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Electrocardiographic features in 6-year-old children who were born with extremely low, very low and low body weight

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ABSTRACT. ***Introduction.*** Identification of electrocardiographic markers of risk of cardiovascular diseases is an actual topic in connection with modern possibilities of nursing of children with birth weight less than 2500 grams. ***The aim of the study*** – to evaluate electrocardiographic parameters in children aged 6 years, born with extremely low, very low and low body weight. ***Materials and methods.*** An electrocardiographic analysis was performed on 6-year-old children who were born with low birth weights. ***Results.*** No significant differences were found in electrocardiographic parameters between 6-year-old children who were born small for gestational age and those who were born weighing more than 2500 g. ***Conclusion.*** Children with extremely low, very low and low body weight at birth are at risk of developing cardiovascular pathology, which requires in-depth diagnostics and further research.

KEYWORDS: *children, electrocardiography, extremely low body weight, ENBW, very low body weight, VLBW, low body weight, LBW*

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Оригинальная статья

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Электрокардиографические особенности у детей 6-летнего возраста, родившихся с экстремально низкой, очень низкой и низкой массой тела

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РЕЗЮМЕ. ***Введение.*** Выявление электрокардиографических маркеров риска развития сердечно-сосудистых заболеваний является актуальной темой в связи с современными возможностями выхаживания детей с массой тела при рождении менее 2500 г. ***Цель исследования*** – оценить электрокардиографические параметры у детей в возрасте 6 лет, родившихся с экстремально низкой, очень низкой и низкой массой тела. ***Материалы и методы.*** Проведен анализ электрокардиограмм у детей шестилетнего возраста, родившихся маловесными. ***Результаты.*** Не выявлено значимых различий в электрокардиографических показателях у детей шестилетнего возраста, родившихся маловесными, и детей с массой тела более 2500 г при рождении. ***Заключение.*** Дети с экстремально низкой, очень низкой и низкой массой тела при рождении составляют группу риска по развитию сердечно-сосудистой патологии, что требует углубленной диагностики и дальнейших исследований.

КЛЮЧЕВЫЕ СЛОВА: *дети, электрокардиография, экстремально низкая масса тела, ЭНМТ, очень низкая масса тела, ОНМТ, низкая масса тела, НМТ*

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.

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INTRODUCTION

Advances in modern medicine have been marked by substantial progress in the care of preterm infants weighing less than 2500 g. The steady improvement in survival of newborns with low birth weight (LBW), very low birth weight (VLBW), and extremely low birth weight (ELBW) has been driven by refinements in medical technology. This progress raises new scientific challenges. Particular relevance is currently attached to the evaluation of long-term sequelae involving various organs and systems in this group of children [1].

The cardiovascular system is exposed to factors related to preterm birth [2]. Accumulated scientific evidence indicates that children born with low birth weight constitute a high-risk group for the development of cardiometabolic disease in adulthood, within the framework of the so-called Developmental Origins of Health and Disease (DOHaD) concept. According to this concept, adverse intrauterine conditions program structural and functional changes in organs, including the cardiovascular system, thereby predisposing to future cardiac disease [3–5].

The cardiovascular system of children born with low birth weight undergoes a range of adaptive and remodeling processes [6]. Compensating for intrauterine hypoxia, the body redistributes cardiac output in favor of vital organs, which imposes a hemodynamic load on the right heart chambers and may lead to their dilation and hypertrophy [7]. In the postnatal period, these children may face the influence of a hemodynamically significant patent ductus arteriosus, bronchopulmonary dysplasia, and pulmonary hypertension, which exert an additional long-term impact on the myocardium and the process of electrical impulse generation within it [8].

Electrocardiography (ECG) is a routine, non-invasive, and highly informative tool for assessing myocardial status, the cardiac conduction system, and electrolyte balance. In six-year-old children who underwent intensive care management during the neonatal period, standard ECG can detect specific features that mirror prior adaptive processes and cardiac remodeling. These features may include repolarization abnormalities, electrocardiographic signs of right and left ventricular myocardial hypertrophy, as well as various rhythm and conduction disturbances. Notably, ECG is not a definitive method for the diagnosis of cardiovascular pathology. A normal ECG does not preclude the presence of current cardiovascular disease, nor does it exclude the possibility of its development in later years.

The age of six years is a critical milestone immediately preceding school entry, which entails a marked increase in physical demands and psychoemotional stress. Furthermore, by this age the principal processes of morphological maturation of the cardiac conduction system are normally completed, and "adult" ECG parameters become established.

Despite the importance of this issue, comprehensive studies specifically addressing ECG features in preschool-aged children with a burdened perinatal history of low birth weight remain scarce in the available literature. Most studies have focused on the neonatal period [9], early childhood [10], or adolescence and adulthood [11, 12]. T.S. Tumaeva and L.A. Balykova demonstrated that ST–T abnormalities, rhythm disturbances (sinus tachycardia or, less commonly, bradycardia), conduction disturbances, and QTc prolongation were more frequent in a specific group of newborns. These findings were more common in newborns who had suffered cerebral ischemia, especially those born preterm, and in children delivered by cesarean section [9]. T. Salaets et al. found no significant relationship between corrected Q–T interval and perinatal factors, including birth weight, in adolescent children [11]. Conversely, A.-S. Gervais et al. reported QTc prolongation during physical exercise among adults [12].

AIM

The aim of this study was to evaluate electrocardiographic parameters in 6-year-old children born with ELBW, VLBW, and LBW.

MATERIALS AND METHODS

A total of 173 children aged 6 years (mean age 6.1±0.24 years) were enrolled in the study, including 78 (45.1%) boys and 95 (54.9%) girls. The main group comprised 94 children with a birth weight below 2500 g. Based on birth weight, the main group (n=94) was stratified into three subgroups. Subgroup 1 consisted of children with extremely low birth weight (ELBW) (n=15), Subgroup 2 — chil-

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dren with very low birth weight (VLBW) (n=25), and Subgroup 3 — children with low birth weight (LBW) (n=54). The control group consisted of children with a birth weight exceeding 2500 g (n=79).

Inclusion criteria for the main group were: preterm infants with a birth weight below 2500 g, physical development parameters appropriate for gestational age, and natural conception. *Inclusion criteria for the control group were:* full-term birth with a birth weight exceeding 2500 g, and natural conception. *Exclusion criteria were:* the presence of congenital or genetic pathology, and physical development parameters inappropriate for gestational age. Written informed voluntary consent for the examination and publication of the results obtained was provided by the children's parents (legal representatives).

Electrocardiography was performed using a Fukuda CardiMax FX 8222 device (Japan). Standard 12-lead ECG was recorded at a paper speed of 50 mm/s, with a 1 mV calibration signal applied to each tracing. ECGs were obtained at rest with the patient lying in the supine position. Alongside visual assessment, the following ECG parameters were analyzed: heart rate (HR), QRS duration, Q–T and Q–Tc intervals, P- and T-wave amplitudes, and ST-segment pattern.

Statistical analysis was performed using conventional methods of descriptive and variational statistics implemented in Microsoft Excel 2010, STATISTICA 12, and MedCalc software. Normality of distribution was verified prior to analysis. Between-group comparisons were performed accounting for sample size and distribution type using nonparametric tests (Pearson's χ^2 test, Mann–Whitney U test, Kruskal–Wallis test). Data are presented as median and interquartile range: Me [Q25; Q75], where Me is the median, and Q25 and Q75 are the lower and upper quartiles. The significance level for hypothesis testing in the study was set at 0.05.

RESULTS

ECG findings in the main group revealed abnormalities in the form of cardiac rhythm and conduction disturbances, as well as altered myocardial repolarization. A normal ECG was recorded in 5 (33.3%) children born with ELBW, 8 (32%) children born with VLBW, and 27 (50%) children born with LBW. In the control group, 38 (48.1%) children had a normal ECG. No statistically significant differences in the frequency of various cardiac rhythm and conduction abnormalities were observed across the study groups. Among cardiac arrhythmias in children born with ELBW, VLBW, and LBW, the most frequently recorded were sinus bradycardia, atrial rhythm, and wandering pacemaker (Fig. 1), which, according to some reports, are considered functional in nature.

Repolarization abnormalities were detected in 27.6% of children with ELBW, 4% of children with VLBW, and 17.0% of children with LBW at birth, as well as in 8.9% of children in the control group (p_{1-2}=0.06, p_{1-3}=0.2, p_{1-4}=0.06, p_{2-3}=0.2, p_{2-4}=0.4, p_{3-4}=0.4).

Q–T interval prolongation exceeding 460 ms was recorded in children with ELBW, VLBW, and LBW at birth and in the control group in 6.7, 8.0, 3.7, and 2.5% of cases, respectively (Table 1).

ECG analysis revealed a vertical cardiac electrical axis in 7 (46.7%) children with ELBW, 10 (40.0%) children with VLBW, 16 (29.6%) children with LBW at birth, and 42 (52.3%) children in the control group. A horizontal axis was identified in 3 (20.0%) children with ELBW, 1 (4.0%) child with VLBW, 2 (3.7%) children with LBW at birth, and 4 (5.1%) children in the control group. Right axis deviation was observed in 3 (5.6%) children with LBW at birth and 7 (8.9%) children in the control group, whereas left axis deviation was observed

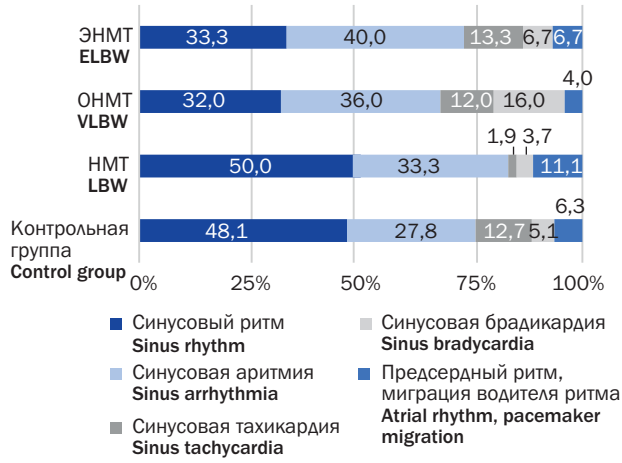

Fig. 1. Distribution of heart rate types in the studied groups: LBW — low body weight; VLBW — very low body weight; ELBW — extremely low body weight (the figure is prepared by the authors using their own data)

Рис. 1. Распределение видов сердечного ритма в исследуемых группах: НМТ — низкая масса тела; ОНМТ — очень низкая масса тела; ЭНМТ — экстремально низкая масса тела (рисунок подготовлен авторами по собственным данным)

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Table 1. Results of electrocardiographic examination in observed children

Таблица 1. Результаты электрокардиографического исследования у наблюдаемых детей

ЭКГ-признак ECG sign	ЭНМТ ELB (n=15)	ОНМТ VLBW (n=25)	НМТ LBW (n=54)	Контрольная группа Control group (n=79)	p
	1	2	3	4	
Нарушение процессов реполяризации Violation of repolarization processes	4 (26,7%)	1 (4%)	7 (13%)	7 (8,9%)	p_{1-2}=0,06 p_{1-3}=0,2 p_{1-4}=0,06 p_{2-3}=0,2 p_{2-4}=0,4 p_{3-4}=0,4
Нарушения сердечной проводимости: НБПНПГ, ПБПНПГ Cardiac conduction disorders: IRBBB, CRBBB	1 (6,7%)	2 (8%)	1 (1,9%)	3 (5,6%)	p_{1-2}=0,9 p_{1-3}=0,3 p_{1-4}=0,6 p_{2-3}=0,2 p_{2-4}=0,4 p_{3-4}=0,5
Блокада передней ветви ЛНПГ Anterior branch block LBB	1 (6,7%)	0	1 (1,9%)	1 (1,3%)	p_{1-2}=0,1 p_{1-3}=0,3 p_{1-4}=0,2 p_{2-3}=0,8 p_{2-4}=0,9 p_{3-4}=0,8
Укорочение интервала P–Q (P–Q <0,1 с) Shortening of the P–Q interval (P–Q <0.1 s)	0	1 (4%)	1 (1,9%)	1 (1,3%)	p_{1-2}=0,6 p_{1-3}=0,9 p_{1-4}=0,6 p_{2-3}=0,6 p_{2-4}=0,4 p_{3-4}=0,8
Удлинение интервала Q–T (Q–Tc >0,46 с) Prolongation of the Q–T interval (Q–Tc >0.46 s)	1 (6,7%)	2 (8%)	2 (3,7%)	2 (2,5%)	p_{1-2}=0,9 p_{1-3}=0,6 p_{1-4}=0,4 p_{2-3}=0,4 p_{2-4}=0,2 p_{3-4}=0,7

The table is prepared by the authors using their own data

Таблица составлена авторами по собственным данным

Note: LBB — left bundle branch; IRBBB — incomplete right bundle branch block; LBW — low body weight; VLBW — very low body weight; CRBBB — complete right bundle branch block; ECG — electrocardiography; ELBW — extremely low body weight.

Примечание: ЛНПГ — левая ножка пучка Гиса; НБПНПГ — неполная блокада правой ножки пучка Гиса; НМТ — низкая масса тела; ОНМТ — очень низкая масса тела; ПБПНПГ — полная блокада правой ножки пучка Гиса; ЭКГ — электрокардиография; ЭНМТ — экстремально низкая масса тела.

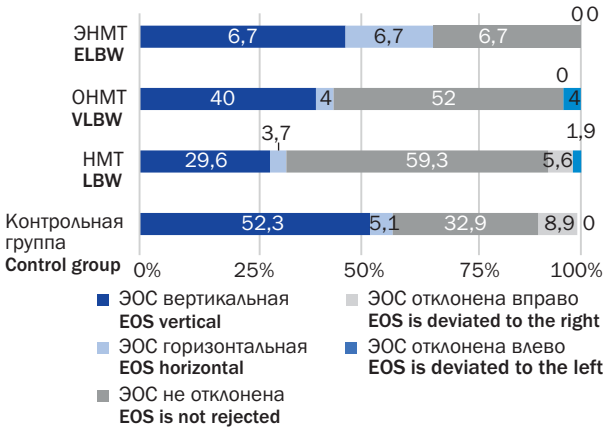

Fig. 2. Distribution of the direction of the electrical axis of the heart in the studied groups: LBW — low body weight; VLBW — very low body weight; ELBW — extremely low body weight; EOS — electrical axis of the heart (the figure is prepared by the authors using their own data)

Рис. 2. Распределение направления электрической оси сердца в исследуемых группах: НМТ — низкая масса тела; ОНМТ — очень низкая масса тела; ЭНМТ — экстремально низкая масса тела; ЭОС — электрическая ось сердца (рисунок подготовлен авторами по собственным данным)

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in 1 (4.0%) child with VLBW at birth and 1 (1.9%) child with LBW at birth. In the majority of children in both the main and control groups, the cardiac electrical axis was within normal limits (Fig. 2). The above findings are consistent with a normal variant for children of this age.

Comparative analysis of the main ECG parameters revealed no significant differences between the study groups. Median heart rate values across all groups fell within age-appropriate normal ranges, with no appreciable between-group differences observed (p=0.8). QRS duration, reflecting the velocity of electrical impulse conduction through the ventricles, was also comparable across groups (p=0.1). Q–T interval values, which characterize the duration of the ventricular repolarization phase, showed no statistically significant variation between the groups (p=0.3). The most clinically relevant parameter was the corrected Q–T interval (Q–Tc), which adjusts for the heart rate dependence of the interval. The statistical significance of the differences was at the trend level (p=0.06) and did not reach the conventional threshold of p<0.05.

In all examined children in both groups, the main ECG intervals remained within age-appropriate normal limits. The obtained values of the main ECG intervals in the groups of children born with ELBW, VLBW, and LBW did not differ significantly from those in the control group (Table 2).

DISCUSSION

The findings of the present study are of interest in the context of the fetal programming hypothesis (DOHaD). According to this concept, adverse intrauterine conditions can lead to structural and functional cardiovascular alterations that become apparent in the long term. Our results demonstrate, however, that by six years of age children born with low birth weight do not develop persistent electrophysiological abnormalities detectable on a standard resting ECG. The absence of significant differences in the main intervals (HR, QRS, Q–T, Q–Tc) and in the frequency of rhythm disturbances may be explained by several factors. First, by preschool age the principal processes of morphofunctional maturation of the myocardium are completed. Second, perinatal hemodynamic disturbances undergo effective compensation. Third, subclinical changes detectable on stress testing or by highly sensitive imaging modalities (speckle-tracking echocardiography, magnetic resonance imaging) may not be apparent on a resting ECG. Our results are consistent with the study by T. Salaets et al., who likewise found no QTc prolongation in adolescents born extremely preterm [11]. Conversely, P.E. Khodkevich et al. demonstrated that certain electrophysiological features may persist in preterm children during early childhood [10], which underscores the importance of longitudinal follow-up and suggests possible normalization of parameters by the preschool period. From a clinical standpoint, the absence of significant ECG abnormalities in the majority of the children examined supports the recommendation of standard follow-up without the need for advanced instrumental investigations in the absence of cardiac complaints and auscultatory abnormalities.

Table 2. Electrocardiographic indicators of the examined children, Me [Q25; Q75]

Таблица 2. Электрокардиографические показатели обследуемых детей, Me [Q25; Q75]

Показатели **Indicators**	**ЭНМТ** **ELB** **(n=15)**	**ОНМТ** **VLBW** **(n=25)**	**НМТ** **LBW** **(n=54)**	**Контрольная группа** **Control group** **(n=79)**	**p**
	1	**2**	**3**	**4**	
ЧСС, уд./мин HR, beats per minute	84 [75;102]	87 [81;102]	87,5 [81;97]	89 [81;100]	p=0,8
QRS, с	86 [85;91]	87 [83;96]	85 [80;91]	90 [85;92]	p=0,1
Q–T, с	331 [297;376]	345 [301;356]	350 [336;365]	355 [339;368]	p=0,3
Q–Tc, с	415 [397;425]	424 [405;439]	428 [412;435]	431 [423;444]	p=0,06

The table is prepared by the authors using their own data

Таблица составлена авторами по собственным данным

Note: LBW — low body weight; VLBW — very low body weight; HR — heart rate; ELBW — extremely low body weight.

Примечание: НМТ — низкая масса тела; ОНМТ — очень низкая масса тела; ЧСС — частота сердечных сокращений; ЭНМТ — экстремально низкая масса тела.

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Children found to have abnormalities (repolarization disturbances, QTc prolongation, clinically significant arrhythmias) should be referred for echocardiography, Holter monitoring, and consultation with a pediatric cardiologist.

CONCLUSION

The present study found no significant differences in ECG parameters between six-year-old children born with low birth weight and their peers with a birth weight exceeding 2500 g. Nonetheless, children born with low, very low, and extremely low birth weight constitute a population at risk for the development of cardiovascular disease. This underscores the need for the application of more extensive and refined diagnostic modalities in these children to enable timely detection of potential abnormalities. Further studies are warranted to achieve a more comprehensive understanding of the cardiovascular status of preschool-aged children born with low birth weight and of the influence of various factors upon it.

ADDITIONAL INFORMATION

Authors' contribution. The concept of the article was developed and the text was written by A.I. Mulyukova, L.V. Yakovleva, Z.K. Galysheva, G.N. Shangareeva; the article was edited by A.I. Mulyukova, L.V. Yakovleva, G.N. Shangareeva; and the final version of the article was approved by L.V. Yakovleva.

All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

Competing interests. The authors declare that they have no competing interests.

Consent for publication. Legal representatives gave informed voluntary consent for the examination and publication of the results obtained.

The study was approved by the decision of the Ethics Committee FSBEI HE BSMU of the Russian Ministry of Health of the dated 13.02.2025.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

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Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

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