

## ESPECIALLY THE CONTENT OF ESSENTIAL SUBSTANCES IN THE BODY OF MODERN SCHOOLBOYS

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Modern children aged from 12 to 17 years often have various health problems [1]. One of the main factors leading to aggravation is nutrition [2]. Primarily, nutrition can influence the parameters of antioxidant status of the child organism [3]. The aim of the study was to investigate the antioxidant status of urban and rural schoolchildren, and their actual nutrition. Antioxidant status was analyzed studying the content of vitamins A, E in schoolchildren biological media, using the fluorometry method, the content of vitamin C, using the visual titration method. The received data testifies that vitamins A, E, ascorbic acid, copper, chromium, ferrum deficiency. That is why it is necessary to correct redox equilibrium parameters developing methodological and organizational approaches to the optimization of urban and rural schoolchildren nutritional status.

**Keywords:** antioxidant status, actual nutrition diet, oxidative stress

### Materials and methods of research

The investigation included the study of especially the content of essential substances in the body of urban ( $n = 250$ ) and rural ( $n = 200$ ) schoolchildren. Each group was divided into two age subgroups – schoolchildren aged from 12 to 14 years ( $n = 150$  among urban and  $n = 100$  among rural schoolchildren) and learners aged from 15 to 17 years ( $n = 100$  among urban and  $n = 100$  among rural schoolchildren). The study was conducted in accordance with the ethic standards, covered by the World Medical Association's Declaration of Helsinki (Seoul, 2008), in particular, informative consents of the parents of the schoolchildren were received. The present study was also approved by the local ethic committee of the SBEI of HPE OrSMU of the Ministry of Health of Russia. The quantitative content of ascorbic acid in morning urine was identified by the visual titration method using the oxidation-reduction reaction with Tillman's reagent (2,6-dichloroindophenol sodium derivative). Total protein level was identified with the help of the method, based on biuret test; albumen level, with the help of colorimetric method with bromocresol green (BCG) in acidic media. Total cholesterol level (TC) and high-density lipoprotein cholesterol (HDL cholesterol) level were identified using direct enzymatic colorimetric method with cholesterol esterase and peroxidase. Triglyceride level (TGs) was identified with the help of enzymatic colorimetric method with glycerophosphoric oxidase; low-density lipoprotein cholesterol (LDL cholesterol), using Friedewald formula (1972).

### Results of research and their discussion

All in all, while evaluating the condition of antioxidant defense we need to take into account that it is characterized by the low level of lipid antioxidant factor – content of vitamins A, E in blood serum, which protect fatty acids from peroxidation in plasma and membrane structures (especially tocopherol) [12]. The urban schoolchildren experience fat-soluble vitamins deficiency in a greater degree than the rural schoolchildren. The content of retinol in blood serum of the urban schoolchildren aged from 12 to 14 years was 26,7% lower than the physiological norm, aged from 15 to 17 years – 20,0% lower than the physiological norm; it is 1,3 times lower than in the rural schoolchildren (Table 1). The content of tocopherol in blood serum of the urban learners aged from 12 to 14 years was  $6,98 \pm 0,25$  mcg/hour that is 12,8% lower than the physiological norm, aged from 15 to 17 years –  $7,22 \pm 0,17$  mcg/hour and 9,8% lower than the physiological norm. As for the rural learners, the content of tocopherol  $7,46 \pm 0,09$  mcg/hour in 12–14 years age group and  $7,22 \pm 0,08$  mcg/hour in 15–17 years age group, that is respectively 6,8 and 9,8% lower than the physiological norm.

Content of vitamins A, E, C in urban and rural schoolchildren

**Table 1**

Age group, years		Vitamins		
		A	E	C
		Physiological norm		
		0,3–0,7 mcg/ml	8–12 mcg/ml	0,7–1,0 mg/hour
12–14	urban	$0,22 \pm 0,01$	$6,98 \pm 0,16$	$0,724 \pm 0,01$
	rural	$0,28 \pm 0,01^*$	$7,46 \pm 0,09^*$	$0,596 \pm 0,02^*$
15–17	urban	$0,24 \pm 0,01$	$7,22 \pm 0,17$	$0,713 \pm 0,01$
	rural	$0,27 \pm 0,01^*$	$7,22 \pm 0,08$	$0,615 \pm 0,01^*$

Note. \* $p \leq 0,05$  while comparing the data of urban and rural schoolchildren inside each age group.

The received data about the content of fat-soluble vitamins in the blood of the urban and rural learners show the unstable balance of antioxidant defense, forming oxidative stress, which can lead to nucleic acids, proteins and lipids damage. A positive predisposing factor of oxidation-reduction balance formation in the urban schoolchildren is considered to be a level of ascorbic acid ( $0,724 \pm 0,01$  mg/hour in the learners, aged from 12 to 14 years and  $0,713 \pm 0,01$  mg/hour in the learners, aged from 15 to 17 years, physiological norm of this age group is 0,700–1,000 mg/hour). This acid is a hydrophilic nonenzymatic antioxidant, which has a strongly pronounced restoring capacity and is oxidized to dehydrogenated form due to 2 electrons and 2 protons recoil (Table 2). At the same time, the level of ascorbic acid in rural schoolchildren appeared to be lower than the physiological norm minimum limit. In learners aged from 12 to 14 years it was  $0,596 \pm 0,02$  mg/hour, that is 14,8% lower than the physiological norm, and in learners aged from 15 to 17 years –  $0,615 \pm 0,01$  mg/hour and 12,1% correspondingly. The higher content of vitamin C in urban schoolchildren compared to rural ones can also be the cause of higher antioxidant defense power of learners, living in urban areas. Moreover, physiological level of ascorbic acid in urban learners provides ROS direct reduction as well as recovery of tocopherol oxidized forms caused by neutralization of membrane lipids free radicals. Under that logic, decreased content of vitamin C on the back of tocopherol deficiency in the rural children can contribute to the developing oxidative stress in the organism.

Antioxidant defense system of the organism is one of the main constituent parts of its adaptive function and a multicomponent cluster of different antiradical mechanisms [13]. Evidently, many biochemical processes, aimed at organism adaptation to exogenous factors

need energy stored in ATP. These biochemical processes may be synthesis of complex chemical compounds from simpler ones (anabolism reaction), muscle activity (mechanical work), transmembrane potential production, active transport across biological membranes. It is known that riboflavin is necessary for full tissue respiration, during which the main energy resource of ATP cell is synthesized. Riboflavin is found in prosthetic groups of flavin mononucleotide coenzymes and flavin adenine dinucleotide (FAD), also oxidase and reductase; performs redox reactions during cell oxidation. Taking into account that B vitamins can influence antioxidant status processes, it was stated that in the urban and rural schoolchildren of any age riboflavin content was 8,9–11,9% lower than physiological norm. But in the rural children aged from 15 to 17 years renal excretion of this vitamin was  $14,2 \pm 0,24$  mcg/hour, i.e. lower limit of normal (Table 2).

Considering the fact that antioxidant defense of organism includes SOD, catalase, peroxidase and other enzymes, it becomes clear that amino acid exchange disorder or amino acid deficiency can affect synthesis of these enzymes. Stated that schoolchildren had sufficient level of protein (it was  $75,6 \pm 2,09$ – $77,2 \pm 1,9$  g/l in the urban children and  $75,1 \pm 4,44$ – $76,6 \pm 4,05$  g/l in the rural children). Higher level of albumin was found in 45–51,8% of the urban learners and 4–14,7% of the rural ones, considering that average member of protein in the urban learners was 9,6–32,5% higher than in the rural ones. Albumin deficiency was found only in 16% of the rural schoolchildren, aged from 12 to 14 years. Nevertheless, studied learners had the risk of amino acid metabolism disorders, presented by aneurine and pyridoxine deficiency, which lead to enzyme synthesis disorder, taking part in antioxidant defense. Stated that only the rural

Table 2

Content of B vitamins in urban and rural schoolchildren

Age groups, years		Vitamin		
		B1	B2	B6
		Physiological norm		
		15–35 mcg/hour	14–30 mcg/hour	40–60 mcg/hour
12–14	urban	$20,42 \pm 0,49$	$12,34 \pm 0,37$	$41,11 \pm 0,80$
	rural	$12,58 \pm 0,25^*$	$13,68 \pm 0,32^*$	$37,92 \pm 0,57^*$
15–17	urban	$21,3 \pm 0,39$	$12,76 \pm 0,41$	$40,33 \pm 0,64$
	rural	$13,19 \pm 0,2^*$	$14,2 \pm 0,24^*$	$37,4 \pm 0,37^*$

Note. \*p < 0,05 while comparing the data of urban and rural schoolchildren inside each age group.

schoolchildren had aneurine deficiency. In the children of 12–14 years it was 16,1% lower than the physiological norm ( $12,58 \pm 0,25$  mcg/hour), in the children of 15–17 years – 12,1% lower ( $13,19 \pm 0,20$  mcg/hour) (Table 2). Pyridoxine deficiency in the rural learners aged from 12 to 14 years was 94,8% of the physiological norm, in the learners aged from 15 to 17 years – 93,5%. The tendency to decrease of aneurine level was identified in the organism of the rural schoolchildren compared to the urban learners of any age. Aneurine content in the urban schoolchildren of 12–14 years was  $20,42 \pm 0,49$  and  $12,58 \pm 0,25$  mcg/hour in the rural ones ( $p \leq 0,05$ ); in the urban learners of 15–17 years –  $21,3 \pm 0,39$  mcg/hour and in the rural ones –  $13,19 \pm 0,2$  mcg/hour ( $p \leq 0,05$ ). As for pyridoxine content in the organism of urban and rural schoolchildren, the same pattern occurred. The level of riboflavin content, on the contrary, showed its growth in the rural learners compared to the urban ones ( $12,34 \pm 0,37$  mcg/hour in the urban children of

12–14 years and  $12,76 \pm 0,41$  mcg/hour in the rural ones,  $p \leq 0,05$ ;  $13,68 \pm 0,32$  mcg/hour in the urban children of 15–17 years and  $14,2 \pm 0,24$  mcg/hour in the rural ones,  $p \leq 0,05$ ).

It is important to say that from 78,3 to 93,1% of urban schoolchildren and from 44 to 55,9% of rural ones have higher level of low density lipoproteins; from 51,7 to 69,6% of urban and from 91,2 to 92% of rural learners have increased level of total cholesterol. Besides, the additional factor of atherogenecity in the urban schoolchildren was the fact that 91,3–93,1% of them had increased level of triacyglyceride, but this index was 14,8 and 17,1% lower in the rural learners aged from 15 to 17 years and from 12 to 14 years respectively. At the same time, decreased level of high density lipoproteins was stated in 45% of urban learners and 42–47% of rural learners. The increased level of this index was indicated in the urban learners and it was 22–49% higher than in the rural ones.

Table 3

Content of vitamins and micronutrients in the daily diet of schoolchildren

Name of micro-nutrient	Age groups					
	12–14 years			15–17 years		
	urban	rural	physiological norm <sup>1</sup>	urban	rural	physiological norm <sup>1</sup>
Vitamin, mcg						
Vitamin A,	$100 \pm 2,0$	$200 \pm 4,0^*$	600	$220,0 \pm 5,0$	$170,0 \pm 3,0^*$	1000
Vitamin B1	$2,7 \pm 0,3$	$1,4 \pm 0,1^*$	1,3	$0,92 \pm 0,2$	$0,81 \pm 0,1$	1,3–1,5
Vitamin B2	$2,1 \pm 0,1$	$1,1 \pm 0,1^*$	1,5	$0,44 \pm 0,08$	$0,65 \pm 0,09^*$	1,5–1,8
Vitamin C	$59,1 \pm 13,8$	$63,1 \pm 12,3^*$	60–70	$99,4 \pm 24,8$	$89,6 \pm 21,0$	70–90
Vitamin B6	$1,2 \pm 0,1$	$0,9 \pm 0,1^*$	1,6–1,7	$0,87 \pm 0,14$	$0,99 \pm 0,15$	1,6–2
Vitamin E	$4,9 \pm 0,7$	$3,4 \pm 0,6^*$	12,0	$5,1 \pm 2,3$	$4,4 \pm 1,1$	15,0
Macro- and micronutrient						
Calcium, mg	$613,3 \pm 87,0$	$577,0 \pm 83,9$	1200	$314,3 \pm 45,6$	$273,2 \pm 43,4$	1200
Magnesium, mg	$347,0 \pm 44,8$	$250,1 \pm 21,8^*$	300	$171,1 \pm 19,8$	$166,8 \pm 20,6$	400
Phosphorus, mg	$1178,4 \pm 213,9$	$1152,5 \pm 112$	1200	$766,7 \pm 77,9$	$673,03 \pm 85$	1200
Potassium, mg	$1499,8 \pm 175,5$	$1343,0 \pm 164$	1500	$1505,8 \pm 233,4$	$1482,9 \pm 237$	2500
Sodium, mg	$544,6 \pm 47,3$	$441,5 \pm 56,1^*$	1100	$401,5 \pm 55,3$	$399,2 \pm 49,2$	1300
Chloride, mg	$625,8 \pm 75,2$	$603,9 \pm 72,2$	1900	$617,3 \pm 88,1$	$594,5 \pm 79,5$	2300
Ferrum, mg	$19,3 \pm 3,5$	$20,4 \pm 3,5$	15,00	$14,6 \pm 3,3$	$13,7 \pm 2,1$	18,0
Zinc, mg	$7,18 \pm 0,6$	$6,31 \pm 0,9$	12,00	$5,8 \pm 0,9$	$4,76 \pm 0,8$	12,0
Iodine, mg	$0,44 \pm 0,19$	$0,23 \pm 0,13$	0,130	$0,13 \pm 0,07$	$0,15 \pm 0,09$	0,15
Copper, mg	$0,6 \pm 0,02$	$0,4 \pm 0,01^*$	0,80	$0,3 \pm 0,02$	$0,2 \pm 0,03^*$	1,00
Selenium, mg	$0,23 \pm 0,05$	$0,12 \pm 0,04^*$	0,04	$0,45 \pm 0,06$	$0,34 \pm 0,02^*$	0,05
Chromium, mg	$12,4 \pm 5,4$	$9,3 \pm 2,7$	25,0	$21,0 \pm 3,8$	$17,8 \pm 3,5$	35,0
Fluorine, mg	$2,6 \pm 0,5$	$1,6 \pm 0,2^*$	4,00	$2,2 \pm 0,3$	$1,5 \pm 0,2^*$	4,00

Notes:

\* $p \leq 0,05$  while comparing the data of urban and rural schoolchildren inside each age group;<sup>1</sup>physiological norm of vitamin, macro- and microelement intake of a learner.

The analysis of daily diet of schoolchildren showed that the rural children had more deficient diet (especially in A and E vitamins) than the urban ones (Table 3). Vitamin A deficiency was 83,3% from the physiological norm in the urban learners and 66,7% in the rural learners of 12–14 years; in the urban and rural learners of 15–17 years it was 90% and 17% respectively. Vitamin E deficiency was 59,2% in the urban schoolchildren and 71,7% in the rural ones aged from 12 to 14 years; in the urban and rural schoolchildren aged from 15 to 17 years it was 66 and 70,7% respectively. The content of ascorbic acid in daily diet of either urban or rural schoolchildren was within the limits of physiological norm.

Nevertheless, in the daily diet of urban and rural learners the deficiency of zinc and chromium intake was stated. Zinc deficiency in the urban and rural children was 68 and 60,7% respectively; chromium deficiency – 87,3 and 74%. Besides, their function can be twofold depending on their concentration. Copper, as an inducer of caeruloplasmin protecting cells from lipid peroxides, can serve as an antioxidant and, at the same time, like nickel and chromium, it can induce lipid peroxidation, i.e. copper has dose-dependent effect [28]. The same can be said about ferrum ions [29]. The analysis of daily diet of schoolchildren showed that ferrum intake was 69,2% in the urban schoolchildren and 58,3% in the rural ones; daily copper intake was 71,4 and 42,9% which testifies to the risk of these microelements deficiency. Other very important macro- and microelements, which provide human homeostasis and maintain oxidation-reduction balance, are calcium, phosphorus, sodium, chloride and magnesium. In daily diet of rural schoolchildren calcium deficiency was higher than in the urban ones (33,8 and 41,8% from the physiological norm respectively). Deficiency of phosphorus, sodium and chloride was also higher in the rural learners. Deviations from the physiological norm of phosphorus intake was 79,9% in the urban schoolchildren and 61,5% in the rural ones, sodium intake – 74,5 and 61,4%, chloride intake – 68,5 and 61,6% respectively. The level of magnesium intake was 16,7% low in the urban learners of 12–14 years, in urban and rural learners of 15–17 years it was 57,2 and 53,8% low respectively.

### Conclusion

It was stated that urban schoolchildren compared to rural ones aged from 12 to 14 years and from 15 to 17 years have higher content of free radical oxidation products,

which is confirmed by exceeded level of the intensity of fast burst in 4,3 and 5,9 times, and the rate of ROS production 4,4–5,7 times higher that is confirmed by the maximum luminosity data. The low level of lipid antioxidant factor – content of vitamins A, E in blood serum was also stated.

A positive predisposing factor of oxidation-reduction balance formation in the urban schoolchildren is considered to be a level of ascorbic acid ( $0,724 \pm 0,01$  mg/hour in the learners, aged from 12 to 14 years and  $0,713 \pm 0,01$  mg/hour in the learners, aged from 15 to 17 years, physiological norm of this age group is 0,700–1,000 mg/hour). The level of ascorbic acid in rural schoolchildren appeared to be lower than the physiological norm minimum limit. In learners aged from 12 to 14 years it was  $0,596 \pm 0,02$  mg/hour, that is 14,8% lower than the physiological norm, and in learners aged from 15 to 17 years –  $0,615 \pm 0,01$  mg/hour and 12,1% correspondingly.

In the urban and rural schoolchildren of any age riboflavin content was 8,9–11,9% lower than physiological norm, but in the rural children aged from 15 to 17 years renal excretion of this vitamin was  $14,2 \pm 0,24$  mcg/hour. Schoolchildren had sufficient level of protein (it was  $75,6 \pm 2,09$ – $77,2 \pm 1,9$  g/l in the urban children and  $75,1 \pm 4,44$ – $76,6 \pm 4,05$  g/l in the rural children). Albumin deficiency was found only in 16% of the rural schoolchildren, aged from 12 to 14 years. Only the rural schoolchildren had aneurine deficiency, in the children of 12–14 years it was 16,1% lower than the physiological norm ( $12,58 \pm 0,25$  mcg/hour), in the children of 15–17 years – 12,1% lower ( $13,19 \pm 0,20$  mcg/hour). Pyridoxine deficiency in the rural learners aged from 12 to 14 years was 94,8% of the physiological norm, in the learners aged from 15 to 17 years – 93,5%. From 78,3 to 93,1% of urban schoolchildren and from 44 to 55,9% of rural ones have higher level of low density lipoproteins; from 51,7 to 69,6% of urban and from 91,2 to 92% of rural learners have increased level of total cholesterol.

Besides, the additional factor of atherogenicity in the urban schoolchildren was the fact that 91,3–93,1% of them had increased level of triacylglyceride, but this index was 14,8 and 17,1% lower in the rural learners aged from 15 to 17 years and from 12 to 14 years respectively. Vitamin A deficiency was 83,3% from the physiological norm in the urban learners and 66,7% in the rural learners of 12–14 years; in the urban and rural learners



of 15–17 years it was 90 and 17% respectively. Vitamin E deficiency was 59,2% in the urban schoolchildren and 71,7% in the rural ones aged from 12 to 14 years; in the urban and rural schoolchildren aged from 15 to 17 years it was 66 and 70,7% respectively. The content of ascorbic acid in daily diet of either urban or rural schoolchildren was within the limits of physiological norm. In the daily diet of urban and rural learners, the deficiency of zinc and chromium intake was stated. Zinc deficiency in the urban and rural children was 68 and 60,7% respectively; chromium deficiency – 87,3 and 74%. Calcium deficiency in the rural children was higher than in the urban ones (33,8 and 41,8% from the physiological norm respectively).

To sum up, considering the received data about the antioxidant status and its forming factors, it is necessary to correct redox equilibrium parameters developing methodological and organizational approaches to the optimization of the urban and rural schoolchildren nutritional status.

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