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Features of Physical and Psychomotor Development in Children with Brain Ischemia

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Abstract

Background: Brain ischemia is one of the leading causes of morbidity and mortality in infants. Currently, many factors influence the degree of development of ischemia and the consequences affecting the child's body. The purpose of this study was to find the characteristics of the physical and psychomotor development of children with brain ischemia.

Methods: Based on empirical data, physical (centile tables were used) and psychomotor development (Griffiths scale was used) were studied in 246 full-term children who suffered mild and moderate brain ischemia (ICD-10 codes: 91.1-91.4). There was a frequency of physical disharmony and psychomotor dysfunction, association with each other and the modeling of prognostic characteristics. The following methods were used for the analysis: Pearson chi-square calculation, Kaplan-Meier method and logistic regression.

Results: The prevalence of physical disharmony in the studied population of children who had cerebral ischemia is 19.5%, and that of psychomotor dysfunction is 35.0%. The results of the analysis indicate the presence of an association between physical development and psychomotor development of children with cerebral ischemia ($P \leq 0.001$; %95 CI OR 1.961-7.270). The disharmony of physical development in children with cerebral ischemia is higher in female children (OR = 2.061, CI = 1.002-4.236), and it grows with an increase in the childbearing age of the mother (OR = 1.090, 95% CI = 1.018-4.236) and decreases with a decrease in the birth weight of the child (OR = 0.189, 95% CI = 0.104-0.345). The probability of occurrence of psychomotor dysfunction is higher in children whose mothers had a complicated birth (OR = 2.065, 95% CI = 1.209-3.527).

Conclusion: In children who have suffered brain ischemia, 1/5 of cases develop physical disharmony, and 1/3 of cases develop psychomotor dysfunction. These long-term consequences studied are interrelated with such prognostic characteristics as childbearing age and complicated childbirth in the mother, as well as the sex and weight of the child. The incidence of a combination of physical disharmony and psychomotor dysfunction in children who have suffered cerebral ischemia is 11.8%.

Keywords: Brain Ischemia, Child Development, Dysfunction, Motor Skills, Sensory Motor Performances

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Introduction

Perinatal lesions of the central nervous system occupy a leading place in the structure of morbidity and mortality in infancy (1, 2). One of the most common causes of morbidity and mortality in children is cerebral ischemia (3, 4). According to some authors, cerebral ischemia occurs with a frequency of 1 to 26 cases per 1000 newborns (5, 6), and terminal outcomes from cerebral ischemia account for 30 to 35 percent of neonatal deaths (7).

The degree of ischemia and the reaction of the child's body to it depends on the total number of risk factors that

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↑What is "already known" in this topic:
Exposure to hypoxia in infants leads to a complex of disorders that can subsequently affect the health of the developing system.

→What this article adds:
Children who have undergone cerebral hypoxia at birth develop physical disharmony (with a frequency of 1/5) and psychomotor dysfunction (with a frequency of 1/3).

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constantly change over time (perinatal period) (8). The most significant factors on the part of the mother include age over 35 years, the presence of endocrine diseases, premature or prolonged labor, late toxicosis, non-compliance with a healthy lifestyle, and the exacerbation of chronic diseases or acute diseases during gestation (9, 10). The most significant factors on the part of the child include low birth weight in relation to gestational age, intrauterine infection, and congenital anomalies (11, 12).

Brain ischemia can lead to long-term consequences that have a certain impact on the further infant development (13, 14). The main indicators of the development of the child should include physical and neuropsychic development (15). From previously published data, it follows that children who have undergone cerebral ischemia may lag behind their peers in terms of physical development and most often have disturbances in the pace of neuropsychic development: a lag in sensory, motor, and speech development and emotional and behavioral disorders (16, 17).

The search for effective technologies for the prevention, treatment, and rehabilitation of cerebral ischemia (including consequences) in children remains one of the most important tasks in medicine (neonatology, pediatrics) and public health. Socio-economic, institutional, natural climatic, behavioral and environmental conditions are rapidly changing. These factors can act as risk factors and the consequences need to be constantly monitored.

The purpose of this study was to research the features of physical and psychomotor development in children with cerebral ischemia. There is a shortage of scientific works by Kazakhstan scientists on the assessment of long-term consequences of cerebral ischemia in children, which led to the initiative to conduct this study.

Methods

This is a cross-sectional study using descriptive and analytical statistics. The objects of the study are children who had brain ischemia in mild and moderate form in anamnesis (ICD-10 codes: 91.1-91.4). A total of 246 full-term children aged from one month to one year took part in the study. When applying to a medical organization, the children were examined by a pediatrician (doctoral student), and anthropometric measurements were carried out in order to assess physical development. Measurements of certain types of children's activities were carried out in order to assess psychomotor development. Data collection was carried out in 2021 at the perinatal center in Almaty, Republic of Kazakhstan (complete sample).

The assessment of the physical development of the child was carried out according to three anthropometric indicators: body length, weight, and chest circumference. We used centile tables recommended in Kazakhstan to assess the psychophysical development of young children (order of the Ministry of Health of the Republic of Kazakhstan dated September 9, 2010, No. 704, “On approval of the Rules for organizing screening”). Estimations about the harmony of the physical development of the children were made on the basis of finding the difference between the maximum and minimum numbers of intervals (corridors) of the centile scale obtained for these three indicators. If the difference was 0 or 1 - physical development was considered harmonious. If the difference was 2 or more - physical development was considered disharmonious. If the difference was 3 or more - physical development was considered sharply disharmonious.

Psychomotor development was assessed using the Griffiths scale (Russian version translated by Keshishyan E.S. 2000). This scale was assessed on the scoring system and susceptibility of such graphs as "Motor Skills", "Social Adaptation", "Hearing and Speech", "Eyes and Hands" and "Ability to Play". After summing up the scores for all columns, an integral indicator of psychomotor development was obtained, which varied depending on the age of the child. Comparison of the measurement scores obtained from each child against the scoring system standards made it possible to classify the development of the child using the categories of norm, lag or advanced.

For the possibility of statistical analysis, the information obtained during the study was coded and formed into a database. The IBM SPSS statistics program served as the main analysis tool.

The assessment of the association of physical and psychomotor development of children with cerebral ischemia is carried out using the Pearson chi-square test and the odds ratio calculation method. The null hypothesis (about the absence of a relationship between the studied characteristics) is rejected in the case of $p<0.05$.

The study of the likelihood of the development of physical disharmony and psychomotor dysfunction in children with cerebral ischemia, depending on the age of the mother, was carried out using the construction of the Kaplan-Meier survival curve. The temporal variable is the mother's age at the time of the birth of the child. The data contains a binary outcome: a value of "0" corresponds to a positive outcome (harmonious physical development and/or psychomotor development within the normal range), and a value of "1" corresponds to a negative outcome (disharmonious physical development and/or abnormal psychomotor development).

Logistic regression is used to model the probabilities of physical and psychomotor development under different conditions in children with cerebral ischemia. We analyze the following relevance predictors (accumulated patient data), that can affect the outcomes under study: "age of the mother" (Q25 = 27 years, Q75 = 34 years), "the presence of chronic diseases in the mother" (no, yes), “peculiarities of the course of pregnancy” (physiological and pathological), “peculiarities of the course of childbirth” (physiological and pathological), “age of the child” (Q25 = 1 month, Q75 = 3 months), “gender of the child” (male, female) and “baby weight at birth” (Q25 = 2.975 kg, Q75 = 3.600 kg).

Results

At the initial stage, the frequency of occurrence of physical disharmony and psychomotor dysfunction in children with cerebral ischemia was analyzed (Table 1). In 48 children who underwent cerebral ischemia (in 19.5% of cases), a violation of the harmony of physical development was ascertained, and in 86 children who underwent cerebral ischemia (in 35.0% of cases), there was a deviation from the

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Table 1. Frequency of occurrence of physical disharmony and psychomotor dysfunction in children with cerebral ischemia

Development of children		Total n=246	Including based on the gender of the child	
			Male n=150	Female n=96
Physical development of children				
	Disharmonious	48 (19.5%)	25 (16.7%)	23 (24.0%)
	Harmonious	198 (80.5%)	125 (83.3%)	73 (76.0%)
Psychomotor development of children				
	Deviation from norm	86 (35.0%)	47 (31.3%)	39 (40.6%)
	Within normal range	160 (65.0%)	103 (68.7%)	57 (59.4%)

Table 2. Association of physical and psychomotor development of children with cerebral ischemia

Physical development of children	Psychomotor development of children	
	Deviation from norm	Within normal range
Disharmonious	29 (60.4%)	19 (39.6%)
Harmonious	57 (28.8%)	141 (71.2%)

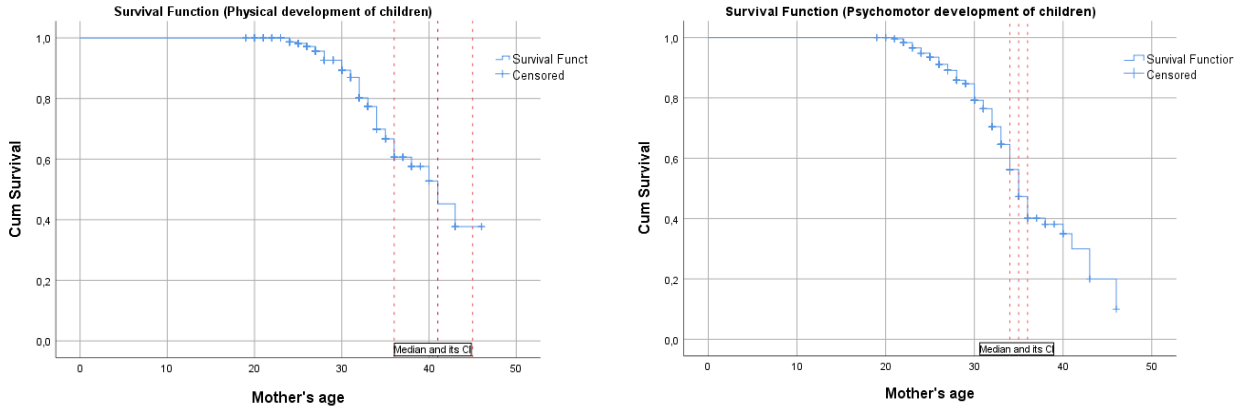

Figure 1. Probability of developing physical disharmony and psychomotor dysfunction in children after cerebral ischemia, depending on the age of the mother (Kaplan-Meier curve)

norm in psychomotor development. It should be noted that the frequency of occurrence (relative frequency) of physical disharmony and psychomotor dysfunction is somewhat higher in female children but not statistically significant ($P > 0.05$).

Along with calculating the frequency of occurrence of physical disharmony and psychomotor dysfunction in children with cerebral ischemia, we studied the association of these phenomena (Table 2). The relationship between psychomotor dysfunction and the physical development of children was revealed who have had cerebral ischemia ($P \leq 0.001$).The chance to have deviations of psychomotor development from the norm is 3.776 times (%95 CI OR 1.961÷7.270) higher in the group of children who have had cerebral ischemia and have disharmonious physical development.

The proportion of children who have had cerebral ischemia and have physical disharmony in combination with psychomotor dysfunction is 11.8% (or 29 children).

Also, we analyzed the probability of development in children with cerebral ischemia of physical disharmony and psychomotor dysfunction, depending on the age of the mother. The Kaplan-Meier curve shows that as the mother's age increases, the cumulative survival function decreases, i.e. the probability that the outcome of interest to us will not occur (Figure 1).

Logistic regression is used to model the probabilities of physical development (model no. 1) and psychomotor development (model no. 2) in children with cerebral ischemia.

In total, it took 3 steps to select predictors that make a statistically significant contribution to the predictive power of model No.1 and 1 step to select predictors that can affect the outcome of model No.2.The predictive value (overall percentage of correct/correct classification) of model No.1 is 83.7% and model No.2 is 65.0%.

According to the results of the regression analysis, model No. 1 gradually included such predictors as "age of the mother", "sex of the child" and "child's weight at birth", and the only predictor, "peculiarities of the course of labor" is included in model No. 2 (Table 3). The remaining predictors, according to the results of the analysis, are excluded due to their insignificance.

Discussion

One of the UN's Sustainable Development Goals is to ensure healthy lifestyles and promote well-being for all people of all ages, especially the child population. Critical indicators for assessing child health are infant mortality and morbidity rates for children under five years of age. The morbidity and mortality of children under five years of age are caused by developmental anomalies, low birth weight, and obstetric causes associated with the presence of risk

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Table 3. Characterization of predictors that make a statistically significant contribution to the predictive power of regression models No.1 and No.2

Predictors		B	S.E.	Wald	df	Sig.	Exp(B)	95% CI for EXP(B)	
Model No. 1 (dependent variable "Physical development of children")									
Step 1	Babyweightatbirth	-1.540	0.291	28.027	1	0.000	0.214	0.121	0.379
	Constant	3.285	0.877	14.030	1	0.000	26.715		
Step 2	Mother's age	0.078	0.034	5.222	1	0.022	1.081	1.011	1.157
	Baby weight at birth	-1.590	0.296	28.774	1	0.000	0.204	0.114	0.365
	Constant	1.035	1.299	0.636	1	0.425	2.816		
Step 3	Mother's age	0.086	0.035	6.110	1	0.013	1.090	1.018	1.168
	Gender of child	0.723	0.368	3.867	1	0.049	2.061	1.002	4.236
	Baby weight at birth	-1.663	0.306	29.538	1	0.000	0.189	0.104	0.345
	Constant	-0.036	1.413	0.001	1	0.980	0.965		
Model No. 2 (dependent variable "Psychomotor development of children")									
Step 1	Features of the course of childbirth	0.725	0.273	7.051	1	0.008	2.065	1.209	3.527
	Constant	-1.728	0.446	15.026	1	0.000	0.178		

factors such as maternal age, abnormalities of pregnancy and delivery, and gestational age (<37 weeks). These risk factors increased the likelihood of adverse neurological outcomes in infants aged 6-12 months (2). Children born with low birth weight (10-4 million in developing countries) are at risk for stunting and metabolic diseases developing in adulthood (7). The prevalence of observed developmental anomalies in a population of infants with neonatal pathology was 21.6% when risk factors were taken into account (2). This diagnostic study collected Perinatal Arterial Ischemic Stroke (PAIS) cases from the Alberta Perinatal Stroke Project, the Canadian Cerebral Palsy Registry, and the International Pediatric Stroke Study sources on the criteria: birth between the year of registry establishment and March 2020, term birth (37 weeks gestation), and no medical comorbidities associated with a stroke diagnosis (e.g., meningitis, major congenital anomaly). The final risk-predictive model using 1924 newborns and 9 clinical factors (maternal age, tobacco exposure, recreational drug exposure, pre-eclampsia, chorioamnionitis, maternal intrauterine fever, emergency surgery, low 5-minute Apgar index, male sex) estimated differences between cases and controls and the sensitivity of it and sensitivity a C statistic of OR 0.71 (95%CI: 0.65-0.77) and good model fit (Hosmer-Lemeshow, $P = 0.86$) (10). Cerebral ischemia occurs in 1-6/1000 live births and 26/1000 live births in developing countries. It is estimated that 30% of neonatal encephalopathy (NE) cases in developed countries and 60% of cases in developing countries have some evidence of intrauterine hypoxic ischemia (3). 15-20% of children with cerebral ischemia die in the early neonatal period, and surviving children have severe neurological disorders, including cerebral palsy, epilepsy, visual and hearing impairment, cognitive impairment, and intellectual, behavioral, and social disorders. Another study shows that PAIS risk differs in many parameters in infants born very or moderately preterm; lower gestational age increases the risk associated with preterm birth (11). In a study of mental health assessment of first-year-of-life children with NE, it was determined that 20% of children had below-average scores and 61% had low scores. Thirty-two percent of children with low scores were from families with severe psychosocial stress (15). Infants with GIE had delays in all sectors of development. Motor abnormalities were frequent, of which gross motor delay was noted in 55 (29.4%) patients, acceptable motor delay in 34 (18.2%), and social developmental delay in 17.1%. While perinatal asphyxia with HIE is responsible for significant mortality and morbidity in developing countries (15). No significant study data on the effect of cerebrospinal ischemia and asphyxia on physical development harmony is determined. Studies of the impact of cerebral ischemia on the development of children and identification of risk factors are small in number.

In the current study, 19.5% of children with cerebral ischemia had a disorder of harmonious physical development, and 35.0% of cases showed a deviation from the norm in psychomotor development. The frequency of physical development disharmony and psychomotor dysfunction was slightly higher in female children ($P > 0.05$). Also, the association between psychomotor dysfunction and the physical development of children was determined in them ($\chi 2 = 16.998$, df = 1, $P \leq 0.001$). The odds of having psychomotor developmental deviations from the norm were 3.776 times (95% CI OR 1.961; 7.270) higher in children with disharmonious physical development. We found that with increasing maternal age (age at delivery), the likelihood of physical disharmony and psychomotor dysfunction in children with cerebral ischemia increased by 10% and 20% at maternal childbearing age of 30 years, and by 40% and 60%, at maternal childbearing age of 40 years, respectively.

A logistic regression was performed to ascertain the effects of "age of the mother", "the presence of chronic diseases in the mother", "peculiarities of the course of pregnancy", "peculiarities of the course of childbirth", "baby's age", "baby's sex", and "baby's birth weight" on the likelihood of physical development and/or psychomotor development in children having cerebral ischemia. The probability of physical disharmony development in children with cerebral ischemia increases with an increase in the childbearing age of the mother (OR = 1.090 95%CI 1.018-1.168) and decreases with a decrease in the birth weight of

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the child (OR = 0.189 95%CI 0.104-0.345). And the probability of developing physical disharmony is higher in female children (OR = 2.061 95%CI 1.002-4.236). It is found that the likelihood of psychomotor dysfunction is higher in those children whose mothers have complicated births (OR = 2.065 95%CI 1.209-3.527).

One of the study's results that requires further discussion is the decreased likelihood of physical disharmony with decreasing birth weight. The result may be a bias error, as the children's body weight was not considered an inclusion criterion when the sample was formed. When selecting observation units in the sample (continuous observations - cases of referral to a medical organization), it was impossible to observe the randomness principle for the parameter "body weight". The argument in favor of this assumption is that 50% of the children in the sample have a body weight that varies within the average statistical norm (Q25 = 2.975 kg, Q75 = 3.600 kg). Further research is needed to verify the controversial result obtained in this study. Due to high mortality and long-term disability, neonatal cerebral ischemia is a major medical and public health problem.

To sum up, the main results of our study are consistent with the scientific literature on the possible features of physical and psychomotor development in children with cerebral ischemia. One of the study's results, which requires further discussion, is associated with a decrease in the probability of physical disharmony when the child's birth weight decreases. In our opinion, the obtained result may be due to bias error since the formation of the sample of children with cerebral ischemia was not randomized according to the parameter "body weight." When selecting observation units in the sample (continuous observations - cases of referral to medical facilities), it was impossible to observe the randomness principle for the parameter "body weight." The argument in favor of this assumption is that 50% of the children in the sample have a body weight that varies within the average statistical norm (Q25 = 2.975 kg, Q75 = 3.600 kg). Further research is needed to verify the controversial result obtained in this study.

Conclusion

Brain ischemia in children can disrupt physical and psychomotor development, leading to physical disharmony and psychomotor dysfunction, the occurrence of which is interrelated and conditioned with such prognostic characteristics as the childbearing age of the mother, the fact of birth complications, sex and weight of the child. The incidence of a combination of physical disharmony and psychomotor dysfunction in children who have suffered brain ischemia is 11.8%.

Authors' Contributions

Shoibekova G.O. was involved in the conception and design of the study, including the literature review, data collection, analysis, and interpretation, and also drafted the manuscript. Turbekova M.N., Iskakova F.A. were involved in the conception and design of the study, including data analysis and interpretation, and also review and evaluation of the manuscript. Other authors were involved in the study design and conduction. All authors reviewed the manuscript critically and approved the final manuscript.

Ethical Considerations

The study was conducted in compliance with ethical principles – patients were examined after obtaining informed consent.

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Conflict of Interests

The authors declare that they have no competing interests.

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