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Physical Development and Renal Functions in Adolescents Consuming Drinking Water with High Content of Vital Cation

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Summary

The article presents the data concerning the influence of drinking water with high content of vital catio s on the physical development and renal functions in adolescents of 10-12 years old. It has been found the marked decrease of physical health and development and changes in osmo-and ionuretic renal functions, reflec ed in the increasing of diuretic and ionuretic response in conditions of spontaneous urination, and a er water loading. Evaluation of the sodium-potassium ratio in saliva demonstrated the rigidity of hormonal mechanisms of sodium-potassium homeostasis regulation following the consumption of hard drinking water, which was manifested in the absence of changes the parameter a er the water load, whereas in the control group, this ratio decreased, reflectin the acti ation of orti osteroid mechanisms.

Keywords: Drinking water; Sodium; Calcium; Magnesium; Physical development of adolescents; Renal function; Sodium-potassium ratio in sali a

Introduction

According to the water strategy adopted by the Government of the Russian Federation for the period up to 2020 [1], access of the population to safe drinking water is recognized as a task of national scale. Despite this, the problem of providing the population with drinking water of good quality remains one of the determining factors for the majority of the country. In 52 regions of the Russian Federation [2] the imbalance in the macro and microelement composition of drinking water is a key issue related to the impact of the water factor and requiring a comprehensive solution to preserve the health of the population. Thus, according to sanitary and hygienic studies conducted by the Novosibirsk center for hygiene and epidemiology in 2016 in the Novosibirsk region there were identified 10 areas unfavorable for mineralization and hardness of drinking water, one of which is the Vengerovo district (Table 1).

It should be noted that ionized minerals of drinking water have high rates of physiological activity, biological availability and absorption. Therefore, even relatively small concentrations of minerals introduced into drinking water can give a pronounced physiological effect [3,4].

Deficit and imbalance of Ca^{2+} and Mg^{2+} can be considered as potential risk factors for urolithiasis, skin diseases, cardiovascular system and digestive organs [5-9]. One of the main effectors of homeostatic regulation of magnesium and calcium balance are kidneys [10-14], while data on the impact of excess Ca^{2+} and Mg^{2+} in drinking water on the functional state of various organs and systems of the growing organism are much less [15].

In this regard, the aim of this research was to study the level of physical development and physical health, as well as kidney functions in pupils of 10-12 years in conditions of long-term consumption of drinking water with high content of sodium, calcium and magnesium.

Materials and Methods

Healthy children (boys and girls of 10-12-years-old) who did not have at the time of examination acute diseases were selected for physiological and hygienic examination of the physical development.

According to the generally accepted methods, basic anthropometric indicators (height, body mass, chest circumference, strength of hand and back muscles) were measured and different indices relatively to body mass were calculated [16,17]. Functional parameters of cardiorespiratory system (heart rate, arterial blood pressure, reaction of cardiovascular system to physical load, vital capacity of lungs, vital index) were determined by the program of complex health assessment, on the basis of which the integral level of physical health was assessed [18]. Renal functions at rest and following 1% of body mass water loading were evaluated in accordance with the guidelines of the Ministry of health of the USSR of 28.12.83 [19].

Concentrations of Na^{+} and K^{+} ions in urine and saliva were determined by flame photometry (BWB-XP Flame Photometer, UK); concentrations of Ca^{2+} and Mg^{2+} ions were determined by

Table 1: Indicators of drinking water quality in the settleme ts of the Novosibirsk region in 2016.

No п/п	Indices	Concentration, mg/dm^3	
		Verkh-Irmen	Vengerovo
1	Sodium	61,17 ± 6,12	224,6 ± 22,5*
2	Potassium	≤ 0,50	≤ 0,50
3	Calcium	65,93 ± 4,35	80,76 ± 5,29*
4	Magnesium	37,54	55,08
5	Iron	0,12 ± 0,30	1,65 ± 0,29*
6	Manganese	≤ 0,01	0,20 ± 0,05
7	Mineralization (d y residue)	493,00 ± 59,20	1114,00 ± 111,40*
8	Total hardness	6,38 ± 0,96	8,56 ± 1,28

Note: *signifi ant di erences at p ≤ 0.05 between water indices in Verkh-Irmen and Vengerovo (data of Verkh-Irmen are presented as control)

biochemical analysis (BS-200E analyzer, China). Statistical analysis of the results was carried out by methods of variation statistics using the parametric Student's t-test, as well as standard programs of Microsoft Office; the differences between measured parameters of children from both schools were considered significant at p ≤ 0.05.

Research Results

The assessment of the integral level of physical health of the surveyed pupils showed the higher health indicators in children of the Verkh-Irmen school, while a larger number of pupils from the Vengerovo School had a low health level (Table 2).

The analysis of morphofunctional parameters of girls of Verkh-Irmen school showed that all relative values of physical development (indeces) corresponded to age and regional standards. At the same time, these data were lower for girls in Vengerovo district, which were due to the low absolute values of parameters. Similar differences were observed in boys (Table 3). Thus, the described results indicated a lower level of health and morphofunctional parameters of Vengerovo school pupils.

One of the most informative methods for assessing kidney functions is a functional test with water load. Table 4 presents the main indicators of osmo-and ionoregulatory renal functions in the conditions of relative rest in the morning on an empty stomach (background) and 2 hours after intake of 1% of body mass water loading.

In conditions of high content of ions in drinking water, pupils have demonstrated the increased diuretic renal function already in background samples. At the same time, after the water loading the examined children from Vengerovo had higher reactivity of the renal response (there was a more pronounced increase in diuresis and excretion of sodium, calcium and especially urea). It can indicate a high reactivity of osmo-and ion-regulating mechanisms. It is also impossible to exclude that the increased excretion of ions was due to the higher intake with drinking water (Table 1). Described differences in renal response in children of these districts could be due to different levels of hormonal activity of the adrenal cortex, involved in the regulation of ionic balance. One of the indicators reflecting the activity of corticosteroid hormones in the blood is the sodium-potassium ratio of saliva. It was used to exclude the stress that can occur during blood collection in children [20].

As can be seen from table 5, in the children from Vengerovo district, where the concentration of sodium in drinking water was 5 times higher than its content in the control area, the background level of sodium-potassium ratio was higher than the control values, that

Table 2: The distribution of children in Verkh-Irmen and Vengerovo schools by physical health (%).

Levels/Groups		n	Low	Below average	Average	Above average	High
Verkh-Irmen (control)	Girls	40	50,5	35,5	10,5	3,5	0,0
	Boys	40	36,5	43,5	20,0	0,0	0,0
Vengerovo (observation	Girls	26	75,5	24,5	0,0	0,0	0,0
	Boys	35	47,0	50,5	2,5	0,0	0,0

Table 3: Morphofunctional indices in pupils of Verkh-Irmen and Vengerovo schools (M ± m)

Parameters/ Groups		Index of the strength of the muscles of the hands (carpal), kg/kg	Vital index, ml/kg	Index of the strength of the back muscles, kg/kg
Verkh-Irmen	Girls	50,1 ± 2,7	46,9 ± 1,8	0,9 ± 0,1
	Boys	55,9 ± 3,0	48,8 ± 2,3	1,17 ± 0,08
Vengerovo	Girls	44,0 ± 2,5*	36,0 ± 2,4*	0,7 ± 0,1*
	Boys	49,5 ± 2,7*	36,9 ± 2,4*	1,04 ± 0,07

Note: *signifi ant di erences at p ≤ 0,05: compared to the corresponding data of Verkh-Irmen pupils.

indicated a reduced production (or activity) of aldosterone and was due to a higher sodium content in the saliva of the examined children.

After the water loading in children of Verkh-Irmen there was a significant decrease in the sodium-potassium ratio of saliva, which indicated an increase in the concentration of corticosteroid hormones (primarily, aldosterone), that under normal conditions caused a decrease in sodium excretion from the body to preserve osmotic homeostasis after water intake [21-24].

However, the sodium-potassium ratio after water load in children from Vengerovo did not change significantly compare to its background level, indicating a weak hormonal response to water intake. This may testify the rigidity of hormonal mechanisms regulating sodium-potassium homeostasis in conditions of prolong consumption of hard drinking water.

Thus, the analysis of diuretic and ionuretic kidney reaction in children living in different areas and consuming drinking water with different content of sodium, calcium and magnesium salts indicates the adaptive response of renal functions depending on the ion composition of drinking water. It reflects the effect of the used water on the mechanisms of homeostatic regulation of renal functions. However, long-term impact on the system probably causes the tension and leads to its exhaustion or rigidity of the hormonal mechanisms of ion balance regulation.

Conclusion

Analysis of all these parameters gives the reason to believe that drinking water with high hardness and mineralization of sodium, magnesium and calcium salts has an adverse effect on the level of physical health and morphofunctional indicators of children, as well as adaptation of the osmo-and ion-regulating renal functions, but causing the rigidity or exhaustion of corticosteroid hormonal mechanisms regulating ion homeostasis.

Table 4: Indicators of renal functions in children of Verkh-Irmen and Vengerovo in conditions of relative rest and in 2 hours after the intake of 1% water load (M ± m).

Indicators		Verkh-Irmen (n=19)	Vengerovo (n=25)
V, ml/min*m^2	background	0,59 ± 0,03	1,43 ± 0,15▲
	after water load	1,57 ± 0,11*	2,14 ± 0,19*▲
GFR, ml/min*m^2	background	52,09 ± 2,76	113,38 ± 15,39▲
	after water load	39,78 ± 1,77*	36,31 ± 2,11*
%RH_2O, %	background	98,82 ± 0,17	98,61 ± 0,15
	after water load	95,87 ± 0,50*	93,77 ± 0,54*▲
Uosm, mosm/l	background	667,11 ± 38,01	805,20 ± 47,51▲
	after water load	272,72 ± 40,28*	260,06 ± 33,83*
UosmV, mcmol/min*m^2	background	355,30 ± 21,06	1113,48 ± 152,33▲
	after water load	294,11 ± 16,66*	463,49 ± 35,91*▲
UNa V, mcmol/min*m^2	background	98,67 ± 6,28	242,80 ± 32,92▲
	after water load	45,47 ± 5,62*	62,98 ± 8,48*
UCa V, mcmol/min*m^2	background	0,50 ± 0,03	3,69 ± 0,53▲
	after water load	0,20 ± 0,04*	0,56 ± 0,15*▲
UMg V, mcmol/min*m^2	background	1,26 ± 0,08	2,77 ± 0,32▲
	after water load	0,75 ± 0,06*	0,83 ± 0,13*
Uurea V, mcmol/min*m^2	background	90,3 ± 4,4	1210,2 ± 157,3▲
	after water load	102,40 ± 6,80*	264,75 ± 31,4*▲
% of urine output for 2 hours after water loading		65,62 ± 2,54	79,00 ± 6,00▲

Note: significant differences at $p \le 0.05$: 1. *significant differences compared with background urine samples;

2. ▲significant differences of indicators between Verkh-Irmen and Vengerovo.

Table 5: Concentration of sodium, potassium and sodium-potassium ratio of saliva in the examined children from Verkh-Irmen and Vengerovo (M ± m).

Indicators		Verkh-Irmen (n=19)	Vengerovo (n=25)
Na, mcmol/l	background	7,55 ± 0,97	11,86 ± 0,25▲
	after water load	5,29 ± 0,83*	11,54 ± 0,41▲
K, mcmol/l	background	16,7 ± 0,73	13,40 ± 0,35▲
	after water load	24,05 ± 0,42	10,98 ± 0,23▲
Na/ K	background	0,45 ± 0,10	0,88 ± 0,13▲
	after water load	0,22 ± 0,08*	1,05 ± 0,05▲

Note: significant differences at $p \le 0.05$: 1. *significant differences compared with background urine samples;

2. ▲significant differences of indicators between Verkh-Irmen and Vengerovo.

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