Nutritional status of polluted region: evaluating student food diary

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Abstract. The purpose of the study was to explore food diaries to identify differences in the received nutrients between students living in a relatively ecologically safe area and polluted region. The sample included 179 participants living in Stavropol (ecologically safe area) and Nevinnomyssk (polluted region) at the age of 17 to 23 years. Dietary intake was estimated using a 7-days food diary and nutrient intake adequacy using the computer program "Nutrition for health and longevity". Participants did not significantly differ in age, gender, height and weight. There were total caloric and nutrients shortage in most of all students, regardless of the residence. Reduced fat consumption and pronounced deficiency of biotin, beta-carotene, choline, vitamins A, C, B6, B12, D, I, manganese, Fe, S, F, Se and Zn was found. Severity of protein, niacin, K, Ca, Mg and P deficiency in diet was higher in polluted area compared to the relatively ecologically safe area. In this regard, there are several related issues that need to be addressed in the future. These are the intake of heavy metals from food, the production and use of environmentally friendly food, and the development of functional products for students and residents of polluted regions.

1. Introduction
In an ecologically unfavourable region, people are exposed to chronic exposure to various environmental pollutants. The intake of pollutants in the human body may change at different times of life, but some of these substances can accumulate in organs and tissues. The presence of heavy metals (Cd and Pb) and micronutrient deficiency (Zn, Fe) in adolescents hair and nails in the region with high chemical pollution (Nevinnomyssk) compared to a relatively non-polluted region (Stavropol) was revealed [1]. Obtained results strongly correlated with overload of the heart central regulatory mechanisms and the predominance of the sympathetic nervous system. The study of soil and plant samples during the long-term monitoring of the Nevinnomyssk industrial zone revealed different concentrations of pollutants like Cd, Ni, Pb [2].
In previous studies we have identified hormonal and rhythmic disorders of functions in residents of the polluted region. An increase of cortisol and testosterone level in adolescents and adult men saliva, with the disappearance of circadian rhythm fluctuations was found. Increase of daytime sleepiness and reduced sleep hygiene was typical for residents living in conditions of the toxic stress [3]. The increase in cortisol levels can alter eating behavior [4] and perception of taste [5]. The level of testosterone also changes the taste perception [6]. Recent studies using questionnaires and objective methods have shown a significant association between exposure to cadmium and taste and smell disorders [7]. The concentration of cadmium in the smoker’s blood is increased and is negatively associated with the consumption of fruit, vitamin C and fiber. However there is no data on nutrient consumption in polluted regions.

Special attention should be paid to young students because nutrition is an important factor that ensures the implementation of academic loads and the formation of necessary skills. Currently, the diet of young people aged 17–23 years is subject to changes due to adaptation to social factors including sleep and rest disbalance, and therefore the regime and composition of food [8]. For people living in a polluted region, it is very important to obtain the composition of products to provide the body with all the necessary nutrients.

We have proposed a hypothesis that students living in conditions of environmental pollution under the influence of toxic substances and changes in the level of hormones can choose food products in accordance with the changed eating behavior. Students can choose foods with a less useful composition and as a result have more pronounced signs of deficiency of certain food components.

The purpose of this study was to assess the nutritional status of students in relatively environmentally safe and polluted regions according to food diaries.

2. Materials and methods

The research involved 179 students aged 17 to 23 years. There were control and experimental groups. The control group consisted of 103 students from Stavropol (a relatively environmentally safe region). In the experimental group, there were 76 students lived in Nevinnomyssk (a polluted region). The inclusion criteria in this study were young men and women attending high school, aged 17–23 years, physically and mentally healthy. The exclusion criterion was the presence of chronic diseases.

Before collecting data, the following were guaranteed to participants: compliance within formation standards, confidentiality, and ethics in data processing. All subjects gave their informed consent for inclusion prior to participating. Each participant in the study provided personal data (sex, age, height, weight). Body mass index (BMI) was calculated as weight in kilo-grams divided by height in meters squared. Participants were asked about state of health, physical, intellectual, mental and environmental stress. Smoking habits, alcohol consumption and dietary supplements were identified was estimated using a questionnaire. Taste preferences were evaluated by scale of taste priority. The purpose of this study was to assess the nutritional status of students in relatively environmentally safe and polluted regions according to food diaries.
Mann-Whitney U test was used to compare independent groups. p-Values <0.05 were deemed significant.

3. Results and discussion

3.1. Sample characteristics

The study sample consisted of 82 female and 21 male from the relatively environmentally safe region and 49 female and 27 male from the polluted area. The gender representation was uniform and did not differ significantly between groups (table 1). The average age of the respondents was about 20 years and did not differ between groups. There was no significant difference by height, weight and BMI among Stavropol and Nevinnomyssk residents. The obtained data indicates the homogeneity of the groups.

We found no differences in the frequency of smoking and alcohol consumption between groups. There were some differences in taste perception. Residents of polluted area preferred the sour taste of the food (p<0.0001). The salty, sweet and bitter taste was chosen equally in both groups. There were no significant differences in changes in appetite in the situation perceived by respondents as stressful. The energy value of the diet of people living in both regions was lower than the recommended norm.

Table 1. Descriptive data of the participants (N=179).

|                      | Stavropol (environmentally safe region) | Nevinnomyssk (polluted area) | P    |
|----------------------|----------------------------------------|-------------------------------|------|
| Age                  | 20.2±1.6                               | 19.6±0.5                     | 0.08 |
| Height               | 169.6±8.2                              | 169.8±8.9                    | 0.96 |
| Weight               | 61.0±13.3                               | 60.8±12.4                    | 0.58 |
| BMI                  | 21.2±4.2                               | 21.0±3.1                     | 0.48 |

3.2. Nutrients insufficiency

According to the results of the analysis of food diaries there is a nutrients insufficiency regardless of the region of residence (table 2). The majority of students (97–100%) did not receive phospholipids, vitamins and minerals from food: biotin, choline, vitamin D, iodine, cobalt, manganese, sulfur, fluorine, and zinc. We discovered deficit of polyunsaturated fatty acids, vitamins A, B12, B6 and iron for 89-100% of the examined patients. In addition, approximately 50% of the respondents showed reduced fat consumption and more than 90% of the survey participants preferred low carbohydrate consumption.

Lower median values of particular macronutrients were found in the polluted region when compared with the control group. The median protein intake indicated adequate intake relative to the individual norm, but compared with the control, the intake was significantly lower (p<0.001). Fat consumption in residents of the polluted region was below the norm and is characterized by a downward trend without significant differences from the control. Carbohydrate intake in both groups was significantly lower than the calculated norms and there were no differences between groups. The total caloric content of the daily diet in Stavropol averaged -32.2 (-47.7; -5.7)% from the norm, and in a Nevinnomyssk it was -22.2 (-46.9; 11.9)% (p>0.05). This indicates a lack of calories in the diet below the recommended norm.

The majority of vitamins in the diet of students were found to be deficient in both regions. The most pronounced lack of vit D, vit A, vit B12 and biotin in the consumed food was found. At the same time deficiency of vit A (p<0.05), vit C (p<0.05), vit D (p<0.05) and niacin (p<0.001) was significantly expressed in Nevinnomyssk.

Residents of Stavropol consumed with food such macronutrients as potassium, calcium, magnesium and phosphorus in the recommended amount. At the same time the significance lack of these macronutrients in the diet of residents of Nevinnomyssk was revealed. The level of trace elements in food.
All subjects are characterized by eating food with insufficient content of trace elements. However, differences in the content of specific trace elements in the diet of residents of the studied regions are characterized by heterogeneity. The degree of severity of the lack of trace elements in Nevinnomyssk is significantly higher for Se ($p<0.0001$), does not differ for Fe ($p>0.05$) and I ($p>0.05$), and lower for S ($p<0.001$), Mn ($p<0.0001$), F ($p<0.05$), Zn ($p<0.05$)

### Table 2. Actual nutrient intake from the norm (%): data of the food diary.

| Nutrient         | Actual nutrient intake from the norm (%) | Stavropol (environmentally safe region) | Nevinnomyssk (polluted area) |
|------------------|-----------------------------------------|---------------------------------------|-------------------------------|
|                  | Me $X_{25}$; $X_{75}$                   | Me $X_{25}$; $X_{75}$                 | p                             |
| Protein          | 49.3; -4.8; 97.8                        | 6.9; -35.7; 44.4                      | 0.000                         |
| Fat              | 1.3; -31.7; 37.1                        | -15.4; -38.2; 27.0                   | 0.099                         |
| Carbohydrate     | -65.1; -78.9; 39.2                     | -63.9; -81.4; -45.3                  | 0.542                         |
| Fiber            | 81.8; -63.3; 245.9                      | -17.2; -50.7; 62.7                   | 0.277                         |
| Phospholipid     | -72.7; -83.0; 55.9                     | -69.3; -83.4; -55.4                  | 0.364                         |
| Beta-carotene    | -59.3; -73.6; -29.8                    | -36.9; -48.9; -1.9                   | 0.000                         |
| Vitamin A        | -80.4; -89.1; -64.0                    | -86.3; -94.4; -77.5                  | 0.003                         |
| Vitamin B6       | -49.4; -63.9; -27.4                    | -43.5; -67.1; -17.9                  | 0.674                         |
| Vitamin B12      | -81.6; -93.3; -30.0                    | -83.5; -94.9; -66.0                  | 0.069                         |
| Thiamine         | -43.8; -70.4; 15.0                     | -53.0; -75.3; -28.3                  | 0.248                         |
| Riboflavin       | -44.7; -56.5; 14.6                     | -27.9; -55.0; -4.6                   | 0.515                         |
| Ascorbic acid    | -16.5; -51.3; 20.3                     | -38.7; -62.5; -7.5                   | 0.014                         |
| Vitamin D        | -82.5; -98.1; -55.4                    | -98.8; -100.0; -75.9                 | 0.001                         |
| Vitamin E        | -35.9; -63.8; -13.2                    | -22.7; -55.3; 10.6                   | 0.109                         |
| Niacin           | 22.6; -28.7; 80.6                      | -56.2; -71.8; -38.2                  | 0.000                         |
| Biotin           | -99.5; -99.7; -99.2                    | -99.3; -99.6; -98.7                  | 0.017                         |
| Choline          | -78.3; -87.1; 71.3                     | -71.8; -82.3; -56.9                  | 0.009                         |
| K                | 3.6; -52.6; 68.5                       | -51.4; -67.2; -30.2                  | 0.000                         |
| Ca               | 30.9; -37.3; 107.1                     | -43.7; -61.9; -14.9                  | 0.000                         |
| Mg               | 8.6; -50.7; 84.9                       | -56.4; -73.5; -39.5                  | 0.000                         |
| Na               | -45.6; -65.6; -22.1                    | -49.2; -69.6; -12.6                  | 0.741                         |
| S                | -80.0; -89.1; 72.6                     | -76.1; -83.4; -61.9                  | 0.007                         |
| P                | 58.8; -14.8; 161.4                     | -2.4; -43.3; 32.7                    | 0.000                         |
| Iron             | -57.9; -73.3; -36.1                    | -49.6; -68.4; -25.5                  | 0.356                         |
| I                | -87.1; -92.6; 74.1                     | -87.6; -94.3; -79.9                  | 0.327                         |
| Mn               | -67.7; -84.1; -45.1                    | -49.7; -75.9; -11.6                  | 0.000                         |
| F                | -95.9; -94.5; -94.1                    | -94.8; -96.4; -90.4                  | 0.025                         |
| Zn               | -77.8; -86.6; 65.8                     | -72.1; -81.9; -56.4                  | 0.044                         |
| Se               | -50.6; -62.7; 32.5                     | -99.9; -100.0; -99.7                 | 0.000                         |

### 4. Discussion

Our study showed significant associations between living in a region with or without pollution and nutrients insufficiency according to food diary. According to the individual calculation of the consumed nutrients level and compared with the recommended norms of food substances, there is a deficit of nutrients in the entire population of students. Our findings were consistent with our previous studies in Stavropol region [8], studies in Russia [10] and other countries [11], [12] and indicate that students have nutritional disorders and lack of nutrients. Most nutrients were deficient in all students, regardless of the region. In the relatively environmentally safe region, consumption rates of beta-carotene, biotin, choline, sulfur, manganese, fluorine, zinc were significantly reduced. The deficit of the nutrients was found in 90-100% of food diary from the Stavropol and in 75-100% of food diary in the polluted area.
Deficiency of most trace elements and vitamins like iodine, cobalt, iron, vitamin B6 and vitamin B12 was found in both regions. The lowest content in the diet of foods with a high content of vitamins A, C, D and selenium was typical for the polluted region. The results are consistent with the deficiency of vitamins D, K and beta-carotene in modern first- and second-year medical students [13] and the vitamin D deficiency in individuals from polluted region [14]. Reduced consumption relatively to the Russia RDA of vitamins B2, C and A took place in 63,54 and 46% of the students respectively [15].

A number of nutrients in the polluted region were consumed in insufficient quantities (the calculated median % was negative), and in the control group they were received at a sufficient level. These nutrients included niacin, K, Ca, Mg, and P. This is not described in the available literature. A relationship between nutritional intake from nutrition questionnaires during pregnancy and levels of lead and cadmium in the blood during different trimesters was described [16]. Consumption of thiamine was negatively associated with blood lead content, while consumption of fat, niacin, vitamin B12, folic acid and zinc was positively associated with blood cadmium levels [16].

The detected lack of protein consumption in the polluted region is not described in the available literature. When evaluating taste preferences it was found that sour taste was preferred in the polluted region which is consistent with a decrease in the perception of this taste under stress [17].

The comprehensive appetite control model currently combines cognitive, homeostatic, and reward mechanisms [18]. According to this theory, the level of serotonin in the brain plays an important role in eating behavior. We suggest the participation of serotonin as one of the pathways in changing eating behavior and reducing protein consumption in the polluted area. Previously, in animal experiments when simulating a decrease in serotonin concentration in the brain, a decrease in protein consumption by 20-30% was found [19]. The choice of nutrition based on serotonin levels has been confirmed in studies involving volunteers. A serotonin reuptake inhibitor was studied to choose between foods that differed in taste and perceived as healthy food, compared to placebo and a norepinephrine reuptake inhibitor. The results confirm the role of serotonin in influencing food choices [20]. In animal experiments when food intake of cadmium with water the level of serotonin decreased in the hypothalamus and its exchange in the posterior hypothalamus was disrupted [21].

5. Conclusion

The study revealed the presence of nutritional deficiencies of vitamins and trace elements in students, regardless of the region of residence. The eating behavior of Russian students is characterized by a low-calorie diet and the choice of a certain group of products and minimal consumption of vegetables and fruits. According to our data, for the first time in a polluted region, students show insufficient consumption of protein, niacin, K, Ca, Mg, P in comparison with a relatively environmentally safe region. This indirectly indicates changes in food preferences and eating behavior based on possible neuroendocrine changes. This hypothesis requires further study.

In this regard, there are several related issues that need to be addressed in the future. These are the intake of heavy metals from food, the production and use of environmentally friendly food, and the development of functional products for students and residents of polluted regions.

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