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SERVICES FOR SCIENCE AND EDUCATION

Effects and Mechanisms of Task-Oriented Training on Improving Motor Function in Children with Spastic Cerebral Palsy: A Literature Review

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ABSTRACT

Spastic cerebral palsy (SCP) is a neurological disorder caused by abnormal brain development or brain injury, and it represents the most common type of motor disability in children. It is primarily characterized by abnormal muscle tone, impaired motor coordination, and restricted motor function, which severely compromise children's health and quality of life. In recent years, task-oriented training (TOT), a rehabilitation approach focused on specific functional goals, has demonstrated significant efficacy in the treatment of children with cerebral palsy. TOT not only improves motor function but also facilitates neuroplastic changes in the brain and spinal cord, thereby enhancing motor control and coordination. Despite growing attention to its therapeutic benefits, the underlying mechanisms through which TOT exerts its effects remain insufficiently understood. This review analyzes the patterns and causes of motor function deterioration in children with SCP and explores the therapeutic role and mechanistic basis of TOT in addressing motor impairments associated with spastic cerebral palsy.

Keywords: Task-Oriented Training, Cerebral Palsy, Spastic, Motor Function.

INTRODUCTION

Cerebral palsy (CP) refers to a group of syndromes characterized by abnormal development of motor posture, resulting from non-progressive disturbances in the developing fetal or infant brain[1]. Spastic cerebral palsy (SCP) is the most common subtype, accounting for approximately 60% to 70% of all CP cases[2]. The clinical characteristics of SCP include muscle spasticity, restricted movement, and abnormal posture. These may lead to complications such as hip pain or dislocation, impaired postural balance, dysfunction of hand movements, and equinovarus foot deformities, all of which severely impact the physical and mental health as well as the quality of life of affected children[3]. The etiology of SCP is multifactorial and includes prematurity, low birth weight, asphyxia, hypoxic-ischemic encephalopathy, kernicterus, inflammation (such as congenital rubella virus or cytomegalovirus infection), and genetic factors[4]. The pathogenesis of SCP is primarily associated with impaired motor regulation resulting from central nervous system damage. A key mechanism involves insufficient inhibitory signaling from the cerebral cortex and its descending pathways, leading to inadequate suppression of Ia afferent fibers in the spinal cord. This disinhibition results in excessive reflexive muscle contractions and the development of spasticity[5]. Given that the disease can impair multiple physiological systems in children, early diagnosis and intervention are of critical importance.

Common treatment approaches for SCP include physical therapy, pharmacological interventions, and surgical procedures. Physical therapy primarily involves the use of physical modalities such as electrical, light, and magnetic stimulation—for example, electrical stimulation therapy and hydrotherapy. These methods can reduce spasticity in the short term; however, they do not repair damage to the brain's central motor control centers, and their overall efficacy remains limited. Botulinum toxin type A and baclofen are commonly used pharmacological agents for reducing muscle tone in clinical practice, but their long-term use may lead to adverse side effects. Surgical treatment, most notably selective dorsal rhizotomy (SDR), can effectively alleviate spasticity; however, it carries certain risks and is associated with potential complications[6]. Task-oriented training (TOT) is a rehabilitation approach based on principles of motor control and motor learning. It addresses the limitations of traditional therapies and has been shown to effectively improve motor function and flexibility in children with SCP[7]. TOT leverages the repetitive nature of tasks to influence the adaptability of the central nervous system and promote functional reorganization of the brain. Studies have shown that TOT can guide the migration of neurofunctional cells toward lesion sites and facilitate the formation of new neural networks, as confirmed by functional magnetic resonance imaging (fMRI). In addition, the training emphasizes task specificity, designing meaningful and life-relevant activities based on individual needs, which significantly enhances the effectiveness of rehabilitation[8]. This method is commonly applied in the rehabilitation of adult stroke patients, while its use in the treatment of children with cerebral palsy remains in the early stages of clinical implementation[9].

As a rehabilitation method centered on functional task performance, TOT has shown significant therapeutic effects in the treatment of children with SCP in recent years. Relevant studies indicate that TOT not only facilitates the recovery of motor skills but also effectively reduces muscle tone, improves joint range of motion, and enhances voluntary motor ability. However, its underlying mechanisms, optimal intervention protocols, and long-term outcomes remain

areas of ongoing investigation, and related clinical evidence and theoretical frameworks are yet to be fully established. Therefore, this review aims to summarize the current research on the effectiveness of TOT in improving motor function in children with SCP, explore its mechanisms and clinical application, and identify future research directions, to provide a theoretical foundation for clinical practice and promote the further development and implementation of TOT in cerebral palsy rehabilitation.

MECHANISMS AND HEALTH IMPACT OF SCP IN CHILDREN

SCP results from central nervous system damage that disrupts the regulation of spinal stretch reflexes by higher motor control centers, ultimately leading to motor dysfunction[10]. The primary sites of pathological involvement in SCP are the pyramidal tract and the cerebral cortex[11]. SCP involves damage to the pyramidal tract system, which can lead to increased muscle spindle sensitivity and loss of inhibitory control over motor neurons in the anterior horn of the spinal cord, thereby inducing hyperactivity of stretch reflexes and limb spasticity [12]. Damage to the cerebral cortex and related structures, such as the thalamus and basal ganglia, is a key factor contributing to motor dysfunction in SCP. Ischemia and hypoxia are the primary pathogenic mechanisms, directly causing both white matter and gray matter injury. During this pathological process, neurons and glial cells within the affected regions are damaged, particularly oligodendrocyte precursor cells (OLs) involved in myelin development. This disruption impairs normal myelination, which in turn compromises the efficiency of neural signal transmission, thereby weakening motor function execution and coordination[13]. Central nervous system damage impairs the coordination of muscle activity, making it difficult for affected children to perform independent and orderly movements such as stretching, grasping, or walking. Motor dysfunction reduces the frequency of voluntary movement attempts in children with SCP, which further exacerbates functional decline and creates a vicious cycle. Prolonged physical inactivity may lead to reduced cardiopulmonary endurance, decreased muscle strength, and increased fatigue, thereby further limiting mobility and severely compromising the overall quality of life.

A hallmark of SCP is abnormal muscle tension, with spasticity commonly defined as a form of increased muscle tone characterized by velocity-dependent resistance to passive stretch, resulting from exaggerated stretch reflexes[14]. Under normal conditions, upper motor neurons regulate muscle tone through inhibitory signaling. SCP is classified as an upper motor neuron syndrome, primarily resulting from damage or lesions to central motor structures or their conducting pathways. This disruption leads to disinhibition of lower motor neuron activity, causing muscle spasticity or hyperactivity, often accompanied by weakness of the antagonistic muscles, ultimately resulting in muscular imbalance[15].In addition, significant loss of sarcomeres, increased stiffness of spastic muscles, and alterations in intramuscular connective tissue contribute to the long-term consequences of muscle spasticity and asymmetric muscle use. These changes lead to muscle fiber shortening, reduced elasticity, and soft tissue contractures, which further restrict joint range of motion and accelerate motor function deterioration[16]. As a result, children with SCP often experience substantial difficulties in performing activities of daily living, such as dressing, eating, and personal hygiene, leading to a high level of dependence on family caregivers. Moreover, due to their limited motor abilities, these children are more vulnerable to social discrimination, which may result in feelings of loneliness, low self-esteem, and social withdrawal. Therefore, early

intervention and active, effective rehabilitation are essential for improving motor abilities and enhancing the quality of life in children with SCP.

EFFECTS OF TOT ON MOTOR FUNCTION IN CHILDREN WITH SCP

Table 1: Effects of Task-Oriented Training on Gross Motor Function in Children with SCP

Researcher	Participants	Training Protocol	Training Effects
Pang Wei (2016)[17]	SCP children (n=40)	Walking and mobility training, 3 months	Improved gross motor and walking function
Eun (2020)[18]	SCP children (n=18)	Daily activity simulation in groups, 8 weeks	Enhanced gross motor function
Rejane (2019)[19]	Unilateral SCP children (n=4)	FES combined with task training, 8 weeks	Increased ankle strength and gait symmetry
Lü Yanbao (2019)[20]	SCP children (n=80)	Walking simulation training, 3 months	Increased stride length and walking ability
Zhang Hongxia (2021)[21]	SCP children (n=95)	Indoor and outdoor walking/obstacle training, 3 months	Improved motor control and muscle extensibility
Zhang Xiaoli(2021) [22]	SCP children (n=78)	Step training, ball kicking, walking, daily living skills, 3 months	Improved muscle function, gross motor skills, and daily living abilities with family involvement in TOT training.
Zhang Qiu (2023)[23]	Spastic hemiplegia CP children (n=75)	Balance and transfer training, 6 weeks	Reduced lower limb spasticity, improved walking
Chen Tingting (2024)[24]	SCP children (n=60)	Group + individualized training, 12 weeks	Significant improvement in gross motor function

Current Research on the Effects of TOT in Improving Gross Motor Function in Children with SCP

As shown in Table 1, multiple experimental studies have demonstrated that TOT can effectively activate muscle fibers, increase muscle strength, and improve gross motor function in children with SCP. Pang Wei et al. (2016)[17] conducted a three-month mobility task training program with 40 children with SCP and found that TOT enhanced postural control, increased muscular endurance, and improved walking ability. Similar findings were reported by Lü Yanbao et al. (2019)[20].Rejane et al. (2019)[19] further combined functional electrical stimulation (FES) with functional task training, which enhanced the explosive strength of the affected limbs in children with unilateral SCP and improved gait symmetry and walking efficiency. Zhang Qiu et al. (2023)[23] investigated the therapeutic effects of low-frequency repetitive transcranial magnetic stimulation (rTMS) combined with TOT in children with spastic hemiplegic cerebral palsy. The results indicated that TOT reduced gastrocnemius spasticity in the lower limbs and improved both gross motor and walking functions. In addition, TOT enhances motor learning and control through individualized task design, thereby increasing motivation for motor participation and improving gross motor function in children with SCP. For example, Eun et al. (2020)[18] implemented TOT in a group setting and found that mutual imitation and competition among participants significantly improved functional movements such as standing and walking, with these effects persisting after the intervention concluded. Zhang Xiaoli et al.

(2021)[22] combined TOT with family involvement, demonstrating that personalized treatment plans tailored to each child's condition fostered greater active engagement. The participation of family members further enhanced the children's motivation to engage in training, leading to more effective restoration of muscle function and improved motor outcomes. Similarly, Chen Tingting et al. (2024)[24] reported that TOT combined with guided education over a 12-week period allowed children to complete training tasks in an enjoyable environment, resulting in significant improvements in GMFM scores post-treatment. Moreover, TOT has been shown to stimulate the motor cortex in children with SCP, enhancing neuroplasticity and progressively improving gross motor function. For instance, Zhang Hongxia et al. (2021)[21] reported that TOT, through environmental modifications and repeated reinforcement training, promotes central nervous system adaptability, strengthens and reorganizes brain function, and thereby improves the control of gross motor abilities. Collectively, these studies demonstrate the effectiveness of TOT in enhancing motor function in children with SCP, particularly in walking ability, postural control, and gross motor performance. Furthermore, combining TOT with other therapeutic modalities, such as FES and rTMS, can further augment rehabilitation outcomes.

Table 2: Effects of Task-Oriented Training on Balance and Coordination in Children with SCP

Researcher	Participants	Training Protocol	Training Effects
Michal (2009)[25]	Children with TBI or CP (n=20)	Home-based sit-to-stand and step training, 6 weeks	Long-term improvement in balance
Zhang Chunyang (2014)[26]	SCP children (n=50)	Balance training + NDT, 3 months	Significant improvement in balance control
Li Xin (2015)[27]	SCP children (n=60)	Sit-to-stand and gait training, 3 months	Improved agility and dynamic balance
Liu Yimei (2019)[28]	Spastic hemiplegia children (n=100)	Modified CIMT combined training, 8 weeks	Enhanced balance and walking abilities
Zhang Weidan (2021)[12]	SCP children (n=123)	Biofeedback + TOT training, 4 months	Reduced spasticity, restored walking and balance
Li Yan (2023)[29]	SCP children (n=86)	Balance and trunk control training, 3 months	Improved balance and gait
Hu Xiaoling (2023)[30]	SCP children (n=46)	TOT in sports game form, 3 months	Enhanced gross motor and coordination
Ajaya (2019)[31]	SDCP children (n=44)	Task training based on NDT principles, 6 weeks	Improved trunk control and balance

Current Research on the Effects of TOT in Improving Balance and Coordination in Children with SCP

In children with SCP, balance and coordination are closely interrelated and mutually influential components of motor function. Impaired balance can exacerbate deficits in coordination, while reduced coordination may further compromise balance. Consequently, improvement in one of these functions often yields positive effects on the other. Multiple experimental studies have shown that TOT can enhance core muscle stability and improve balance in children with SCP. Michal et al. (2009)[25] reported that after six weeks of sit-to-stand and stair-climbing exercises, children with SCP demonstrated significant improvements in balance, which were

maintained during a six-week follow-up period. Liu Yimei et al. (2019)[28] further combined modified constraint-induced movement therapy with TOT and found that upright posture training effectively enhanced muscle strength, promoted upper limb function recovery, and improved balance control in the intervention group. Li Yan et al. (2023)[29] enriched the training tasks by incorporating elbow-supported exercises, trunk rotation training, and pelvic control training. Their results indicated that targeted motor training through TOT improved lower limb coordination, increased muscle strength and motor control, reduced spasticity, and significantly enhanced standing and balance abilities in children with SCP.In addition, TOT can enhance the ability of children with SCP to integrate external sensory information, thereby improving their capacity to adjust movements and posture, and ultimately enhancing motor balance. Zhang Chunyang et al. (2014)[26] demonstrated that three months of multisensory stimulation combined with goal-directed task training strengthened the adaptability of the nervous system to movement demands and improved postural control and balance adjustment in children with SCP. Hu Xiaoling et al. (2023)[30] incorporated physical activity games into TOT and found that such interventions, through the integration of vestibular, visual, and proprioceptive inputs, enhanced the central nervous system's capacity for multimodal sensory integration, optimized neuromuscular control, and improved both static and dynamic balance in children with SCP. TOT has also demonstrated significant effectiveness in improving coordination in children with SCP. By engaging multiple muscle groups in synergistic activity, TOT enhances movement fluidity and stability. Li Xin et al. (2015)[27] found that repeated practice in dynamic environments through TOT strengthened muscular power and flexibility, thereby improving motor coordination. Zhang Weidan et al. (2021)[12] further integrated TOT with biofeedback technology and reported that post-intervention, children with SCP achieved better control of muscle activity, promoted central nervous system reorganization and functional recovery, and enhanced both motor control and limb coordination. Moreover, TOT facilitates the re-establishment of neural pathways for motor control in the brain, thereby improving coordination. For example, Ajaya et al. (2019)[31] found that task-oriented training based on neurodevelopmental therapy (NDT) helped the brain relearn and activate typical postural control patterns, resulting in improved gait stability and coordination in children with spastic diplegia. Collectively, these studies suggest that TOT, as a task-based rehabilitation approach, can effectively promote the recovery of balance, coordination, and motor control abilities in children with SCP.

MECHANISMS UNDERLYING THE EFFECTS OF TOT ON MOTOR FUNCTION IMPROVEMENT IN CHILDREN WITH SCP

Enhancement of Motor Function and Muscle Strength

Children with SCP often present with increased muscle tone, which compromises motor coordination and postural stability, ultimately leading to motor dysfunction. TOT addresses these challenges by analyzing abnormal movement patterns and designing targeted training tasks. Through repeated practice, it improves the length–tension relationship of muscle fibers, reduces muscle stiffness, restores elasticity and extensibility, and alleviates spasticity. Clinical studies have shown that TOT significantly enhances motor abilities in children with SCP, particularly in improving gross motor function[21]. Wang Xiaoyan et al. (2023)[7] reported that TOT, by structuring and breaking down tasks, effectively improves muscle strength, endurance, gait parameters, and both gross motor and balance functions. Compared with traditional, single-modality physical therapy, TOT—characterized by diverse, continuous

movements closely related to daily life—has been shown to increase the efficiency of functional recovery and accelerate the rehabilitation process[32]. In summary, when combined with conventional rehabilitation, TOT can significantly improve motor function and reduce muscle tone in children with SCP.

Optimization of Motor Learning and Control

Due to brain injury, joint deformities, muscle contractures, and other contributing factors, children with SCP often exhibit abnormal movement patterns. Based on the theory of motor control, TOT enhances motor learning and control by setting appropriate training goals, selecting effective movements, and implementing repeated, precise, high-intensity task execution. Eun et al. (2020)[18] demonstrated that TOT, by providing realistic and functionally meaningful training goals, enhances children's engagement and motivation, thereby facilitating the development of motor skills. Moreover, TOT emphasizes the training of coordination between upper and lower limbs, balance, and functional activities of daily living, such as standing, sitting balance, and bilateral hand use. Zhang Weidan et al. (2021)[12] found that following intervention, the spasticity level (as measured by the MAS score) in the intervention group was significantly lower than in the control group, along with notable improvements in balance, motor function, and cognitive ability. This training model supports the progressive recovery of normal movement patterns by continuously adapting motor strategies, reducing muscle spasticity, and enhancing motor control. In summary, TOT, through targeted functional task training and adaptive environmental engagement, can significantly improve task execution, reduce spasticity, and enhance both balance and motor abilities in children with SCP.

Improvement of the Sensory Feedback System

Chronic spasticity in children with SCP often leads to sensory dysfunctions, primarily manifested as difficulties in sensory information processing, poor motor feedback, and impaired balance and postural control. TOT addresses these issues by establishing specific and challenging goals that help improve the sensorimotor feedback system. Through repetitive practice, children gradually learn correct movement patterns and optimize their neural networks. For example, upper limb tasks such as object grasping require the integration of visual and tactile input with motor control, thereby facilitating the brain’s processing and feedback mechanisms. During training, therapists reduce external guidance and encourage children to adjust their movements using intrinsic feedback, fostering the formation of automated motor programs. As task difficulty progressively increases, children gain experience through both success and failure, which improves coordination, adaptability, and feedforward control[33]. Additionally, TOT requires children to continuously analyze and interpret task-relevant information, using ongoing motor feedback to adjust movement patterns. This process supports the formation of new neural networks and motor programs, thereby promoting motor function recovery and reducing muscle spasticity[12]. In summary, by providing task-related feedback and guiding adjustments in movement patterns, TOT enhances environmental adaptability and improves dynamic balance and coordination in children with SCP.

Enhancement of Neuroplasticity

Due to damage in brain regions responsible for motor control, children with SCP often experience significant limitations in motor function[34]. TOT has been shown to promote functional brain reorganization and enhance neuroplasticity in these children. By repeatedly

engaging in functional motor tasks, TOT activates motor neural networks within the central nervous system, facilitates neuronal reorganization and pathway strengthening, and thereby enhances the brain's capacity for plasticity. This process supports the formation of new motor patterns through learning[35]. Ajaya et al. (2019)[31] found that targeted motor training combined with high-intensity voluntary movements promoted the reorganization of functional areas within the central nervous system, contributing to the development of normalized motor patterns and improvements in trunk stability and balance control. Moreover, the incorporation of multitasking and challenging exercises during training can further stimulate neural networks, accelerating neural adaptation and functional recovery. In summary, TOT emphasizes goal-directed performance and engages the brain in precise motor regulation through task-driven training, thereby activating and shaping the relevant neural networks.

CONCLUSION

Central nervous system damage is a key factor contributing to the motor abnormalities in SCP, and long-term muscle tone abnormalities lead to the degradation of motor function. Numerous studies have shown that TOT is an effective approach for improving motor function in children with SCP. The possible mechanisms include:

1) Enhancement of motor function and muscle strength, improvement of muscle fiber elasticity, and balance of muscle activity, leading to improved gait, standing, and balance control;
2) Optimization of motor learning and control through the establishment of functional goals, enhancing motor initiative and execution ability;
3) Improvement of the sensory feedback system, adjustment of movement patterns, and the formation of automated motor programs, thereby promoting the recovery of motor function and reducing muscle spasticity;
4) Reinforcement of neuroadaptive processes, reorganization of neural networks in the brain, and improvement in trunk stability and balance.

TOT has shown significant progress in improving motor function in children with SCP; however, certain limitations remain. For instance, many studies have small sample sizes and a broad age range. Additionally, most existing research focuses on the short-term effects of TOT, with a lack of systematic evaluation of its long-term outcomes, and there are few trials examining social and environmental adaptation. Therefore, future research should include larger and more diverse samples, extend the duration of interventions and follow-ups, and explore the application of TOT in school, home, and social environments, providing a foundation for improving the generalizability and applicability of this approach in the rehabilitation of children with SCP.

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