Article's History: Received: 19.06.2025; Revised: 23.10.2025; Accepted: 25.11.2025

Bulletin of Medical and Biological Research

Vol. 7, No. 4
2025

DOI: 10.63341/bmbr/4.2025.27

Journal homepage: https://bmbr.com.ua/en

UDC 616-053.2-007.5:612.825:577.1

Investigation of brain-derived neurotrophic factor as a diagnostic marker of neuroplasticity in children with motor disorder delay

Tetiana Bakaliuk*

Doctor of Medical Sciences, Professor
I. Horbachevsky Ternopil National Medical University
46001, 1 Maidan Voli, Ternopil, Ukraine
https://orcid.org/0000-0002-7619-0264

Maria Vitsentovych

Postgraduate Student
Ternopil Volodymyr Hnatiuk National Pedagogical University
46027, 2 Maksym Kryvonos Str., Ternopil, Ukraine
https://orcid.org/0000-0002-6492-3635

Abstract. The relevance of researching biomarkers of neuroplasticity lies in the growing prevalence of motor disorders in children, as timely diagnosis and early intervention are critical for improving prognosis. The aim of the study was to evaluate the diagnostic significance of brain-derived neurotrophic factor levels as a potential marker of neuroplasticity in children aged 7-8 months with motor development delay through an integrated analysis of gestational age, body weight, motor skills according to the Alberta Infant Motor Scale, and brain-derived neurotrophic factor concentration. The study involved 25 healthy children aged 7-8 months without motor disorders and 56 children of the same age with motor development delay, including 28 children who were born full-term but had motor disorders and 28 children who were born prematurely with motor disorders. The study found a significant correlation between the level of brain-derived neurotrophic factor in blood serum and the degree of motor development impairment in children. Median levels of brain-derived neurotrophic factor were highest in the control group (22.76 pg/mL) and progressively decreased in groups with motor development disorders (11.25 pg/mL and 8.30 pg/mL). Statistically significant differences in serum brain-derived neurotrophic factor levels were found between all study groups ($p < 0.00001$). The results indicated that children with motor development disorders had significantly lower levels of brain-derived neurotrophic factor than their healthy peers, which may indicate reduced neuroplasticity in these groups. These results highlighted the potential of brain-derived neurotrophic factor as an objective criterion for early diagnosis, prognosis, and evaluation of the effectiveness of rehabilitation interventions in children with motor development delays

Keywords: biomarker of motor disorders; early diagnosis; full-term infants; preterm infants; Alberta Infant Motor Scale

INTRODUCTION

The increase in the number of motor disorders in childhood determines the relevance of finding effective tools for early diagnosis. Timely detection and intervention are crucial for improving the long-term prognosis, as the first years of life are critical for a child's development. During this period, the brain exhibits the highest neuroplasticity, which creates unique opportunities for the correction of motor and cognitive functions. However, the potential of neuroplasticity is still underutilised in early intervention, especially in the global healthcare system [1].

One of the key mechanisms that ensure neuroplasticity is the action of neurotrophic factors. According to a review by W.M. Stansberry & B.A. Pierchala [2], brain-derived neurotrophic factor (BDNF), ciliary neurotrophic factor (CNTF) and glial cell line-derived neurotrophic factor (GDNF) play a leading role in the development and regeneration of motor neurons. This provides a basis for considering them not only as biological regulators, but also as potential diagnostic and prognostic markers in neurological diseases, including in children with motor disorders.

Suggested Citation:
Bakaliuk T, Vitsentovych M. Investigation of brain-derived neurotrophic factor as a diagnostic marker of neuroplasticity in children with motor disorder delay. Bull Med Biol Res. 2025;7(4):27–36. DOI: 10.63341/bmbr/4.2025.27

*Corresponding author

At the same time, BDNF is being studied as a universal biomarker of neuroplasticity. A review by A. Treble-Barna *et al*. [3] systematised data on its changes in acquired lesions of the central nervous system (CNS) in children. The authors emphasised that BDNF is sensitive to trauma, rehabilitation interventions and environmental influences, but methodological differences and inter-study heterogeneity complicated the interpretation of the results. BDNF plays an important role in the survival and plasticity of neurons and is associated with physical ability and inflammatory processes [4]. A study by H.Y. Xiong *et al*. [5] demonstrated a positive correlation between BDNF levels and the function of the CNS and peripheral nervous system.

The role of BDNF in the development of psychoneurological disorders is of particular scientific interest. A.G. Barbosa *et al*. [6] showed that this factor may be involved in the pathophysiology of autism spectrum disorders, although its expression level depends on a number of factors that have not yet been sufficiently studied. In a study by U. Pauli-Pott *et al*. [7], BDNF concentration in hair was considered a prognostic indicator of the risk of developing anxiety and depressive symptoms, as well as attention deficit hyperactivity disorder. Equally important is the study of the relationship between physical activity and BDNF levels. Thus, F. Vasileva*et al.* [8] demonstrated that integrated three-month neuromuscular training in schoolchildren contributed to an increase in BDNF concentration in saliva and the development of fundamental motor skills. A meta-analysis by Y.H. Wang *et al.* [9] proved that intense and prolonged aerobic exercise is most effective in increasing BDNF levels, which, in turn, can activate a series of neuronal reactions aimed at improving cognitive functions. Similar results were obtained in a study by M. Rico-González *et al*. [10], which emphasised the importance of cognitively engaging physical activity (in particular, neuromotor exercises and martial arts) for optimising brain development in children.

Recent studies expand the understanding of the role of BDNF in adulthood. For example, S.V. Shevchuk & T.V. Stepaniuk [11] showed that in patients with systemic lupus erythematosus, serum BDNF levels were reduced by 44.7% compared to the control group, which was associated with cognitive impairment and mental health disorders. A study by Y. Havlovska *et al.* [12] confirmed the importance of BDNF as an objective biomarker of severity and prognosis of recovery after ischaemic stroke. In a review by N. Bouhaddou *et al.* [13], scientists emphasised the multifunctional role of platelets in the development of neurological disorders, in particular highlighting their function as a reservoir of BDNF and other neurotrophic factors. Platelet BDNF has a significant impact on the processes of neuroplasticity, neuroprotection, and cognitive functioning, which is potentially important for the pathogenesis of a wide range of neurological and psychiatric diseases.

Therefore, studying BDNF levels in children with motor development delays is particularly important. This could form the basis for using this neurotrophic factor as a reliable diagnostic marker of neuroplasticity, an important predictor of further development, and an objective criterion for evaluating the effectiveness of rehabilitation strategies. The aim of the study was to investigate the relationship between BDNF concentration in blood serum and motor skill indicators in children with developmental delay, as well as to determine whether this biomarker can serve as an objective criterion for early diagnosis.

MATERIALS AND METHODS

The study was conducted at the Ternopil Regional Children's Clinical Hospital, a municipal non-profit enterprise of the Ternopil Regional Council, from September 2023 to May 2025. The inclusion criteria were: age of the child 7-8 months, adjusted age up to 7 months for premature babies, diagnosed motor development delay. Some of the children included in the study had risk factors at birth; the relevant information obtained from the medical history is presented in Table 1. Most children with motor development delay had a complicated perinatal history, dominated by factors associated with premature birth and low birth weight. This highlights the need to consider perinatal characteristics in the further assessment of neuroplasticity and motor function development. The exclusion criteria were: motor disorders syndromes (spastic paresis, manifestations of pyramidal insufficiency, pseudobulbar syndrome, hyperkinesis, muscle hypo- or dystonia, ataxia); syndrome of increased reflex excitability of the nervous system; hydrocephalic and epileptic syndromes; severe motor disorders corresponding to levels IV-V on the Gross Motor Function Classification System scale; significant congenital developmental anomalies, as well as pronounced somatic and symptomatic disorders.

Table 1. Risk factors at birth in the studied children

Risk factor	Number of children (n)	Percentage (%)
Mild prematurity (35-37 weeks) and/or low birth weight (2,000-2,500 g)	11	19.6
Prematurity (28-37 weeks) and/or very low birth weight (500-2,500 g)	22	39.2
Mild neonatal encephalopathy	10	17.8
Multiple pregnancy	5	8.9
Neonatal jaundice requiring phototherapy	7	12.5

Source: compiled by the authors based on research

The family paediatrician selected 25 healthy children without motor disorders aged 7-8 months to be included in the Control group (CG). Among the children referred by paediatric neurologists, orthopaedists or family paediatricians to the Centre for Comprehensive Medical Rehabilitation of Children with Nervous System and Mental Disorders in Outpatient Settings of the Ternopil Regional Children's Hospital, 56 children aged 7-8 months (32 boys, 24 girls) with delayed motor development were selected. Among them were 28 full-term infants with motor disorders (FIMD) and 28 premature infants with movement disorders (PIMD), taking into account their corrected age.

At the time of examination, all children were 7-8 months old. The study took into account their gestational age, body weight at the time of examination, number of motor skills according to the Alberta Infant Motor Scale (AIMS) and BDNF level. AIMS is a standardised tool used to assess motor development in young children, usually from 0 to 18 months. Motor skills were assessed according to the age of 7-8 months in 4 basic positions: lying on the back, lying on the stomach, sitting, standing. The level of BDNF in the patients' blood serum was quantified using a solid-phase enzyme-linked immunosorbent assay with a highly sensitive Human BDNF ELISA test assay Company ELK (Wuhan, Biotechnology CO., Ltd.) according to the manufacturer's instructions in pg/mL.

In the statistical analysis, quantitative data were described using the median (Me) and interquartile range (IQR). For a graphical representation of the distribution of indicators such as gestational age, body weight, number of motor skills according to AIMS, and serum BDNF levels, boxplots were constructed to visually display the median values and IQR and to assess the variability and symmetry of the distribution within each group (Control, FIMD, PIMD). Boxplots were used as an auxiliary tool for descriptive statistics and visual assessment of differences between groups, as well as to identify trends in changes in indicators. To assess the differences between the three independent groups (control, FIMD and PIMD), statistical analysis was performed using the non-parametric Kruskal-Wallis test. This test was chosen due to the absence of normal distribution of the studied indicators (verified by the Shapiro-Wilk test) and the heterogeneity of variances. The level of statistical significance was set at $p < 0.05$. Data processing was performed using Statistica 12 software (StatSoft Inc.).

The parents of the children included in the study were informed about the method and purpose of the study and gave their written consent for their children to participate in the study and for the anonymous publication of the results. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki of the World Medical Association[14] and was approved by the local ethics committee (Protocol No. 37/2, 17 December 2024). However, the study had certain limitations that are important to consider when interpreting the results. First, the small sample size (56 children with motor development delay) may affect the statistical power and generalisability of the findings. Although the correlations obtained were statistically significant, further studies with a larger number of participants are needed to confirm and extrapolate these results to a wider population of children with motor development delay. Second, a single measurement of serum BDNF levels was used. This approach allowed to show BDNF levels at a specific point in time, but did not allow to assess the dynamics of this indicator. Given that BDNF can be influenced by various factors (e.g., physical therapy), longitudinal studies with multiple measurements would be more informative. They would allow to track how changes in BDNF levels over time correlate with changes in a child's motor development and how they respond to rehabilitation interventions.

RESULTS

When analysing the gestational age of children in three groups: Control group, FIMD and PIMD, the results showed a difference in Me and IQR, which were visualised on a boxplot and confirmed the importance of stratifying study participants (Fig. 1).

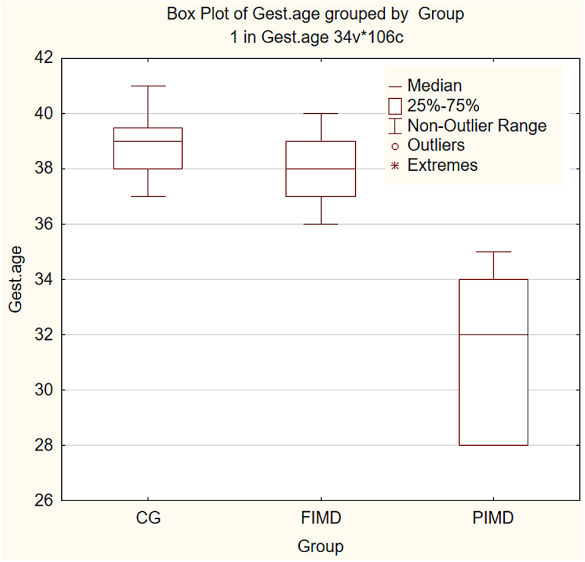

Figure 1. Boxplot of gestational age in the study groups
Source: compiled by the authors based on research

Analysis of gestational age indicators showed a gradual decrease in values from the control group to children born prematurely with PIMD. The lowest median values were observed in the PIMD group (31.14) compared to other groups (38.66 in CG and 38.00 in FIMD), reflecting the most pronounced differences in this category. In addition, only in the PIMD group was the interquartile range relatively wide, indicating greater variability in gestational age among these children. Table 2 showed the results of comparing gestational age indicators between groups.

Table 2. Comparison of gestational age indicators between groups

No.	Group	(Me (IQR)	Significance level	Presence (+)/ absence (-) of statistically significant difference
1	CG	38.66 (37.42; 39.90)	0.06	-
	FIMD	38.00 (37.03; 38.96)		
2	CG	38.66 (37.42; 39.90)	0.00001	+
	PIMD	31.14 (28.29; 33.99)		
3	FIMD	38.00 (37.03; 38.96)	0.00001	+
	PIMD	31.14 (28.29; 33.99)		

Source: compiled by the authors based on research

In CG and FIMD, the medians were higher and the distribution of data was narrower, indicating greater homogeneity of indicators in these samples. The difference in gestational age between CG and FIMD is not statistically significant, since $p > 0.05$, i.e. both groups have similar gestational ages. When comparing CG with PIMD and FIMD with PIMD: $p = < 0.05$, i.e. the difference was statistically significant. This means that the gestational age in the PIMD group is significantly lower compared to the other two groups and indicates a significant contribution of premature birth to the formation of motor development disorders, while in children with FIMD, the gestational age was close to full-term, which may indicate other aetiological mechanisms. When analysing the body weight of children in the three study groups, the results showed a clear gradation in body weight according to membership in one group or another (Fig. 2).

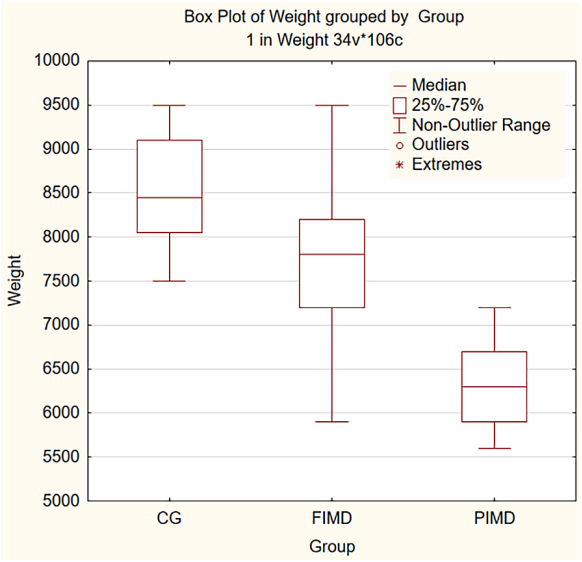

Figure 2. Boxplot of body weight in the study groups

Source: compiled by the authors based on research

The boxplot showed a clear downward trend in body weight – from the control group (Me 8,491.66) to FIMD (Me 7,761.48), and further to PIMD (Me 6,217.03). Decreased body weight may be an indicator of delayed somatic development associated with motor or neurophysiological limitations. The FIMD group showed the greatest variability, which may indicate heterogeneity of clinical manifestations – from almost normal indicators to significant disorders. In turn, the PIMD group was characterised by the lowest and most homogeneous body weight indicators, which corresponds to a more severe developmental condition. Body weight indicators decrease significantly with increasing severity of motor disorders. This may indicate the negative impact of the severity of motor disorders on the nutritional status and physical development of the child. Table 3 showed the results of a comparison of body weight indicators between groups.

Table 3. Comparison of gestational age indicators between groups

No.	Group	(Me (IQR)	Significance level	Presence (+)/ absence (-) of statistically significant difference
1	CG	8,491.66 (7,873.17; 9,110.16)	0.0032	+
	FIMD	7,761.48 (6,916.09; 8,606.86)		
2	CG	8,491.66 (7,873.17; 9,110.16)	0.00001	+
	PIMD	6,217.03 (5,729.03; 6,705.03)		

Table 3. Continued

No.	Group	(Me (IQR)	Significance level	Presence (+)/ absence (-) of statistically significant difference
3	FIMD	7,761.48 (6,916.09; 8,606.86)	0.00001	+
	PIMD	6,217.03 (5,729.03; 6,705.03)		

Source: compiled by the authors based on research

Based on the data presented, body weight indicators differed significantly in all three groups compared. In the FIMD group, there was a significant decrease in body weight compared to CG, while in patients with PIMD, body weight was even lower – both relative to the control group and compared to the FIMD group. All intergroup differences were statistically significant, indicating a close relationship between the level of motor deficit and indicators of somatic development in children. Thus, the boxplot and table confirmed both the statistical and clinical significance of differences in body weight between children in different groups and can be considered as an additional criterion in assessing the degree of motor disorders and the overall somatic status of the child. Motor skills were assessed using AIMS (Fig. 3).

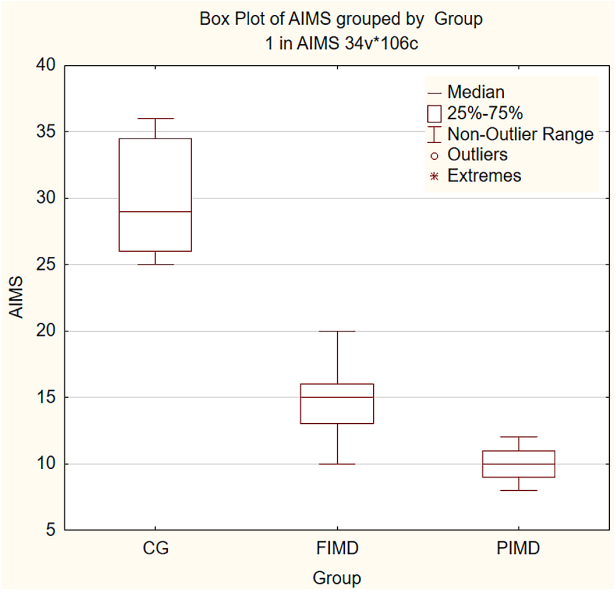

Figure 3. Boxplot of motor skills according to AIMS in the study groups
Source: compiled by the authors based on research

The results of the AIMS motor skills assessment clearly demonstrated the relationship between the level of motor development of children and their belonging to different study groups – the control group and two groups with motor development delays. The boxplot showed a clear decrease in the median from the CG to the PIMD group. In the CG, the scores were the highest and had a wide IQR, indicating greater variability in motor skills among healthy children. In the FIMD group, the results were significantly lower, with moderate variability, while in the PIMD group, they were the lowest and with minimal dispersion, reflecting a consistently low level of motor function in premature infants. Table 4 showed the results of comparing AIMS motor skill scores between groups.

Table 4. Comparison of motor skill scores according to AIMS between groups

No.	Group	(Me (IQR)	Significance level	Presence (+)/ absence (-) of statistically significant difference
1	CG	29.83 (25.66; 34.00)	0.00001	+
	FIMD	14.59 (12.18; 16.99)		
2	CG	29.83 (25.66; 34.00)	0.00001	+
	PIMD	9.81 (8.51; 11.11)		
3	FIMD	14.59 (12.18; 16.99)	0.00001	+
	PIMD	9.81 (8.51; 11.11)		

Source: compiled by the authors based on research

All comparisons of motor skills indicators on the AIMS scale showed significant differences between the groups. The control group had the highest level of motor function development. Patients in the FIMD group showed a decrease in motor development indicators, while the PIMD group showed an even more pronounced deterioration. Thus, motor skills progressively deteriorate with increasing motor deficit severity, which is confirmed by statistically significant p-values in all comparisons. The results confirmed that children with delayed motor development have significantly lower motor skills compared to their healthy peers, with the most pronounced impairments found in premature babies. Given these data, AIMS has confirmed its effectiveness and reliability as a tool for quantitatively assessing the degree of motor deficit in children. AIMS allows for objective differentiation of the level of preservation or loss of motor functions, which is an important component of a comprehensive clinical assessment. Since the AIMS assessment effectively reflects the difference in motor development levels between groups, these data can be used for early diagnosis, risk stratification, and planning of rehabilitation interventions in children with motor disorders. When analysing BDNF in blood serum in children in the three study groups, significant intergroup differences were found (Fig. 4).

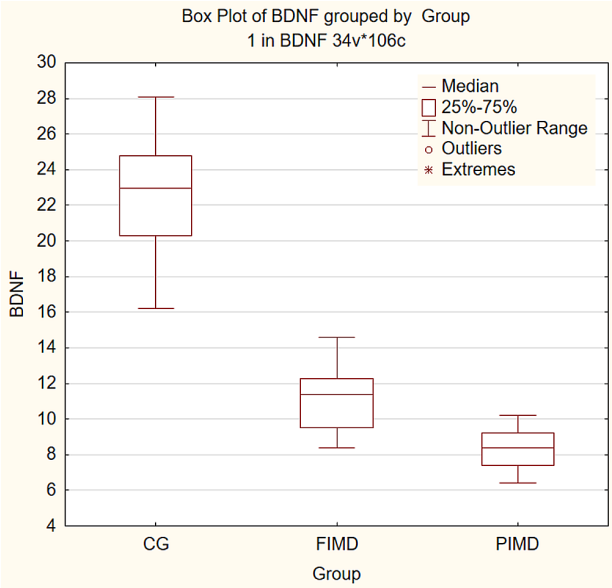

Figure 4. Boxplot of BDNF in the study groups
Source: compiled by the authors based on research

When comparing BDNF levels in three groups of children: CG, FIMD and PIMD, the boxplot showed a clear decrease in the median from the control group to the PIMD group. The highest values were observed in CG, with significant variability and a wide interquartile range, indicating individual differences in BDNF concentration among healthy children. In the FIMD group, BDNF levels were significantly lower and with a moderate spread of values. The lowest and most consistently low values were found in PIMD, reflecting a deeper decline in neuroplasticity in premature children with motor disorders. The results indicated a statistically significant difference in BDNF levels between the groups. This provides grounds for considering BDNF concentration as a potential indicator of clinical state differentiation. Table 5 showed the results of comparing AIMS motor skill scores between groups.

Table 5. Comparison of BDNF levels between groups

No.	Comparison groups of indicators of gestational age	(Me (IQR)	Significance level	Presence (+)/ absence (-) of statistically significant difference
1	CG	22.76 (19.35; 26.17)	0.00001	+
	FIMD	11.26 (9.46; 13.06)		
2	CG	22.76 (19.35; 26.17)	0.00001	+
	PIMD	8.30 (7.17; 9.43)		
3	FIMD	11.26 (9.46; 13.06)	0.00001	+
	PIMD	8.30 (7.17; 9.43)		

Source: compiled by the authors based on research

Statistically significant differences in serum BDNF levels were found between all study groups ($p < 0.00001$). CG children had the highest levels, while children with motor development delays had significantly lower levels. The lowest values were recorded in premature children with motor disorders, while in full-term infants with similar disorders,

BDNF levels were intermediate. The data obtained indicate that a decrease in BDNF levels is associated with motor disorders in children and may also reflect the effect of prematurity on neuroplasticity. Overall, the results showed a clear trend: in children with motor development disorders, especially in the PIMD group, BDNF levels were significantly lower than in healthy peers, which may indicate reduced neuroplasticity in these groups. Summarising the results, it can be noted that gestational age, body weight, level of motor disorders, and BDNF levels showed a clear downward trend in children with motor disorders.

DISCUSSION

This study was aimed at solving the problem of objectifying the assessment of neuroplasticity in children with delayed motor development, which is critical for early intervention. The hypothesis was put forward that the BDNF level could serve as an informative auxiliary marker, reflecting the degree of motor development impairment and the potential for recovery, which is essential for individualising and monitoring the effectiveness of rehabilitation measures. Despite the frequent use of biomarkers in medical practice, there is relatively little information on validated paediatric biomarkers. Biomarkers that have been proven effective in the adult population are often automatically extrapolated to paediatric practice without taking into account the specifics of the child's body, in particular differences in the pathogenesis of diseases and the influence of ontogenetic factors on the course of the disease and therapeutic response. This necessitates the introduction of new approaches aimed at identifying reliable and validated biomarkers adapted to the characteristics of the paediatric population in order to improve the effectiveness of diagnosis and treatment in paediatrics [15].

The scientific community is showing growing interest in BDNF as an important diagnostic indicator of neuroplastic processes. BDNF plays an important role in the development and functioning of the nervous system. It also improves synaptic function in both the cerebral cortex and the hippocampus [16]. The basis for the future use of BDNF as a biomarker in the paediatric population was provided by a study by J.D. Chew *et al*. [17], which evaluated brain-derived neurotrophic factor and osteopontin in a healthy paediatric population. This study provided preliminary data on serum BDNF and plasma osteopontin levels in children and analysed their relationship with cardiovascular health and physical fitness indicators in the paediatric population.

In the study, children aged 7-8 months were analysed using boxplots of gestational age, body weight at the time of examination, number of motor skills according to AIMS, and BDNF levels in three groups. The changes identified provided insight into the potential of BDNF as a marker of neuroplastic processes. The study showed a clear trend towards a decrease in serum BDNF levels from the control group to the FIMD group, and further to the PIMD group. This dynamic may indicate a gradual decrease in neuroplastic activity in children with motor development delays. This result showed that low BDNF levels may not only accompany but also be one of the factors influencing the formation of motor skills. This may also be due to the fact that reduced BDNF concentration leads to insufficient support for neurons, disruption of their differentiation, and a decrease in the plastic properties of the brain. Thus, BDNF can act as an objective indicator of the state of neuroplasticity. The results obtained are partially consistent with the data presented in other studies.

In particular, A. Ghassabian *et al*. [18] showed that in premature infants, higher neonatal BDNF levels are associated with a lower likelihood of developmental delays in any area, even after adjusting for the influence of concomitant factors and methods of infertility treatment in the mother. The authors also noted that BDNF levels in newborns may depend on the mother's lifestyle, and a decrease in BDNF may serve as an early marker of abnormal neurodevelopment in preterm infants. The findings of the study regarding the lowest BDNF levels in the PIMD group are consistent with the conclusions of a systematic review and meta-analysis conducted by F.C. Krey *et al*. [19]. The authors compared the levels of a number of neurotrophic factors (BDNF, NGF, NT-3, NT-4, and GDNF) in term and preterm infants and showed that preterm infants have lower levels of BDNF and NT-3 compared to term infants. These changes may be directly related to the fact of premature birth, which probably reflects the limited capacity for neuroplastic response of the nervous system in conditions of immaturity.

The results indicated a decrease in BDNF levels in children with motor development delay, which is consistent with the data of L. Mercado *et al*. [20], a link was established between the concentration of biomarkers in maternal and umbilical cord blood and foetal brain activity indicators obtained using non-invasive foetal magnetoencephalography. The authors found that maternal BDNF levels are directly related to foetal brain activity, highlighting the importance of this neurotrophic factor in early neurodevelopmental processes. Their data confirmed the feasibility of using BDNF as a potential biomarker, including in combination with methods for assessing electrophysiological brain activity, to monitor the development of the nervous system during the intrauterine period. Similarly, the authors' results are consistent with those of H. Dingsdale *et al*. [21], who showed that lower levels of BDNF in umbilical cord blood serum at birth, especially in male children, may be a factor in the increased risk of neurodevelopmental disorders. This confirmed the potential diagnostic value of BDNF as an early biomarker capable of signalling the likelihood of developmental abnormalities even before the onset of clinical symptoms. Similar conclusions were reached by C.H. Su *et al*. [22], who found that children born to mothers with gestational diabetes at 12 months of age showed lower speech development scores, accompanied by reduced serum BDNF levels. The authors suggested a close relationship between BDNF levels and language outcomes, which is consistent with the authors' observations on the role of neurotrophic factors in the formation of cognitive and motor functions in children. This highlighted the need for further longitudinal studies to determine the long-term consequences of reduced BDNF levels in early childhood.

The strong positive correlation found between serum BDNF levels and motor development scores on the AIMS scale is an important contribution to understanding the pathophysiology of motor development delay. This result is consistent with data from other studies, which also indicate a direct link between BDNF and neuroplasticity, synaptogenesis, and motor neuron function. The results

obtained indicated a strong correlation between BDNF levels and motor development scores on the AIMS scale, which has been confirmed in existing clinical studies. A study by J. Hua *et al*. [23] showed that early motor stages, such as crawling and walking, are key markers for identifying coordination disorders. Even a slight delay in their mastery in infancy significantly increases the risk of further motor disorders. At the same time, individual studies emphasise the advisability of adapting care conditions to the neurological vulnerability of the child as early as the neonatal period, which is consistent with the concept of early intervention [24]. In addition, children with such disorders demonstrate abnormal patterns of transition from crawling to walking, which can be noticeable as early as 6-8 months of age. Thus, the data revealed in the study, demonstrating the relationship between BDNF and motor development, are of particular importance in the context of the concept of neuroplasticity.

The brain demonstrates its highest potential for neuroplasticity during the first two postnatal years, creating an optimal "window of opportunity" for the correction of developmental disorders [25]. As noted by B.O. Olusanya *et al*. [1], a misunderstanding of this biological basis often leads to ineffective approaches in the early intervention system. Instead of making the most of this critical period, assistance programmes may be insufficiently intensive or start too late. The results of the study emphasised the importance not only of early detection of motor development delays, but also of the use of effective, evidence-based rehabilitation measures in the first years of life. The use of BDNF as a biomarker can help to objectively assess the potential for neuroplasticity and target therapy to make the most of this "window of opportunity".

A summary of the studies provided and their comparison with the current work confirmed the existence of a consistent association between BDNF levels and motor development indicators in young children. The dynamics of changes in this neurotrophic factor in different clinical groups are consistent with current ideas about neuroplasticity and its impairment in motor development delay. Comparison of the data obtained with previous studies has deepened understanding of the role of BDNF in the formation of motor skills during the most vulnerable period of postnatal development.

CONCLUSIONS

Children with motor development delay tend to have lower gestational age, body weight, and motor skills, which confirms the importance of early somatic and neurological status for further development. Gestational age in children with PIMD was significantly lower compared to CG and FIMD ($p < 0.05$), which emphasised the role of premature birth in the formation of severe motor disorders. In children with FIMD, gestational age was close to full term, indicating the likelihood of other aetiological mechanisms. Body weight indicators differed significantly between all groups: in children with FIMD, they were lower than in the control group, and in PIMD, they were even lower, confirming the relationship between the degree of motor deficit and somatic development. All study groups also had statistically significant differences in motor skills on the AIMS scale. The best indicators were recorded in the control group, while patients with motor disorders, especially in the PIMD group, showed progressive deterioration in motor development. This confirms that the degree of motor deficit directly correlates with the level of motor skills.

Since BDNF is one of the key proteins that support the development, survival, and functioning of neurons, a decrease in its level may reflect disturbances in the mechanisms of neuroplasticity that are necessary for adaptive changes in the nervous system, especially in early childhood, when the brain has a high capacity for restructuring. Median BDNF levels were highest in the control group (22.76 pg/mL) and progressively decreased in groups with motor development disorders (11.25 pg/mL and 8.30 pg/mL). Statistically significant differences in serum BDNF levels were found between all study groups ($p < 0.00001$). Since BDNF levels were lower in premature infants with motor disorders compared to the control group and full-term infants with motor deficits, this may indicate reduced neuroplastic potential in this category of patients, which hinders the normal formation of complex motor patterns and leads to delays in mastering basic motor milestones.

An integrated analysis of gestational age, body weight, motor skill level, and BDNF concentration demonstrated their coordinated influence on the clinical severity of motor deficits, allowing BDNF levels to be considered a promising diagnostic marker of neuroplasticity in young children. In combination with traditional methods of clinical assessment of motor skills, determining BDNF levels can significantly improve the early detection of motor disorders. This paves the way for more effective early intervention, which is critical for optimising long-term functional outcomes in children. An important next step in further research is to conduct longitudinal studies to track BDNF levels in children with motor development delays over a long period of time, compare BDNF with changes in motor development, and track how these indicators change under the influence of early intervention. Further research should also focus on studying the response of BDNF to individual rehabilitation programmes.

ACKNOWLEDGEMENTS

None.

FUNDING

None.

CONFLICT OF INTEREST

None.

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Дослідження нейротрофічного фактору мозку як діагностичного маркера нейропластичності у дітей із затримкою рухового розладу

Тетяна Бакалюк

Доктор медичних наук, професор
Тернопільський національний медичний університет ім. І.Я. Горбачевського
46001, майдан Волі, 1, м. Тернопіль, Україна
https://orcid.org/0000-0002-7619-0264

Марія Віцентович

Аспірант
Тернопільський національний педагогічний університет імені Володимира Гнатюка
46027, вул. Максима Кривоноса, 2, м. Тернопіль, Україна
https://orcid.org/0000-0002-6492-3635

Анотація. Актуальність дослідження біомаркерів нейропластичності полягає у зростаючій поширеності рухових порушень у дітей, оскільки своєчасна діагностика і раннє втручання критично важливі для покращення прогнозу. Метою роботи було оцінити діагностичне значення рівня нейротрофічного фактора мозку як потенційного маркера нейропластичності у дітей віком 7-8 місяців із затримкою рухового розвитку шляхом інтегрального аналізу показників гестаційного віку, маси тіла, рівня рухових навичок за шкалою Alberta Infant Motor Scale та концентрацією нейротрофічного фактора мозку. В дослідженні взяло участь 25 здорових дітей віком 7-8 місяців без рухових порушень та 56 дітей того ж віку з затримкою рухового розвитку, серед яких було 28 дітей, які народились доношеними, але мали рухові порушення, та 28 дітей, які народились недоношеними з руховими порушеннями. В дослідженні було виявлено значущий взаємозв'язок між рівнем нейротрофічного фактора мозку у сироватці крові та ступенем порушення моторного розвитку у дітей. Медіанні рівні нейротрофічного фактора мозку були найвищими в контрольній групі (22,76 пг/мл) і прогресивно знижувалися в групах з порушенням моторного розвитку (11,25 пг/мл та 8,30 пг/мл). Між усіма досліджуваними групами було виявлено статистично значущі відмінності у рівнях нейротрофічного фактора мозку у сироватці крові ($p < 0,00001$). Результати вказали, що у дітей із порушенням моторного розвитку рівень нейротрофічного фактора мозку значно нижчий, ніж у здорових однолітків, що може свідчити про знижену нейропластичність у цих групах. Ці результати підкреслили потенціал нейротрофічного фактора мозку як об'єктивного критерію для ранньої діагностики, прогнозування та оцінки ефективності реабілітаційних втручань у дітей із затримкою рухового розвитку

Ключові слова: біомаркер рухових порушень; рання діагностика; доношені немовлята; недоношені немовлята; шкала рухового розвитку немовлят Альберта