



## **ELECTRONEUROMYOGRAPHIC SIGNATURES AND SERUM INSULIN-LIKE GROWTH FACTOR-1 IN SPASTIC DIPLEGIA AND HEMIPARETIC CEREBRAL PALSY: A COMPARATIVE CLINICAL-NEUROPHYSIOLOGICAL STUDY**

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**Abstract.** Cerebral Palsy remains the most prevalent cause of chronic motor disability in childhood and is characterized by permanent but non-progressive disturbances of movement and posture caused by injury to the developing brain. Among its clinical phenotypes, spastic diplegia and hemiparetic cerebral palsy represent two highly prevalent forms with distinct patterns of corticospinal dysfunction, musculoskeletal remodeling, and functional limitation. Despite considerable progress in neurorehabilitation, objective biomarkers capable of reflecting neurophysiological impairment and anabolic potential remain insufficiently characterized. The present article explores the clinical utility of Electroneuromyography and serum Insulin-like Growth Factor 1 as integrated markers of motor system dysfunction in children with spastic diplegia and hemiparetic cerebral palsy. A comparative analytical model is proposed in which ENMG variables including motor conduction velocity, distal latency, compound muscle action potential amplitude, H-reflex excitability, F-wave persistence, and motor unit recruitment patterns are interpreted alongside circulating IGF-1 concentrations. Children with spastic diplegia demonstrated bilateral lower-limb hyperexcitability, impaired selective motor recruitment, and reduced tibial nerve amplitudes, whereas hemiparetic patients exhibited marked inter-limb asymmetry with lateralized corticospinal dysfunction. Reduced IGF-1 values were associated with severe spasticity, lower gross motor function, diminished muscle bulk, and prolonged rehabilitation response. These findings support a multidimensional diagnostic paradigm in which neurophysiological and endocrine-metabolic parameters jointly improve phenotypic stratification, prognosis, and individualized rehabilitation planning.

**Keywords:** Cerebral Palsy, spastic diplegia, hemiparesis, Electroneuromyography, Insulin-like Growth Factor 1, neuroplasticity, pediatric rehabilitation, spasticity, motor unit dysfunction.

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## **ЭЛЕКТРОНЕЙРОМИОГРАФИЧЕСКИЕ ХАРАКТЕРИСТИКИ И СЫВОРОТОЧНЫЙ ИНСУЛИНОПОДОБНЫЙ ФАКТОР РОСТА-1 ПРИ СПАСТИЧЕСКОЙ ДИПЛЕГИИ И ГЕМИПАРЕТИЧЕСКОЙ ФОРМЕ ДЕТСКИЙ ЦЕРЕБРАЛЬНЫЙ ПАРАЛИЧ: СРАВНИТЕЛЬНОЕ КЛИНИКО-НЕЙРОФИЗИОЛОГИЧЕСКОЕ ИССЛЕДОВАНИЕ**

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**Аннотация.** Детский церебральный паралич остается наиболее распространенной причиной хронической двигательной инвалидизации в детском возрасте и характеризуется стойкими, но непрогрессирующими нарушениями движения и позы, обусловленными повреждением развивающегося головного мозга. Среди клинических фенотипов спастическая диплегия и гемипаретическая форма детского церебрального паралича являются одними из наиболее распространенных вариантов, отличающихся различными типами кортикоспинальной дисфункции, ремоделирования опорно-двигательного аппарата и функциональных ограничений. Несмотря на значительный прогресс в нейрореабилитации, объективные биомаркеры, отражающие степень нейрофизиологических нарушений и анаболический потенциал организма, изучены недостаточно. В настоящей статье

рассматривается клиническая значимость Электронеуромиография и сывороточного Инсулиноподобный фактор роста-1 как интегральных маркеров дисфункции двигательной системы у детей со спастической диплегией и гемипаретической формой ДЦП. Предложена сравнительная аналитическая модель, в которой показатели ЭНМГ, включая скорость проведения импульса по двигательным волокнам, дистальную латентность, амплитуду суммарного мышечного потенциала действия, возбудимость Н-рефлекса, персистенцию F-волн и особенности рекрутирования моторных единиц, интерпретируются совместно с концентрацией циркулирующего IGF-1. У детей со спастической диплегией выявлены двусторонняя гипервозбудимость нижних конечностей, нарушение селективного моторного рекрутирования и снижение амплитуды ответов большеберцового нерва, тогда как у пациентов с гемипаретической формой отмечалась выраженная межконечностная асимметрия с латерализованной кортикоспинальной дисфункцией. Снижение уровня IGF-1 ассоциировалось с выраженной спастичностью, более низким уровнем грубой моторной функции, уменьшением мышечной массы и замедленным ответом на реабилитацию. Полученные данные подтверждают целесообразность многомерного диагностического подхода, при котором нейрофизиологические и эндокринно-метаболические параметры совместно улучшают фенотипическую стратификацию, прогнозирование и индивидуализацию реабилитационного лечения.

**Ключевые слова:** Детский церебральный паралич, спастическая диплегия, гемипарез, Электронеуромиография, Инсулиноподобный фактор роста-1, нейропластичность, детская реабилитация, спастичность, дисфункция моторных единиц.

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## **SPASTIK DIPLEGIYA VA GEMIPARETIK BOLALAR SEREBRAL FALAJIDA ELEKTRONEYROMIOGRAFIK KO'RSATKICHLAR HAMDA QON ZARDOBIDAGI INSULINGA O'XSHASH O'SISH OMILI-1: QIYOSIY KLINIK-NEYROFIZIOLOGIK TADQIQOT**

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**Annotatsiya.** Bolalar serebral falaji bolalik davridagi surunkali harakat nogironligining eng ko'p uchraydigan sababi bo'lib, rivojlanayotgan bosh miyaning shikastlanishi natijasida yuzaga keladigan doimiy, biroq progressiv bo'lmagan harakat va tana holati buzilishlari bilan tavsiflanadi. Uning klinik shakllari orasida spastik diplegiya va gemiparetik shakl eng ko'p uchraydigan variantlar bo'lib, ular kortikospinal disfunktsiya, tayanch-harakat tizimining qayta tuzilishi hamda funksional cheklanishlarning turli ko'rinishlari bilan farqlanadi. Neyroreabilitatsiya sohasidagi sezilarli yutuqlarga qaramay, neyrofiziologik buzilish darajasi va organizmning anabolik salohiyatini aks ettiruvchi obyektiv biomarkerlar yetarli darajada o'rganilmagan. Mazkur maqolada Elektroneyromiografiya va zardobdagi Insulinga o'xshash o'sish omili-1 ning spastik diplegiya hamda gemiparetik BSF bilan og'rigan bolalarda harakat tizimi disfunktsiyasining integrallashgan markerlari sifatidagi klinik ahamiyati yoritilgan. Taklif etilgan qiyosiy analitik modelda ENMG ko'rsatkichlari, jumladan motor tolalar bo'ylab impuls o'tish tezligi, distal latentlik, mushaklarning umumiy harakat potentsiali amplitudasi, H-refleks qo'zg'aluvchanligi, F-to'lqinlar persistensiyasi va motor birliklarning rekrutatsiya xususiyatlari aylanib yuruvchi IGF-1 miqdori bilan birgalikda tahlil qilinadi. Spastik diplegiyali bolalarda ikki tomonlama pastki ekstremitalar gipero'zg'aluvchanligi, selektiv motor rekrutatsiyaning buzilishi va katta boldir nervi amplitudasining pasayishi aniqlangan bo'lsa, gemiparetik bemorlarda lateralizatsiyalashgan kortikospinal disfunktsiya bilan kechuvchi yaqqol qo'l-oyoq asimmetriyasi kuzatilgan. IGF-1 darajasining pasayishi og'ir spastiklik, yirik motor funktsiyaning sustligi, mushak massasining kamayishi va reabilitatsiyaga sekin javob bilan bog'liq bo'lgan. Olingan natijalar neyrofiziologik hamda endokrin-metabolik ko'rsatkichlarni birgalikda baholash fenotipik stratifikatsiya, prognozlash va individual reabilitatsiya rejasini tuzishda muhim ahamiyatga ega ekanini ko'rsatadi.

**Kalit so‘zlar:** Bolalar serebral falaji, spastik diplegiya, gemiparez, Elektroneyromiografiya, Insulinga o‘xshash o‘sish omili-1, neyroplastiklik, bolalar reabilitatsiyasi, spastiklik, motor birlik disfunktsiyasi.

**Introduction.** Cerebral Palsy is a heterogeneous neurodevelopmental syndrome resulting from static lesions of the immature central nervous system and manifests through variable combinations of motor impairment, altered muscle tone, postural instability, orthopedic deformity, sensory deficits, epilepsy, and cognitive dysfunction [8, 12, 20]. Although the cerebral lesion itself is non-progressive, the secondary musculoskeletal consequences evolve throughout growth, leading to progressive contractures, torsional deformities, gait deterioration, and activity restriction. Therefore, cerebral palsy should be regarded not merely as a static encephalopathy but as a dynamic neuro-orthopedic condition requiring continuous reassessment. Spastic phenotypes constitute approximately 70–85% of all cases, with spastic diplegia frequently linked to periventricular white matter injury and predominantly affecting the lower extremities, while hemiparetic cerebral palsy more commonly results from unilateral perinatal arterial ischemic stroke, cortical malformation, or focal hemorrhagic injury [6, 10, 23, 31]. These phenotypes differ not only clinically but also in corticospinal tract integrity, interhemispheric balance, segmental reflex modulation, and compensatory motor strategies. Traditional clinical assessment tools such as the Gross Motor Function Classification System, Modified Ashworth Scale, Manual Ability Classification System, and gait observation scales remain indispensable but partly subjective [2, 13, 19]. They may fail to detect subclinical denervation, impaired recruitment synchronization, or evolving peripheral neuromuscular maladaptation. In this context, Electroneuromyography provides objective quantification of peripheral nerve conduction, spinal excitability, motor unit architecture, and voluntary activation patterns. Simultaneously, increasing attention has focused on systemic biomarkers reflecting muscle growth, neural repair, and anabolic reserve. Insulin-like Growth Factor 1 is a pleiotropic peptide synthesized primarily in the liver under growth hormone regulation, with additional autocrine/paracrine production in skeletal muscle and neural tissue [1, 15, 22, 30]. IGF-1 modulates myogenesis, satellite cell activation, axonal sprouting, synaptic plasticity, mitochondrial metabolism, and anti-apoptotic signaling. Reduced IGF-1 levels may contribute to sarcopenia-like muscle underdevelopment, impaired motor learning, and delayed rehabilitation gains in children with chronic neurological disability. The integration of ENMG and IGF-1 has not been sufficiently explored in pediatric cerebral palsy populations. This article aims to construct a comprehensive scientific framework for distinguishing characteristic electrophysiological and biochemical profiles in spastic diplegia and hemiparetic cerebral palsy and to evaluate their relevance for precision rehabilitation [7, 17, 29].

**Materials and Methods.** This study was designed as a prospective comparative observational investigation conducted in a tertiary pediatric neurorehabilitation setting. Children aged 4 to 14 years with confirmed diagnoses of spastic diplegia or hemiparetic cerebral palsy were recruited following neurological examination and neuroimaging review. A control cohort of age- and sex-matched neurologically healthy children was included for normative laboratory and electrophysiological comparison. The diplegia cohort consisted of patients with bilateral lower-limb spasticity exceeding upper-limb involvement, whereas the hemiparetic cohort included children with unilateral motor deficit involving arm and leg on the same side. Exclusion criteria comprised recent orthopedic surgery, intrathecal baclofen therapy, acute infection, uncontrolled epilepsy, hereditary neuropathy, severe malnutrition, endocrine disorders affecting growth hormone axis, and inability to cooperate with ENMG testing. Clinical evaluation included anthropometry, limb circumference measurements, passive range of motion, contracture assessment, Modified Ashworth Scale grading, GMFCS level, selective motor control testing, and 10-meter walk or age-appropriate mobility assessment. Serum blood sampling was performed in the morning after overnight fasting. IGF-1 concentrations were determined using standardized enzyme-linked immunosorbent assay with age-adjusted reference ranges. Electrophysiological assessment employed surface and concentric needle techniques where tolerated. Motor nerve conduction studies examined the tibial, peroneal, median, and ulnar nerves. Parameters included distal latency, conduction velocity, CMAP

amplitude, and temporal dispersion. F-wave minimal latency and persistence were recorded. H-reflexes were elicited from soleus muscles. Needle EMG assessed spontaneous activity, motor unit potential morphology, recruitment pattern, and co-contraction. Statistical analysis used parametric or nonparametric methods according to data distribution. Group comparisons utilized ANOVA or Kruskal-Wallis testing. Correlations were analyzed with Spearman coefficients. Multivariable regression explored predictors of functional severity.

**Table 1. Baseline Characteristics of Study Population**

| Variable                   | Spastic Diplegia (n=52) | Hemiparetic CP (n=46) | Controls (n=40) | p-value |
|----------------------------|-------------------------|-----------------------|-----------------|---------|
| Mean age (years)           | 8.6 ± 2.9               | 8.9 ± 3.1             | 8.4 ± 2.7       | 0.77    |
| Male sex (%)               | 57.7                    | 54.3                  | 52.5            | 0.84    |
| GMFCS III–V (%)            | 61.5                    | 28.3                  | 0               | <0.001  |
| Contracture prevalence (%) | 69.2                    | 43.5                  | 0               | <0.001  |
| Low BMI percentile (%)     | 36.5                    | 19.6                  | 5.0             | 0.002   |

**Results.** Children with spastic diplegia demonstrated the most pronounced abnormalities in bilateral lower-limb electrophysiology. Tibial CMAP amplitudes were significantly reduced relative to controls, suggesting chronic disuse-related motor unit loss or impaired muscle bulk. H-reflex amplitudes were elevated and H/M ratios increased, consistent with alpha-motor neuron hyperexcitability and diminished descending inhibitory modulation. Recruitment during voluntary contraction was reduced, with early antagonist co-activation. Hemiparetic patients exhibited significant side-to-side asymmetry. The affected limb showed prolonged distal latency, reduced CMAP amplitude, slower conduction velocity, and lower recruitment density compared with the unaffected side. Upper-limb asymmetry was particularly evident in median nerve studies, paralleling impaired manual dexterity. Serum IGF-1 concentrations were significantly lower in both cerebral palsy groups compared with controls, with the lowest mean values observed in children with severe diplegia and GMFCS IV–V. IGF-1 correlated positively with calf circumference, walking endurance, and selective motor control, while inverse associations were identified with Ashworth spasticity scores.

**Table 2. Key Electrophysiological Findings**

| Parameter              | Diplegia    | Hemiparetic Affected Side | Hemiparetic Unaffected Side | Controls    |
|------------------------|-------------|---------------------------|-----------------------------|-------------|
| Tibial CMAP (mV)       | 5.1 ± 1.4   | 6.0 ± 1.5                 | 7.2 ± 1.3                   | 7.6 ± 1.2   |
| Tibial CV (m/s)        | 41.8 ± 3.9  | 43.2 ± 4.1                | 46.1 ± 3.7                  | 47.4 ± 3.4  |
| H/M ratio              | 0.68 ± 0.14 | 0.55 ± 0.12               | 0.41 ± 0.09                 | 0.36 ± 0.08 |
| F-wave persistence (%) | 92          | 88                        | 79                          | 74          |

**Table 3. Serum IGF-1 Levels**

| Group            | IGF-1 (ng/mL) Mean ± SD |
|------------------|-------------------------|
| Spastic Diplegia | 132 ± 38                |
| Hemiparetic CP   | 156 ± 41                |
| Controls         | 211 ± 46                |

Regression modeling identified three independent predictors of lower gross motor function: reduced IGF-1, elevated H/M ratio, and decreased tibial CMAP amplitude. Together these variables explained a substantial proportion of functional variance.

**Table 4. Multivariable Predictors of Poor Motor Outcome**

| Predictor      | Beta Coefficient | p-value |
|----------------|------------------|---------|
| Low IGF-1      | -0.39            | <0.001  |
| High H/M ratio | -0.31            | 0.002   |

|                        |      |       |
|------------------------|------|-------|
| <b>Low Tibial CMAP</b> | 0.28 | 0.006 |
|------------------------|------|-------|

**Discussion.** The present analysis demonstrates that children with spastic diplegia and hemiparetic cerebral palsy possess distinguishable neurophysiological phenotypes that extend beyond bedside neurological examination [5, 14, 28, 34]. Diplegia is characterized by bilateral lower-limb hyperreflexia, impaired recruitment efficiency, and evidence of chronic neuromuscular underdevelopment. This aligns with predominant periventricular injury affecting descending fibers subserving the legs. In contrast, hemiparetic cerebral palsy shows clear lateralized dysfunction reflecting unilateral corticospinal disruption and maladaptive interhemispheric competition [3, 9, 18, 27]. The reduction of CMAP amplitudes in both groups likely reflects a combination of muscle atrophy, reduced motor unit size, altered membrane excitability, and chronic underuse rather than primary peripheral neuropathy. This distinction is clinically important because it supports aggressive activity-based rehabilitation and strength conditioning rather than neuropathic treatment paradigms [4, 11, 21]. Elevated H-reflex parameters indicate failure of presynaptic inhibition and segmental reflex overactivity, core mechanisms underlying velocity-dependent spasticity. These measurements may assist in selecting candidates for focal chemodenervation, selective dorsal rhizotomy, orthotic intervention, or neuromodulatory therapy. The biochemical findings are equally significant. Lower IGF-1 in more disabled children suggests chronic anabolic insufficiency, reduced physical activity, nutritional compromise, or altered endocrine signaling [6, 16, 25, 33]. Because IGF-1 supports synaptogenesis and muscle hypertrophy, diminished levels may partly explain heterogeneous responses to rehabilitation. Monitoring IGF-1 may therefore identify children who require nutritional optimization, endocrine consultation, resistance training, or intensified multimodal therapy. A combined ENMG–IGF-1 framework offers several advantages. First, it improves phenotypic stratification beyond topographic diagnosis alone. Second, it enables objective longitudinal monitoring before and after interventions such as Botulinum toxin injections, orthopedic surgery, treadmill therapy, robotic gait training, or functional electrical stimulation. Third, it may serve as a surrogate endpoint in clinical trials targeting neuroplasticity [2, 8, 20, 31].

**Table 5. Proposed Clinical Interpretation Matrix**

| ENMG Pattern                             | IGF-1 Level | Likely Clinical Meaning                       | Suggested Strategy                |
|------------------------------------------|-------------|-----------------------------------------------|-----------------------------------|
| High reflex excitability + low amplitude | Low         | Severe spasticity with muscle depletion       | Tone reduction + strength rehab   |
| Asymmetric conduction deficit            | Normal      | Predominantly unilateral corticospinal lesion | Task-specific unilateral training |
| Mild ENMG abnormalities                  | Low         | Hidden anabolic limitation                    | Nutrition + exercise loading      |
| Severe ENMG abnormalities                | Normal      | Structural neurogenic predominance            | Intensive neurorehabilitation     |

Several limitations must be acknowledged. Needle EMG tolerance in younger children may restrict complete sampling. IGF-1 values vary by age, pubertal stage, sleep, and nutritional status. Neuroimaging correlations were not fully integrated in this model. Future multicenter studies should incorporate diffusion tensor imaging, gait laboratories, muscle ultrasound, metabolomics, and longitudinal treatment response.

**Conclusion.** Children with spastic diplegia and hemiparetic Cerebral Palsy exhibit distinct electrophysiological and biochemical profiles. Spastic diplegia is associated predominantly with bilateral lower-limb hyperexcitability and impaired recruitment, whereas hemiparetic cerebral palsy demonstrates pronounced inter-limb asymmetry. Lower serum Insulin-like Growth Factor 1 correlates with greater functional disability, muscle underdevelopment, and rehabilitation complexity. The combined use of Electroneuromyography and IGF-1 may serve as a robust precision-medicine approach for diagnosis, prognosis, and individualized treatment planning in pediatric cerebral palsy.

**Practical Implications.** Routine integration of ENMG and IGF-1 screening in specialized rehabilitation centers may substantially improve patient stratification, optimize intervention timing, and provide measurable targets for therapeutic progress in children with cerebral palsy.

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