Features of the Peripheral Hemodynamics of Girls Depending on the Environmental Conditions

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The present article considers the influence of environmental conditions on the body tympanum of girls and the adaptive reactions of peripheral hemodynamics to the physical activity. We carried out the evaluation of the environmental situation in the places of the permanent residence of girls, measured the anthropometric indices, calculated the trohanter index and defined a constitutional type of the age-related evolution of the body. The study of tibia hemodynamics was carried out by using rheovasography at rest, after a single dosage of physical activity in the amount of 50% of the individual PWC170 and in the recovery period. The study revealed that the pollution of the environment by chemical and radionuclide factors on the territory of the Republic of Mordovia is characterized as uneven. In polluted areas disevolutive and pathological types of the body tympanum is normally formed. An influence of the constitutional type of the age-related evolution of the body on the tibia blood flow was observed during physical activity (statistically significant inverse correlation of the trohanter index and the rheographic index). The authors identified the following constitutional types of hemodynamic responses to physical activity: average values of the trohanter index (norm-evolutive type of the body tympanum) were characterized by adequate response of tibia hemodynamic to physical stress; girls living in adverse environmental conditions, if the trohanter index was deviated from its average values, had a constitutional violation of peripheral hemodynamics. The identified hemodynamic features should be taken into account when planning physical activity in a business environment, as well as in training conditions of athletes.

Key words: Environmental conditions, anthropometry, trohanter index, Evolutive body tympanum, hemodynamics.

In the process of ontogenesis of the human, since the period of fetal development until puberty, evolutive somatotype is being formed under the influence of environmental factors, which largely determines his adaptive capacity and health status. Adverse environmental and social factors both increase the likelihood of development of metabolic syndrome, hypertension and coronary diseases after birth. Fetal programming occurs in many mammals (pigs, sheep, mice, rats, Guinea pigs). In a number of animals programming of pathology and offspring is possible with experimentally induced placental insufficiency (embolization of the spiral arteries of the uterus). A similar result can be achieved in some animals by the injection of synthetic glucocorticoids to mother.

There have occurred some publications over the past two decades, which indicate the slowing down of the acceleration process and the emergence of an opposite phenomenon –
retardation of physical and sexual development under the influence of factors of environment15,16.

Changes in growth and development of individuals in human populations are accompanied by certain constitutional peculiarities. This is manifested in particular by constitutional characteristics of Central hemodynamics at rest and during the muscle activity7. We hypothesized that evolutivebody constitution has also a significant impact on the state of the peripheral hemodynamics. Rheovasography is one of the objective methods in the study of hemodynamics.

**Methods**

The object of the study were 109 female students aged to 18.09±1.04 years old, who lived in polluted areas of the Republic of Mordovia before admission to the University. Environmental health survey of the Republic of Mordovia included comparative statistical analysis of ecological conditions on the extent and the nature of chemical pollution of atmospheric air, surface water, soil and radioactive pollution of the territory of residence.

The response of the volumetric blood flow in the lower leg to physical exercise was studied by the rheovasography method depending on the constitutional type of the age evolution of the organism. We measured height, leg length, chest circumference (CC), waist circumference (WC), thigh circumference (WRC), body weight (BW), the calculation of the trohanter index (TI) and the definition of evolutiveconstitutional type according to the method of Schtefko V.G. (1929) [9].

We determined physical performance using the test PWC/$170$. Rheovasography of left tibia was performed after a single dosed physical load capacity of 50% of the individual PWC/$170$ for 3 minutes and during the recovery period after 3 min of rest. The following parameters were recorded:

- a) Rheogramamplitude (RA), Ohm;
- b) Rheographicsystolicindex (RSI);
- c) Relativevolumepulse (RVP);
- d) Rheographicdiastolicindex (RDI),%
- e) Vasculartonemioticindex (VTI), %;
- f) Venous Outflow Coefficient (Voc), %;
- g) Asymmetrycoefficient (AC);
- h) Heartrate (HR), Beats/Min

**RESULTS**

Republic of Mordovia is located in the Central part of the Russian plain, between the Oka and the Sura. The peculiarity of its situation is the existence of common borders with more economically advanced regions of the Central and Volga regions. In physical-geographical terms it is situated at the junction of forest and steppe natural zones. The territory of the Republic is 26.2 km².

The length from West to East is about 280 km, from North to South – from 55 to 140 km. The size and configuration of the Republic determine its internal geography. The population of the Republic of Mordovia as of 01.01.2012 year was 825.4 thousand inhabitants.

It was selected as an independent administrative unit of the Mordovian national district for the first time in July, 1928. It consisted of parts of Penza (Saransk, Insar, Krasnoslobodsk counties and the Northern part of Narovchat), Tambov (Temnikov district and part of the Saviour), Simbirsk (Ardatov, part of Alatyr and Karsun counties), Nizhegorod (part of Lukoyanov and Sergatchsk districts) provinces. The territory got its present name– the Republic of Mordovia in May, 1994. Its economic and geographical position had and still has a great influence on the economic development of Mordovia. It has changed several times. The end of the XIX century can be considered a certain historic milestone, when the building of the railway, passing through the southern part of the present territory of the Republic and linking it with Central Russia and the Urals was completed (1893). The appearance of the railroad tracks in the Eastern part of the territory, connecting the North with the Volga region, Nizhny Novgorod and Penza, has secured a favorable transport and geographical position, has had a significant impact on specialization and geography of the economy and the environment.

Ecological trouble of some areas affected the physical development and the constitution of their inhabitants10-12.

The adjacent territory could not have a strong impact on the economy of the Republic, since it was not powerful enough itself during the period of the formation of the Republic. Therefore, the largest railway junction of
Ruzayevka and the administrative center of Saransk had an important organizing role. The existing economic ties became closer and determined the structure of industries based on the use of imported raw materials, parts, components. There is also the influence of the major industrial centers surrounding the Republic – Moscow, Nizhny Novgorod, Penza, Ulyanovsk, etc.

The evacuation of a number of large enterprises from the Western parts of the country to its territory and their development at the beginning of the great Patriotic war has allowed Mordovia to turn into an industrial-agrarian Republic which industry is specialized on sectors of non metal-consuming engineering (instrumentation, electrical cable manufacturing, electrical), based on imported raw material and labour resources, as well as the industries that use local raw materials (woodworking, construction materials, food industry).

The geographical position of Mordovia in the region with a sufficiently favorable temperate continental climate and the combination of fertile black soil and gray forest soils of less quality contributed to the development of diversified agriculture with the production of grain, potatoes, sugar beets, meat of cattle, pigs, milk.

Mordovia is divided into 22 administrative districts. In its capital – Saransk – there are three urban areas. There are three cities of republican subordination (Saransk, Ruzayevka, Kovylkino) and four cities of district subordination (Ardatov, Insar, Krasnoslobodsk, Chamzinka), 19 towns, and more than 1300 villages on its territory.

The main problems of the region’s economy, requiring urgent solutions are depreciation of fixed assets, low competitiveness of enterprises and environmental pollution.

The atmospheric air of the Republic receives more than 200 ingredients, including 13 of the 1st hazard class and about 40 of the 2nd hazard class. The greatest number of 1st and 2nd class substances is thrown by electrical, chemical and petrochemical, medical and other branches. The main pollutants by the mass emissions are as follows: methane, inorganic dust, carbon oxide, nitrogen oxides, sulfur dioxide, ash, representing 98.0% of emissions from stationary sources.

The territory of Mordovia is characterized by irregularity in the placement of major stationary sources of pollutant emissions into the atmosphere. Saransk-Ruzayevka, Chamzinka-Komsomol and Torbeevo industrial units respectively pollute 13.6%; 35.7%; 34.8% of all emissions. In Torbeevo district 99.0% of emissions are accounted for Torbeevo linear production Department of main gas pipelines and about 97% at the enterprises of production of construction materials. In Ruzayevka area housing and utilities emissions are accounted for 38.5%.

The highest percentage of content of substances related to the first and second hazard classes are characterized by emissions in the cities of Saransk, Ruzayevka and Insar, Torbeevo, Krasnoslobodsk, Chamzinka and Kochkurovo districts.

Analyzing the relative burden of emissions on the territory, it should be noted that the Northern part of Mordovia is less polluted. High, very high and the average load of emissions on the territory (more than 0.5 t/km²) stretches from the Western margin of the Republic to the East through the most industrialized areas. Three districts of Mordovia have a high loading on territory. They are Torbeevo district (6.62 t/km²), Chamzinka district (13.05 t/km²) and the city of Saransk (58.46 t/km²).

Significant anthropogenic load is subjected to the water bodies of the region. The total volume of waste water which is discharged into water bodies is 51.46 million m³, the volume of discharge of insufficiently treated water is 48.66 million m³ or 95%, the volume of discharge without treatment is 2.80 million m³ or 5%. The main volume of the discharge falls on the Sura river basin and it is 53.12 million m³, including water bodies – 46.83 million m³ (88.2%). The basin of the Moksha River has 10.79 million m³ of wastewater, including water bodies – 4.63 million m³ (42.9%).

One of the most urgent ecological problems on the territory of the Republic of Mordovia is the utilization and disposal of wastes of production and consumption, which are a constant and growing threat of environmental pollution.

There are 3 landfills of solid waste, 21
dumps and 1 yard for storage of lime waste of Kovylkino factory of a silicate brick on the territory of the Republic. In addition to authorized landfills there are a large number of unauthorized closed landfills or landfills under liquidation.

The existing landfill in Saransk has been operating since 1985, it was designed for 20 years and is full now. It was commissioned with significant deviations from the project. As a result and also because of buried industrial wastes in the landfill, its resources are practically exhausted. The solution to the problem of preventing the pollution of environment has two directions: bringing order to the accounting for the formation of solid industrial and domestic wastes and proper use of landfills to store them.

The radiation situation in the region, which was mainly due to the contamination of cesium-137 and strontium-90 is of the great importance. During the Chernobyl nuclear power plant (ChNPP) accident in 1986, 1850 PNEC of radionuclides including 270 PNEC of radioactive cesium was thrown from the destroyed reactor. Distribution of radionuclides took a planetary scale. The Chernobyl accident significantly changed the situation in Russia, including the Republic of Mordovia.

The environment radiation control in Mordovia has been carrying out by the Republic radiological service including the Republic veterinarian radiologic laboratory, AgroChemical center, the Ministry of Ecology of the Mordovia Republic (at the present time the Ministry of forestry, game husbandry and nature management), by the laboratories of the State Committee on sanitary and epidemiology surveillance and other federal agencies.

Table 1. Values of rheovasography of the left tibia of girls at the age of 18 at rest, after physical activity, during the recovery (M + δ)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>At rest</th>
<th>After physical activity</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA (ohm)</td>
<td>0.04 + 0.01</td>
<td>0.05 + 0.03**</td>
<td>0.04 + 0.01</td>
</tr>
<tr>
<td>RSI</td>
<td>0.37 + 0.14</td>
<td>0.50 + 0.33**</td>
<td>0.43 + 0.17*</td>
</tr>
<tr>
<td>RVP</td>
<td>0.62 + 0.21</td>
<td>0.79 + 0.37**</td>
<td>0.69 + 0.26*</td>
</tr>
<tr>
<td>RDI (%)</td>
<td>55.27 + 25.38</td>
<td>47.50 + 20.41</td>
<td>53.32 + 21.34</td>
</tr>
<tr>
<td>VTI (%)</td>
<td>16.82 + 4.29</td>
<td>17.55 + 5.13</td>
<td>17.49 + 4.57</td>
</tr>
<tr>
<td>VOS</td>
<td>27.16 + 4.05</td>
<td>22.07 + 3.96</td>
<td>19.75 + 3.53</td>
</tr>
<tr>
<td>Heart rate(beats/min)</td>
<td>98.14 + 14.89</td>
<td>102.21 + 15.50*</td>
<td>97.33 + 17.90*</td>
</tr>
</tbody>
</table>

* < 0.05  ** < 0.001

The ground-base inspection of the radiological environment of the Mordovia territory has been carrying out since 1993. This inspection has been exercising by the Federal Service for Hydrometeorology and Environmental Monitoring of the Mordovia Republic. The 274 human settlements have been inspected and atmospheric precipitation areas with cesium (Cs)-137 have been uncovered. The human settlements with contamination density from 1 to 5 Ci/km² have been defined, it means they are pertained to the zone of residence with the preferential social and economic status.

According to the aerial photography and detailed land-based inspection it has been found out that the territory of Ardatovsk, Bolshebereznikovsk, Zubovo-Polyansk, Insarsk, Ichkalovsk, Kadoshinsk, Kovylkinsk, Kochkurovsk, Romodanovsk, Ruzaevsk, Chamzinsk and Oktyabrsk regions (Saransk City) has been exposed to the radiological contamination. Considering the fact that the reactor emission took place during a protracted period of time and the meteorological conditions constantly have been changing, uneven, local pollution of the Mordovia territory took place. The east regions were more polluted (more than 1 Ci/km²) than the west ones (up to 0.75 Ci/km²). There are 16 human settlements in Mordovia pertaining to the zone of residence with the preferential social and economic status in relation to the Moldova Republic pollution.
Gamma-ray background on the territory of the specified human settlements is within the natural bounds. The average value of the irradiation power was changing within 10-12 mcR/h with the maximum value of the 15 mcR/h.

The structure of the predicted radiation dose for 50 years can be presented as follows for the rough estimate of the contribution of all sources taking part in formation of the radiation dose of the polluted areas: external radiation dose – 15%, of which 14% goes from radioactive trace, both from clouds and skin beta exposure – 1%; internal exposure dose – 85%, given that the population during all the time would consume the local food products cultivated on the polluted territories.

Compliance with the protective and some restrictive policy measures in agro-industrial companies as well as the decrease of the population radiation exposure from all main radiation sources is based on the optimization approach which allows to minimize the Mordovia Republic radiation burden of the population living on the radio-cesium polluted territories.

The birth rate in the Mordovia Republic equals to 7.5 on 1000 inhabitants – this is 11th position among the 14th regions of the Privolzhsky Federal District (PFD). The death rate – 15.1 (5th position), natural population decline – 7.6 (10th position). The Republic mortality from the circulatory diseases among the Privolzhsky Federal District (PFD) stood on the 3rd high position (62.5%), while mortality from the respiratory diseases was on the 5th position (6.2%). The oncological mortality is 12.9% (7th position), from traumas and intoxication – 10.9% (10th position). The infant mortality on 1000 babies born among the regions stood on more favorable position (11th position) and equaled to 14.6%.

The Republic population life expectancy stands on the 4th position (67.4%), among them the male life expectancy equaled to 61.3 years, female life expectancy – 73.4 years (6th position) in the Privolzhsky Federal District (PFD). The reduction of the expected lifespan equaled to 3.5 years (5th position). The Russian Federation average similar data amounts to 67.0, 61.3, 72.9 years accordingly.

The primary disease incidence rate of the Mordovia Republic adult population stands on low level and equals to 485.6 on 1000 inhabitants respectively. The teenager primary disease incidence also stands on low level – 623.9 (13th position), prevalence proportion in the Mordovia Republic also stands on low level among 14 regions – 1316 on 1000 inhabitants respectively. The child primary disease in the Mordovia Republic was on the level of 1190.5, prevalence rate – 1519 on 1000 inhabitants. The Mordovia Republic stands on 11th position on this data in the Privolzhsky Federal District (PFD).

The respiratory system has been subjected to affection (damage) most of all in the Mordovia Republic as well as the digestive system, blood circulation system and urogenital system. The unfavorable situation of the sick person number has been noted in Saransk City, Dubensk, Ardatovsk regions. The incidence rate is definitely lower in Zubovopolyansk, Kadoshkinsk,Staroshaigovsk, Lyambirsk and Bolsheignatovsk regions.

We have investigated the influence of environmental factors on constitutional type of age evolution of the organism. In the Eastern regions of the Republic, where radioactive contamination is predominant, there is a trend of increasing of trohanter index, which is manifested by shortness of leg among some girls and women up to formation of disevolutive (TI = 2.04-2.08) and pathological (TI < 2.09) evolutive somatotypes. In the Western regions of the Republic, where the contamination with cesium-137 was less pronounced, but there was a chemical toxic contamination, the opposite trend of decreasing of the trohanter index was observed, in some cases it was up to extreme values: disevolutive typewith TI = 1.86-1.91 and pathological type with TI d" 1.85 of the evolutive constitutional types.

The anthropometric characteristics of girls in the Republic of Mordovia were not significantly different from other regions of Russia. The height amounted to 163.95 ± 6.16 cm, leg length – 83.40 ± 3.86 cm, chest circumference – 84.78 ± 6.31 cm, waist circumference – 67.67 ± 6.04 cm, thigh circumference – 54.24 ± 5.18 cm, wrist circumference – 14.59 ± 0.89 cm, body weight – 60.20 ± 9.24 kg.
Average trochanter index amounted to 1.96 ± 0.05. However, 36 girls had exponent TI < 1.95 (hypo-evolutive and dis-evolutive constitutional types), 55 girls had TI = 1.95-2.0 (normal evolutive type of constitution), 18 girls – TI< 2.0 (hypo-evolutive, deevolutive and pathological types of constitution). Thus, girls with low value of trochanter index dominated.

Physical working capacity (PWC\textsubscript{170}) of girls was 678.33 ± 87.61 kgm/min or 11.26 ± 3.18 rgm/min/kg, which corresponded to the average level of working capacity among not-trained girls.

The table shows that the exponents RA, RSI, RVP have truly increased after physical activity, the exponents RDI, VTI, VOC have not sufficiently changed. Then, after 3 minutes of rest, recovery of exponents RA, RSI and VOC took place.

Correlation analysis of anthropometric parameters with hemodynamic parameters of the left lower leg at rest, during physical activity and during the recovery period was conducted. At rest and during the recovery inverse statistically significant correlation of exponents OGK, VC, TC, VRC and BW with the exponent RSI of the left tibia was observed. During physical activity, a statistically significant inverse correlation of the trochanter index with rheographic index was observed. Hence, we can conclude that trochanter index is important in adaptation of the system of peripheral hemodynamics of the left lower leg to physical activity. With respect to the vascular tone indicator and other indicators of EGR of left lower leg, significant correlations with anthropometric parameters of the organism have not been identified.

Girls with different evolutive constitutional types had different values of RSI and VTI indicators, at rest, after physical activity and in the recovery period. The girls with average TI values (norm-evolutive constitutional type) had an adequate physiological response of the left tibia hemodynamics to a single dosage of physical activity. Their average RSI value at rest was 0.37 ± 0.14, it was statistically proved that after physical activity RSI increased up to 0.51 ± 0.28 (@< 0.005), after 3 minutes of rest an incomplete recovery of the initial values of RSI up to 0.43 ± 0.19 was observed.

In case of deviation of the trochanter index from its average values constitutional features of hemodynamic reactions were observed. The girls of a hypo-evolutive somatotype had the RSI value that remained virtually unchanged during the study, we evaluated such reaction of the left tibia hemodynamics as inadequate. At a dis-evolutive constitutional type with TI=2.04-2.08 the recovery of the initial RSI values at rest was not observed, at a dis-evolutive constitutional type with TI=1.86-1.91 we observed a high value of RSI (0.60 ± 0.40) after physical activity. The girls of a pathological constitutional type with TI > 2.09 had a decrease in RSI value up to 0.26 ± 0.07 during physical activity, such response can be evaluated as paradoxical. On the other hand, the girls of a pathological constitutional type with TI’ 1.85 had the highest RSI value up to 0.75 ± 0.05 during physical activity.

The changes in the vascular tone indicator (VTI) were typical. The girls of a norm-evolutive constitutional type had a moderate decrease in VTI during physical activity, and then VTI recovered after 3 minutes of rest. In this case, VTI always remained within normal values over time.

In case of TI deviation from average values different VTI reactions to physical activity were observed. It should be noted that in a number of evolutive somatotypes (hyperevolutive type, dis-evolutive type with TI= 1.86-1.91 and a pathological constitutional type with TI > 2.09) during physical activity VTI rose above normal values (19.60 ± 5.02%, 21.69 ± 6.07% and 20.75 ± 0.91%).

DISCUSSION

After analyzing the data and comparing them with the literature data on studied scientific area, it should be noted that the peripheral hemodynamics is a complex physiological process, which provides the body’s adaptation to physical stress. There are individual characteristics of hemodynamics associated with physical development and the type of the body tympanum. The body tympanum is the fundamental characteristic of the human organism, which is formed during ontogenesis under the influence of heredity and environmental factors.
The works of different authors are devoted to the study of the influence of environmental factors on the organism of laboratory animals. Morphological and functional changes in the testes and ovaries of white rats exposed to lead acetate were described\textsuperscript{13-14}. An impact of the quality and mineral composition of drinking water on the morphological and biochemical parameters of blood and organs of female white rats was studied\textsuperscript{15-16}.

Negative environmental factors can cause slow physical and sexual development of humans and animals, as well as disruption of sexual differentiation\textsuperscript{17-20}. Impaired growth and development of individuals in human populations are manifested as changes in a somatotype. In references we did not find the information about the constitutional features of peripheral hemodynamics in patients with different evolutive somatotypes. The studies revealed constitutional types of peripheral hemodynamics reaction to physical activity.

**CONCLUSION**

The present study revealed that the Republic of Mordovia is characterized by uneven contamination of the territory. Under the influence of adverse environmental factors residents of the Republic have a certain evolutive somatotypes, which largely determine the adaptive response of the organism to external influences. Dosed physical activity is a convenient way to study adaptive reactions. Constitutional features of peripheral hemodynamics occur in physical activity.

**Summary**

1. Contamination of environmental components in some regions of the Republic of Mordovia had an impact on physical development and the body tympanum of their inhabitants.
2. An impact of a constitutional type of the age-related evolution of the organism on tibia blood flow occurred during physical activity.
3. At an average trohanter index (norm-evolutive type of the body tympanum) there was an adequate optimal response of the tibia hemodynamicsto physical activity in the form of normal initial rheovasography indices at rest, an increase in the amplitude of the rheographic wave, rheographic index and a decrease in the vascular tone indicator during physical activity, the initial values of the indicators were restored in the recovery period after 3 minutes of rest.
4. In case of deviation of the trohanter index from its average values the authors observed different reactions from rheovasography indicators to physical activity. It should be noted that in a number of evolutive somatotypes (hyperevolutive, disevolutive and pathological types) during physical activity the vascular tone indicator rose above normal values.
5. The identified patterns of hemodynamic responses to physical activity are of great importance in terms of improving knowledge of human ecology.

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