



INTEGRATED REHABILITATION AND HABILITATION PROGRAM FOR CHILDREN WITH CEREBRAL PALSY USING PNF THERAPY AND THE KORVIT SYSTEM: A PROSPECTIVE CONTROLLED CLINICAL STUDY

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Abstract. Cerebral Palsy remains one of the leading causes of persistent motor disability in childhood and is associated with disturbances of posture, voluntary movement, selective motor control, gait biomechanics, and psychosocial adaptation. Conventional rehabilitation strategies often provide incomplete recovery because they insufficiently address multisystem neuroplastic mechanisms, proprioceptive integration, and task-specific locomotor retraining. The present study proposes and scientifically substantiates the efficacy of a comprehensive rehabilitation and habilitation program integrating Proprioceptive Neuromuscular Facilitation and the Korvit System in children with spastic forms of cerebral palsy. A prospective controlled design was developed involving children with spastic diplegia, hemiparetic cerebral palsy, and mixed spastic phenotypes. The intervention combined diagonal movement patterns, neuromuscular facilitation, trunk stabilization, reciprocal gait activation, sensory afferentation, dynamic weight-bearing simulation, balance retraining, and parent-guided home exercises. Functional outcomes were assessed using GMFM-66, GMFCS, Modified Ashworth Scale, gait velocity, six-minute walk distance, Pediatric Quality of Life Inventory, stabilometric indicators, and electrophysiological markers where available. The integrated program demonstrated superior improvement in gross motor function, postural symmetry, walking endurance, spasticity reduction, and adaptive independence compared with standard rehabilitation. The synergistic interaction between central motor relearning induced by PNF and peripheral sensory locomotor stimulation generated by the Korvit system may enhance corticospinal reorganization and spinal pattern generator modulation. These findings support implementation of combined technology-assisted rehabilitation protocols in pediatric neurorehabilitation centers.

Keywords: Cerebral Palsy, pediatric neurorehabilitation, Proprioceptive Neuromuscular Facilitation, Korvit System, gait training, spasticity, habilitation, neuroplasticity, motor control.

ИНТЕГРИРОВАННАЯ ПРОГРАММА РЕАБИЛИТАЦИИ И АБИЛИТАЦИИ ДЕТЕЙ С ДЕТСКИЙ ЦЕРЕБРАЛЬНЫЙ ПАРАЛИЧ С ИСПОЛЬЗОВАНИЕМ PNF-ТЕРАПИИ И СИСТЕМЫ КОРВИТ: ПРОСПЕКТИВНОЕ КОНТРОЛИРУЕМОЕ КЛИНИЧЕСКОЕ ИССЛЕДОВАНИЕ

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Аннотация. Детский церебральный паралич остается одной из ведущих причин стойкой двигательной инвалидизации в детском возрасте и сопровождается нарушениями позы, произвольных движений, селективного моторного контроля, биомеханики походки и психосоциальной адаптации. Традиционные реабилитационные стратегии нередко обеспечивают неполное восстановление, поскольку недостаточно воздействуют на мультисистемные механизмы нейропластичности, проприоцептивную интеграцию и локомоторное переобучение, ориентированное на конкретные задачи. В настоящем исследовании предложена и научно обоснована эффективность комплексной программы реабилитации и абилитации, объединяющей Проприоцептивная нейромышечная

фасилитация и систему Корвит у детей со спастическими формами церебрального паралича. Разработан перспективный контролируемый дизайн с включением детей со спастической диплегией, гемипаретической формой ДЦП и смешанными спастическими фенотипами. Интервенционная программа включала диагональные двигательные паттерны, нейромышечную фасилитацию, стабилизацию туловища, активацию реципрокной походки, сенсорную афферентацию, динамическую имитацию опорной нагрузки, тренировку равновесия и домашние упражнения под руководством родителей. Функциональные исходы оценивались с использованием GMFM-66, GMFCS, Modified Ashworth Scale, скорости ходьбы, шестиминутного теста ходьбы, Pediatric Quality of Life Inventory, стабилметрических показателей и электрофизиологических маркеров при наличии возможности. Комплексная программа продемонстрировала более выраженное улучшение грубой моторной функции, постуральной симметрии, выносливости при ходьбе, снижение спастичности и рост уровня самостоятельности по сравнению со стандартной реабилитацией. Синергическое взаимодействие центрального моторного переобучения, индуцированного PNF, и периферической сенсорной локомоторной стимуляции, создаваемой системой Корвит, может способствовать реорганизации кортикоспинальных путей и модуляции спинальных генераторов шагания. Полученные результаты подтверждают целесообразность внедрения комбинированных технологически поддерживаемых реабилитационных протоколов в детских нейрореабилитационных центрах.

Ключевые слова: Детский церебральный паралич, детская нейрореабилитация, Проприоцептивная нейромышечная фасилитация, Корвит, тренировка ходьбы, спастичность, абилитация, нейропластичность, моторный контроль.

BOLALAR SEREBRAL FALAJI BO‘LGAN BOLALAR UCHUN PNF TERAPIYA VA KORVIT TIZIMI ASOSIDAGI INTEGRATSIYALASHGAN REABILITATSIYA VA ABILITATSIYA DASTURI: PROSPEKTIV NAZORATLI KLINIK TADQIQOT

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Annotatsiya. Bolalar serebral falaji bolalik davridagi doimiy harakat nogironligining yetakchi sabablaridan biri bo‘lib, tana holati, ixtiyoriy harakatlar, selektiv motor nazorat, yurish biomexanikasi hamda psixososial moslashuv buzilishlari bilan kechadi. An‘anaviy rehabilitatsiya usullari ko‘pincha to‘liq tiklanishni ta‘minlamaydi, chunki ular neyropastiklikning ko‘p tizimli mexanizmlari, proprioseptiv integratsiya va vazifaga yo‘naltirilgan lokomotor qayta o‘qitishni yetarli darajada qamrab olmaydi. Mazkur tadqiqotda spastik shakldagi serebral falajli bolalarda Proprioseptiv neyromushak fasilitatsiyasi hamda Korvit tizimi ni birlashtirgan kompleks rehabilitatsiya va abilitatsiya dasturining samaradorligi ilmiy asoslab berildi. Prospektiv nazoratli dizayn doirasida spastik diplegiya, gemiparetik shakl va aralash spastik fenotipli bolalar tadqiqotga kiritildi. Intervensiya dasturi diagonal harakat patternlari, neyromushak fasilitatsiyasi, gavdani stabilizatsiya qilish, retsiprok yurish faollashuvi, sensor afferentatsiya, tayanch yuklamasining dinamik imitatsiyasi, muvozanat mashqlari va ota-onalar nazoratidagi uy mashqlarini o‘z ichiga oldi. Funktsional natijalar GMFM-66, GMFCS, Modified Ashworth Scale, yurish tezligi, olti daqiqalik yurish testi, Pediatric Quality of Life Inventory, stabilometrik ko‘rsatkichlar hamda mavjud bo‘lganda elektrofiziologik markerlar orqali baholandi. Integratsiyalashgan dastur standart rehabilitatsiyaga nisbatan yirik motor funksiyasi, postural simmetriya, yurish chidamliligi, spastiklikning kamayishi va mustaqillik darajasining sezilarli yaxshilanishini ko‘rsatdi. PNF orqali yuzaga kelgan markaziy motor qayta o‘rganish va Korvit tizimi hosil qiladigan periferik sensor lokomotor stimulyatsiyaning sinergik ta‘siri kortikospinal yo‘llarning qayta tashkil topishi hamda orqa miya qadam generatorlari faoliyatining modulyatsiyasiga yordam berishi mumkin. Olingan natijalar bolalar neyrorreabilitatsiya markazlarida texnologik qo‘llab-quvvatlangan kombinatsiyalashgan rehabilitatsiya protokollarini joriy etish maqsadga muvofiqligini ko‘rsatadi.

Kalit soʻzlar: Bolalar serebral falaji, bolalar neyroeabilitatsiyasi, Proprioseptiv neyromushak fasilitatsiyasi, Korvit tizimi, yurishni mashq qildirish, spastiklik, abilitatsiya, neyroplastiklik, motor nazorat.

Introduction. Cerebral Palsy is a non-progressive but clinically evolving syndrome caused by disturbances in the developing fetal or infant brain. Although the primary neuropathological lesion remains static, the musculoskeletal, sensorimotor, and psychosocial consequences change throughout childhood and adolescence [1, 10, 19, 32]. Children frequently develop progressive contractures, impaired postural alignment, reduced endurance, learned non-use, skeletal deformity, and participation restrictions. Consequently, cerebral palsy is not merely a motor disorder but a lifelong multidimensional condition requiring individualized and dynamic management. Spastic forms constitute the majority of cerebral palsy cases. Spastic diplegia typically presents with predominant lower-limb involvement secondary to periventricular white matter injury, whereas hemiparetic forms are often associated with unilateral cortical or subcortical insults [7, 13, 24]. Across phenotypes, common impairments include hypertonia, abnormal reflex excitability, reduced reciprocal inhibition, poor anticipatory postural control, impaired selective motor control, decreased balance reactions, and inefficient gait energetics. Traditional rehabilitation programs—stretching, generic exercise therapy, massage, passive mobilization, and routine physiotherapy—may improve comfort and joint range but often fail to produce durable functional gains when neuroplastic principles are not systematically integrated. Contemporary pediatric neurorehabilitation increasingly emphasizes intensity, repetition, task specificity, enriched sensory input, motivation, and family-centered continuity [5, 12, 22, 30]. Proprioceptive Neuromuscular Facilitation is a therapeutic concept based on spiral-diagonal movement patterns, irradiation phenomena, proprioceptive stimulation, resistance-mediated motor recruitment, and facilitation of coordinated functional synergies. PNF is especially relevant in children with cerebral palsy because it can target trunk control, pelvic alignment, gait transitions, bilateral integration, and selective activation [3, 15, 26]. The Korvit System is a neurorehabilitation device that simulates alternating plantar loading and locomotor support stimulation. By rhythmically activating plantar mechanoreceptors and lower-limb afferent pathways, it may modulate spinal locomotor circuits, improve extensor support responses, facilitate stepping patterns, and enhance central nervous system sensory-motor integration. Although both modalities are clinically used in some rehabilitation settings, high-quality integrated protocols combining PNF and Korvit remain insufficiently investigated. The scientific rationale for combining them lies in bidirectional neuroplastic stimulation: top-down motor planning enhancement through PNF and bottom-up afferent locomotor input through Korvit [4, 9, 17, 34]. The aim of this study was to develop, standardize, and evaluate the efficacy of a comprehensive rehabilitation and habilitation program for children with cerebral palsy incorporating PNF therapy and the Korvit system.

Materials and Methods. This investigation was structured as a prospective controlled clinical study performed in a specialized pediatric neurorehabilitation center. Children aged 3 to 14 years with confirmed spastic forms of Cerebral Palsy were screened for participation. Diagnoses were established by pediatric neurologists based on clinical history, neurodevelopmental examination, and available neuroimaging. Eligible participants included children with spastic diplegia, hemiparetic cerebral palsy, and mixed bilateral spastic phenotypes classified as GMFCS levels I to IV. Exclusion criteria comprised uncontrolled epilepsy, severe cardiopulmonary disease, acute orthopedic pain, recent lower-limb surgery within six months, severe behavioral dysregulation preventing participation, and progressive neurological disease. A total cohort of 96 children was divided into two groups. The intervention group received a structured integrated program consisting of standard rehabilitation plus PNF plus Korvit-assisted sessions. The control group received standard multidisciplinary rehabilitation alone. Standard rehabilitation included stretching, therapeutic exercise, gait training, occupational therapy, speech therapy when indicated, orthotic optimization, and parent education. The integrated protocol lasted eight weeks with five treatment days weekly. Each session included trunk activation, pelvic dissociation drills, scapulopelvic linkage patterns, lower-limb diagonal PNF patterns, transitional mobility tasks, standing balance

retraining, and Korvit-assisted plantar stimulation. Korvit sessions lasted 20–30 minutes with individualized load intensity and cadence. Outcome assessment occurred at baseline, week 4, week 8, and follow-up at 3 and 6 months. Primary outcomes included Gross Motor Function Measure-66 and walking velocity. Secondary outcomes included Modified Ashworth Scale, six-minute walk distance, Pediatric Quality of Life Inventory, Timed Up and Go when feasible, static balance metrics, caregiver burden index, and surface Electroneuromyography in a subset. Statistical analysis employed repeated-measures ANOVA, mixed-effects modeling, effect size calculation, and subgroup analysis by phenotype and GMFCS level.

Table 1. Baseline Characteristics of the Study Population

Variable	Integrated Program (n=48)	Control (n=48)	p-value
Mean age (years)	7.9 ± 2.8	8.1 ± 3.0	0.74
Male sex (%)	56.3	54.2	0.83
Spastic diplegia (%)	52.1	50.0	0.84
Hemiparetic CP (%)	33.3	35.4	0.81
GMFCS III–IV (%)	47.9	50.0	0.82
Mean Ashworth lower limb	2.4 ± 0.6	2.5 ± 0.7	0.56

Intervention Design and Neurophysiological Rationale. PNF sessions emphasized motor overflow, timing for emphasis, rhythmic initiation, hold-relax strategies, alternating isometrics, and resisted diagonal patterns resembling real-life functional movement. These techniques were selected to enhance cortical recruitment, improve sequencing, and normalize co-contraction. The Korvit system generated alternating support impulses to the plantar surface, promoting stance-phase sensory feedback and locomotor rhythm entrainment. Repetitive plantar input may influence spinal central pattern generators and ascending somatosensory pathways involved in postural adaptation. The combination was intentionally sequenced: PNF primed proximal control and selective movement, while Korvit consolidated gait-related sensorimotor patterns.

Results. At week 8, the integrated group showed significantly greater gains in GMFM-66 total score than controls. Improvements were most pronounced in standing, walking, running, and jumping domains among ambulatory participants. Walking speed increased substantially in the intervention cohort, accompanied by longer step length, reduced double-support time, and improved symmetry indices in hemiparetic participants. Six-minute walk distance improved beyond clinically meaningful thresholds. Spasticity reduction was moderate but significant, especially in gastrocnemius, hamstrings, and hip adductors. Importantly, tone reduction occurred alongside functional improvement rather than generalized weakness. Children with GMFCS II–III exhibited the strongest response, suggesting sufficient residual motor capacity to capitalize on repetitive task-specific training. Children with GMFCS IV improved in trunk control, transfers, and supported standing more than in independent gait.

Table 2. Primary Functional Outcomes After 8 Weeks

Outcome	Integrated Program	Control	Between-Group p
GMFM-66 change	+8.7 ± 3.1	+3.9 ± 2.4	<0.001
Gait speed (m/s) change	+0.21 ± 0.09	+0.08 ± 0.06	<0.001
6MWT distance (m) change	+58 ± 24	+22 ± 19	<0.001
TUG improvement (sec)	-3.1 ± 1.2	-1.0 ± 0.9	<0.001

Table 3. Spasticity and Postural Outcomes

Variable	Integrated Program	Control	p-value
Ashworth calf muscles change	-0.8 ± 0.4	-0.3 ± 0.2	<0.001
Ashworth adductors change	-0.6 ± 0.3	-0.2 ± 0.2	<0.001
Static sway area (%) improvement	+27	+10	0.002
Sit-to-stand independence (%)	68.7	41.6	0.01

Electrophysiological monitoring in a subgroup revealed more organized agonist-antagonist activation timing, reduced pathological co-contraction, and improved recruitment amplitude after treatment. These findings suggest genuine neuromotor reorganization rather than simple compensatory adaptation.

Table 4. ENMG Subgroup Findings

Parameter	Baseline	Week 8	p-value
Tibialis anterior recruitment index	0.52	0.71	0.004
Co-contraction ratio	1.48	1.12	0.009
Gastrocnemius resting hyperactivity (%)	44	23	0.01

Quality-of-life scores improved not only in physical domains but also emotional and social functioning, likely due to enhanced mobility and autonomy. Caregiver burden decreased significantly in the integrated cohort.

Table 5. Pediatric Quality of Life Outcomes

Domain	Integrated Program Change	Control Change	p-value
Physical functioning	+18.4	+7.2	<0.001
Emotional functioning	+10.1	+4.3	0.01
Social functioning	+12.7	+5.1	0.008
Parent burden reduction	+16.3	+6.8	0.003

At six-month follow-up, a substantial proportion of gains were maintained, particularly in children whose families adhered to home exercise continuation.

Discussion. This study demonstrates that a structured integrated rehabilitation model combining Proprioceptive Neuromuscular Facilitation and the Korvit System yields superior functional outcomes compared with standard therapy alone in children with spastic Cerebral Palsy. The observed improvements likely arise from complementary mechanisms [2, 7, 14]. PNF enhances motor planning, intersegmental coordination, postural set generation, reciprocal activation, and selective control through high-quality therapist-guided movement experience. Meanwhile, Korvit provides repetitive afferent stimulation critical for recalibrating stance reactions, gait rhythm, and body schema representation [1, 5, 11, 23]. Children with cerebral palsy often experience degraded sensory feedback and maladaptive movement learning. Therefore, interventions addressing both efferent command and afferent input are theoretically superior to unimodal approaches. Our data support this principle. The substantial response among GMFCS II–III participants suggests that moderate impairment groups may represent optimal candidates for intensive combined programs [3, 8]. However, benefits in severe phenotypes should not be underestimated, as gains in transfers, sitting balance, caregiver handling, and orthostatic tolerance are clinically meaningful. The ENMG findings are particularly valuable because they indicate changes in neuromuscular coordination rather than only symptom suppression. Reduced co-contraction and improved recruitment efficiency may translate into lower energy expenditure during walking and better long-term musculoskeletal preservation [4, 9, 18]. From a habilitation perspective, younger children may especially benefit because motor patterns are still being established. Repeated exposure to normalized locomotor input during sensitive developmental periods may influence cortical map formation and body awareness. The program also has health-system relevance. If implemented efficiently, it may reduce future orthopedic surgery burden, contracture progression, assistive dependency, and caregiver strain [6, 12, 21].

Clinical Algorithm Proposed. Children should undergo phenotype classification, GMFCS staging, spasticity mapping, gait assessment, and family readiness evaluation. Those with adequate tolerance can enter an 8-week combined cycle with reassessment every four weeks. Maintenance blocks may be repeated quarterly.

Limitations. The study was conducted in a single specialized center. Blinding of therapists was impossible. Long-term neuroimaging correlates were not assessed. Further multicenter randomized trials with motion-capture gait laboratories and cost-effectiveness analysis are warranted.

Conclusion. A comprehensive rehabilitation and habilitation strategy integrating Proprioceptive Neuromuscular Facilitation with the Korvit System significantly improves gross motor performance, gait efficiency, balance, spasticity profile, adaptive independence, and quality of life in children with spastic Cerebral Palsy. The synergy of top-down motor facilitation and

bottom-up sensory locomotor stimulation represents a promising precision-rehabilitation paradigm. This protocol deserves broader implementation and further scientific validation.

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