet, in kcal;
x_3 – consumption of vegetables and melons, in g;
x_4 – consumption of fruits and berries, in g.
Chaddock's scale for assessing the strength of the relationship of the correlation coefficient:
$0.5 < r_{xy} < 0.7$: significant;
$0.7 < r_{xy} < 0.9$: high;
$0.9 < r_{xy} < 1$: very high.

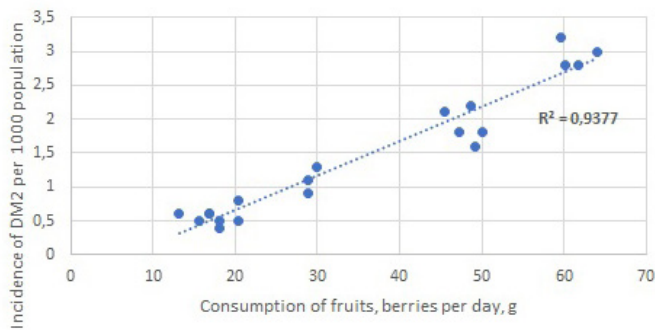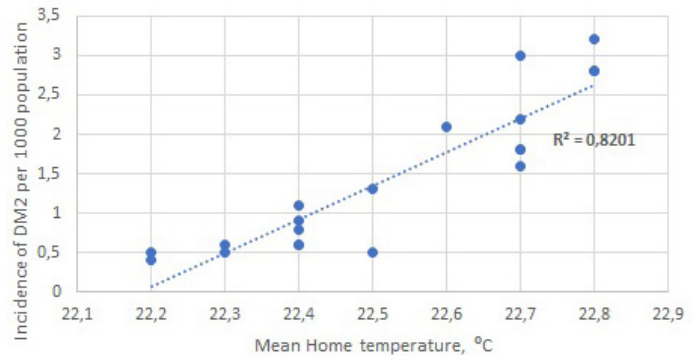Fig. 1. The level of consumption of fruits, berries and the incidence DM2

Fig. 2. Mean Home temperature and incidence of DM2

According to the calculations, the statistical significance of the regression coefficient in the multiple regression model with 5 independent variables (see Table 3) was confirmed only for the independent variable x_4 – consumption of fruits and berries per day (g.), at $p<0.05$ (for details, Supplementary material).

It should be noted that, according to literature sources, fructose abuse is a driver of diabetes development [13]. A number of researchers consider it a metabolic toxin [14]. It is known that the indigenous population of Yakutia up until the October Revolution of 1917 consumed berries containing fructose in small quantities, but never consumed fruits rich in this monosaccharide.

Conclusion. Thus, there are positive linear statistically significant pair correlations between the incidence of DM2 and the consumption of fruits and berries, the average housing temperature, the consumption of vegetables and melons, and the calorie content of the diet, but when analyzing multiple regression, the role of each factor in the development of DM2 turns out to be statistically unreliable, except the level of consumption of fruits and berries (at $p > 0.05$). It should be noted that a sharp increase in the incidence of DM2 in the population of Yakutia (including indigenous people) is associated with many factors, but the role of increased consumption of fruits and berries in its development should be considered causal, probably due to the lack of adaptation of the body of northerners to intake of large amounts of fructose, with a high level of fat intake.

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Contributions. All co-authors contributed equally to the work and have read and approved the final version of the manuscript before publication.

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