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Impact of Task-Specific Electrical Stimulation on Upper Limb Functional Motor Skills in Children with Spastic Quadriplegia.

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Abstract
Background: Spastic quadriplegic children have major functional deficits, mainly related to upper limb restrictions. Task-specific electrical stimulation is being investigated as an adjunct intervention to facilitate active, goal-directed movement and therefore promote motor recovery. Objectives: To examine how spastic quadriplegia (SQ) children's functional motor skills in their upper limbs are affected by task-specific electrical stimulation.
Methods: 30 children with SQ were randomly divided into 2 groups. Group A had a standardised program of physical therapy. Group B received the same program plus a task-specific electrical stimulation. The outcome measures were selected from the weight bearing domain of the Quality of Upper Extremity Skills Test (QUEST). Assessments were done before and after intervention and were analysed by acceptable statistical procedures.
Results: The results of the QUEST weight bearing domain after treatment were significantly improved in both groups ($p < 0.001$) with much better results in group B than in group A. Conclusion: The added benefit of combining conventional physical therapy with task specific electrical stimulation is to improve the weight bearing capacity in children with SQ as compared to physical therapy alone. These findings are consistent with the hypothesis that this population might benefit from rehabilitation programs with task-specific electrical stimulation.....
Keywords: Spastic Quadriplegia, Task-specific electrical stimulation, Upper limb gross motor function, Electrical stimulation, Upper limb function...

Introduction

Cerebral palsy (CP) is characterized as a non-progressive primary brain damage; nonetheless, children frequently experience progressive musculoskeletal complications (e.g., joint deformities, contractures, and secondary functional restrictions) that may increasingly restrict their involvement in everyday activities as they age **(Bax et al., 2022).** The motor functional skills of children's upper limbs directly influence quality of life indicators such as involvement and activity **(Palisano RJ, 2009).** When it comes to rehabilitation, task-specific electrical stimulation (TASES) is the go-to method for enhancing motor function. By electrically stimulating specific muscles during certain actions, TASES aims to improve mobility and optimise motor learning.
Treatment for these children focuses on improving functional capacities. To address the paucity of literature on the topic, this study intends to investigate, in children suffering from spastic quadriplegia (SQ), how task-specific electrical stimulation affects their functional motor abilities in the upper limbs.
Additional research into TASES as an adjunct to physical therapy is warranted because of the growing body of evidence demonstrating the benefits of task-specific treatments for children with spastic CP, whose upper limb dysfunction significantly impacts their ability to participate in everyday activities.
Statement of the problem: Can functional motor abilities in the upper limbs be affected in children with SQ with task-specific electrical stimulation?
The aim of the study is to evaluate the effect of TASES on gross motor function of upper limb in children with SQ, using the latest advances in neurorehabilitation and paediatric therapy research.

Worldwide, cerebral palsy is the most common kind of physical disability among children. Damage to or faulty development of the developing brain causes this complex, long-term mobility disorder. SQ is among the most severe forms of CP. It is a quadrupedal affliction. Significant motor and postural impairments. The shoulder, elbow, and wrist joints became much more stiff, weak, and limited in their range of motion. The capacity to reach, grasp, and bear weight is severely hindered by these deficiencies, which in turn affects the child's independence and quality of life **(Smith et al., 2024).**

Task-oriented, activity-based treatment is progressively utilized in the rehabilitation of children with CP and has demonstrated enhancements in motor learning and neuroplasticity. Within this framework, functional electrical stimulation (FES) and neuromuscular electrical stimulation (NMES) have arisen as noteworthy adjunctive techniques. They have demonstrated improvements in muscular strength, regulated selective movement, and upper limb use when combined with established therapeutic protocols. (**Wilson et al., 2025; Peterson & Martin, 2023).**

Importantly, comprehensive evaluations showed that NMES and related approaches could improve upper limb outcomes in juvenile CP but the benefits are protocol and patient subgroup dependant **(Almeida et al., 2024).** A more targeted approach, task specific electrical stimulation (TASES) combines electrical stimulation with voluntary goal directed activity.

Applying sensory feedback together with active motor intent is hypothesised to generate greater improvements in motor function based on principles of experience-dependent neuroplasticity **(Ng & Gordon, 2024).** Although TASES has demonstrated encouraging outcomes in adult neurorehabilitation, its efficacy in helping children with SQ restore gross motor function in their upper limbs has not been investigated yet **(Lee et al., 2025).**

Materials and methods

The study was a 2-month pre-test post-test single blind randomised comparative trial. The study was performed at the Al-Raml Children's Hospital and the Roiaa Centre for Paediatric Rehabilitation. Following the guidelines laid out in the Declaration of Helsinki (1975), the experimental procedure was approved by the Ethical Committee for Human Research (Study number: KFSIRB200-1060). Date of approval: (P.T/PED/5/2026/25) at the Faculty of Physical Therapy, Kafrelsheikh University. Clinical Trials.gov (**NCT07631390)** was notified.

Subjects

Thirty children with spastic quadriplegic CP (SQCP) were randomly assigned to two groups: the control group (Group A) and the experimental group (Group B), based on a pediatrician's advice. The control group underwent a standardized physical therapy regimen, whereas the experimental group participated in the same regimen supplemented with TASES.

A medical diagnosis of SQ CP by paediatricians or paediatric neurologists, determined as Level III or IV on the Gross Motor Functional Classification System (GMFCS), was necessary for inclusion in the study. Level I is the least severe and Level V is the most severe according to the GMFCS, a system for classifying the severity of mobility disability in children with CP.

Participants exhibited a spasticity grade of 1+ to 2 on the Modified Ashworth Scale (MAS), a metric for assessing muscle tone, where a higher grade signifies increased spasticity. The participants' ages varied from 4 to 7 years. All adolescents successfully comprehended and adhered to verbal instructions and commands throughout assessment and therapeutic sessions. The exclusion criteria comprised: fixed joint abnormalities of the upper limbs, diagnoses other than CP, significant auditory or visual impairments, prior surgical interventions in the upper extremities, and inconsistent attendance at examinations or therapy sessions.

Calculation of Sample Size

Sample size (n) can be calculated by using Cochran's formula. Here, z is the chosen z value ($z = 1.96$) for the desired confidence level ($\alpha = .05$), p is the estimated proportion of a population characteristic ($p = .025$) and e is the margin of error ($e = .06$). We need around 30 people total (15 in each group).

Randomisation

The subjects were split into two equal groups using the sealed opaque envelope method of randomisation. The trial used opaque sequentially numbered envelopes with the group allocations sealed inside. After participant enrolment and baseline assessment, one envelope was opened for each child to assign group. This method ensured adequate allocation concealment and randomisation.

Outcome Measures: The key outcome measure was the upper limb weight bearing ability measured by the weight bearing domain of the QUEST.

Instruments:

Quality of Upper Extremity Test (QUEST)

The QUEST assesses upper limb functionality in pediatric patients with neuromotor disorders characterized by spasticity or hypertonia. It evaluates elements of manual dexterity and the level of upper limb mobility. The test measures four different abilities: detachment of movement, gripping, bearing weight, and protective extension. In this investigation, the QUEST was used to assess the weight-bearing domain. One quality measure used to assess the functional capacity and patterns of hand mobility in children with CP is the upper extremity skills evaluation. Dissociated movement, grip, protective extension, and weight bearing were the four domains that had to be evaluated in order to determine the quality of the upper extremity activities. Children between the ages of 18 months and 8 years old can take the QUEST with confidence. **(DeMatteo C et al, 1993).** Furthermore, QUEST has been found to have good reliability for 12 years old children (**Megan et al, 2011).** QUEST has demonstrated excellent inter-observer reliability, observer reliability and good test-retest reliability **(Corn K et al, 2003).**

The Chattanooga Continuum™
The physical treatment program was supplemented by task-specific electrical stimulation with NMES (Neuromuscular Electrical Stimulation) for 20 min per session. Used in NMES mode on the Chattanooga ContinuumTM (Portable two channel stimulator) The device was frequently used for muscle re-education, strengthening and functional rehabilitation. Functional weight bearing exercises were performed while electrical stimulation was delivered in a task specific manner

Study Procedures
For Evaluation
The weight bearing domain was scored using the QUEST manual. If you're lying on your stomach and bearing weight, it should be on the floor or on the mat and not a bolster. The child can be either prone or 4 point kneeling. This should be marked on the score sheet and repeated on subsequent QUEST exams. Then best sitting posture is cross legged posture ring and long sitting. If the child is not able to sit on the floor, you can use a bench or a high mat to compensate the lower limbs muscles tightness. Record the position used and repeat on subsequent QUEST exams. The score item is on left. In the middle of the page is the scoring method and on the right side of the page are the criteria. The therapist must place the child in this position, or the child must get into this position on his/her own and hold it for a minimum of 2 seconds. The amount of shoulder rotation is not a criterion and should not affect the child's score on the items in this section.
For treatment
The treatment was classified into 2 types.
Physical therapy program: All patients received a standardised physical therapy program (1 hour, 3 times/week, for 2 months). The program included weight bearing activities of the upper limb such as push ups, prone-on-hands, quadruped exercises and transition exercises such as side sitting to quadruped.
Task specific electrical stimulation: The children in the study group were given the designed physical therapy program plus TASES during weight bearing exercises including push up exercises, prone-on-hands exercises, quadruped with weight shifting and transition activities such as side sitting to quadruped.
Application NMES mode in the Chattanooga Continuum. Stimulation parameters were usually: Pulse Duration 250 to 300 microseconds, Frequency 25 to 50 Hz and Intensity adjusted to produce a strong but pleasant contraction of the muscle. Each treatment session was 20 min in length. Electrodes were placed on the target muscle as follows: For activation of the elbow extensors (channel 1) one electrode is implanted in the middle of the triceps muscle and the second one more distal, near the elbow joint itself (around 3 cm above the olecranon process). Electrodes will be positioned at the motor points of the fingers and wrist extensors to activate them, and the second channel will be utilised to stimulate these muscles. The second electrode will be positioned on the tendinous region of the forearm, close to the joint where the flexor tendons of the radialis and ulnaris muscles attach. The study group children performed weight bearing exercises with TASES as a specified physical therapy program.
Duration: Treatment sessions lasted for 20 minutes each.

Statistical Analyses
The groups were compared using the age, weight, and height variables using the unpaired t-test. To examine the distribution of spasticity grades among groups, the Chi-squared test was used. To compare the levels of GMFCS between the groups, the Mann-Whitney U test was used. The unpaired t-test was used to examine the difference in weight-bearing domain inside QUEST between the groups. We used a paired t-test to compare the QUEST weight-bearing domains before and after treatment for each group. A significance level of $p < 0.05$ was used for all statistical analyses. Results were analysed statistically using SPSS 25 for Windows, developed by IBM SPSS in Chicago, IL, USA.

Results
This research examined the effect of TASES of the upper limbs in children with SQCP. Two equal groups were

formed from thirty persons who were assigned at random. People in Group A participated in the prescribed physical therapy programme, whereas those in Group B received electrical stimulation tailored to their individual tasks. Every single one of the participants made it through the intervention and were evaluated both before and after treatment.

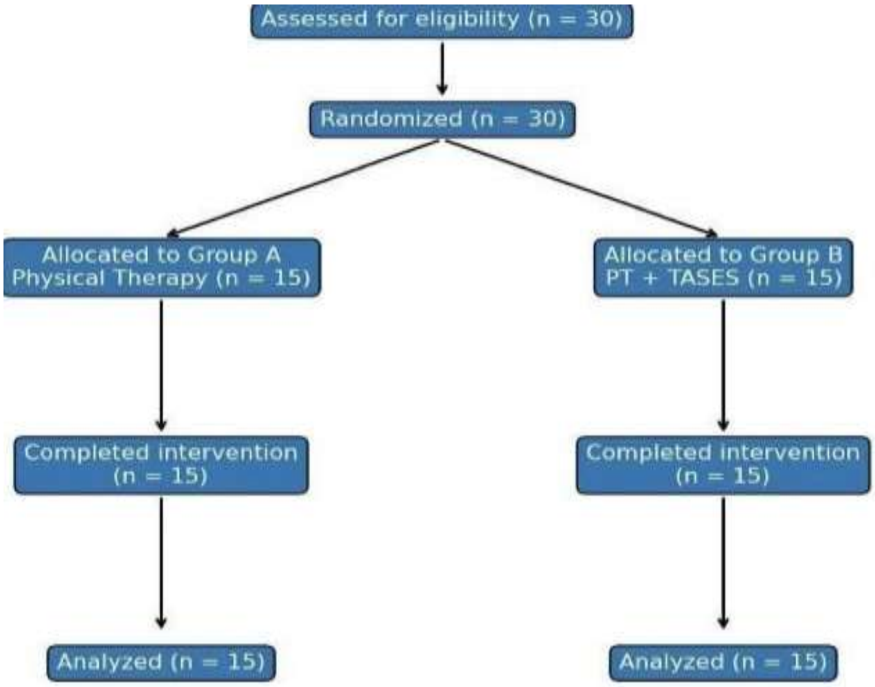

FIGURE (1): Flow chart diagram

Characteristics of Participants

The demographic and clinical characteristics of both groups are presented in Table 1. No substantial differences were observed across groups for age, weight, height, spasticity grade, and GMFCS level ($p > 0.05$). **(fig.2).**

TABLE 1 Demographics of the assessed groups.

Characters		**Group A**	**Group B**	***P***
Age (years)		6.167±0.911	6.147±1.0769	0.957
Weight (kg)		23.8±3.783	23.47±4.291	0.823
Height (cm)		103.8±7.75	104.33±8.33	0.857
Ashworth	Grade +1	10 (66.7%)	9 (60%)	0.71
	Grade 2	5 (33.3%)	6 (40%)	
GMFM	Grade 3	9 (60%)	9 (60%)	1
	Grade 4	6 (40%)	6 (40%)	

Data is reported as Mean ± SD or frequency (%).

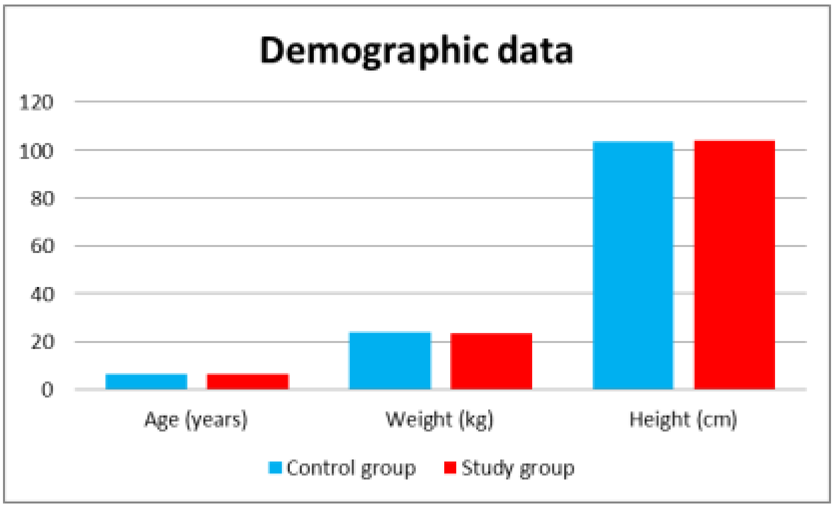

FIGURE (2): Demographic data

Effect of treatment on QUEST weight-bearing domain

Within-Group Comparison

The QUEST weight-bearing domain for both groups post-therapy was considerably improved compared to pre-treatment ($p < 0.05$). Group B had a more pronounced enhancement relative to Group A.

Between-Group Comparison

Before treatment, all pre-treatment variables were statistically equivalent ($p = 0.95$). Following the treatment, Group B exhibited a substantial enhancement in the QUEST weight-bearing domain relative to Group A ($p < 0.001$).**(Fig.3)**.

Table (2): Mean values of QUEST weight-bearing domain for both groups pre- and post-treatment Prior to therapy, all pre-treatment variables were statistically equivalent ($p = 0.95$). Following the treatment, Group B exhibited a substantial enhancement in the QUEST weight-bearing domain relative to Group A ($p < 0.001$).

QUEST Weight Bearing	**Group A**	**Group B**	**t**	**MD**	**P.value**
Pretreatment	22.8±2.624	22.87±3.137	-.063	-.067	0.95
Postreatment	40.73±4.832	56.93±6.638	-7.641	-16.2	<0.001
Cohen's d	3.807	4.35			
P.value	<0.001	<0.001			

Mean ± SD is how the data is presented.

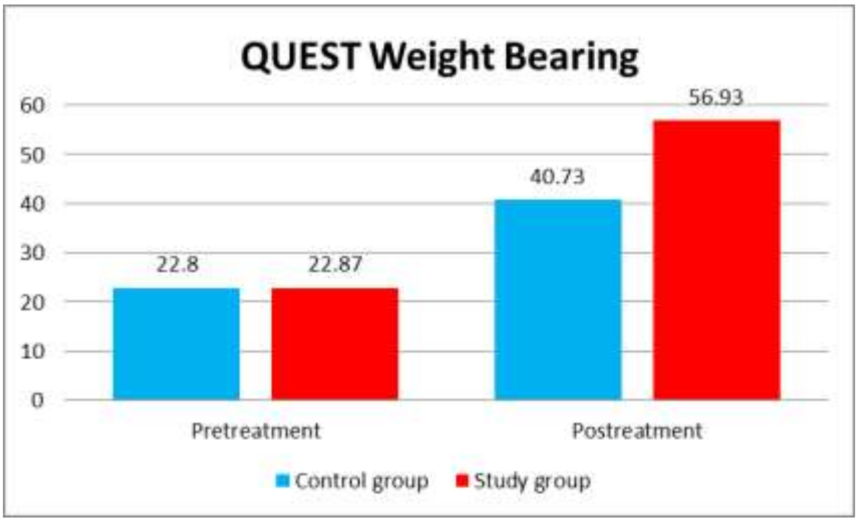

Figure (3): Effect of treatment on QUEST weight-bearing domain

Effect size

The effect size calculation for the primary outcome (QUEST weight-bearing domain) indicated a very strong treatment effect (Cohen's d = 4.35) meaning that the changes seen in Group B were both statistically significant and clinically relevant.

Summary of results

The introduction of the task-specific electrical stimulation to the routine physical treatment led to a significant improvement in weight bearing in both groups.

Discussion

The current research evaluated the impacts of addition of TASES to the normal physical therapy program on upper limb weight bearing capacities in children with SQCP. In both groups, statistically significant improvement of the QUEST weight-bearing domain after therapy was found. The group that received task-specific electrical stimulation + physical therapy (Group B) showed significantly greater improvement than the group that received physical therapy alone (Group A). These findings contribute to an expanding body of research endorsing the use of neuromuscular or task-specific electrical stimulation into rehabilitation programs to enhance functional motor outcomes for children with CP.

Both groups exhibited substantial enhancements attributable to the beneficial benefits of conventional physical therapy, including postural control, proximal stability, muscle growth, and motor learning. Children with SQ have usually inadequate trunk stability, deficient selective motor control, abnormal muscle tone, and poor upper limb control. These influence functional weight-bearing activities. Traditional physical therapy interventions aim to enhance neuromuscular coordination and functional movement patterns, potentially contributing to the favorable outcomes shown in across groups.

The QUEST weight-bearing score post-treatment was much superior in group B (56.93 ± 6.638) compared to group A (40.73 ± 4.832), signifying more favorable outcomes for group B. The mean difference across groups post-treatment was extremely significant ($P < 0.001$), demonstrating a supplementary therapeutic advantage of TASES compared to conventional therapy alone. Furthermore, the effect size in Group B was substantial (Cohen's d = 4.35), indicating that the enhancement was both statistically significant and clinically relevant. Various physiological reasons may have influenced the superior results in the electrical stimulation cohort. Repetitive sensory and motor input, coupled with task-specific electrical stimulation, enhances motor unit recruitment, muscle activation timing, and cortical excitability. Deficient voluntary motor control is a prevalent characteristic in children with CP, attributed to compromised sensory integration and diminished activation of agonist muscles. In contrast to these impairments, electrical stimulation enables the simultaneous activation of specific muscles during functional tasks and may be enhanced by offering sensory feedback within an active task context, integrating electrical stimulation with the concurrent execution of upper limb functional activities that may foster neuroplasticity and motor relearning. This combination may yield enhanced movement patterns and superior postural control. The enhanced weight-bearing capabilities seen in this study may be associated with the augmented stability of the proximal shoulder girdle. Weight-bearing movements necessitate the co-contraction of shoulder stabilizers, elbow extensors, and trunk musculature. Children with SQ often have inadequate coordination and muscular weakness, rendering them unable to support body weight via their upper extremities. TASES likely enhanced the muscular activation and endurance of these stabilizing muscles, resulting in more effective weight transfer and upper limb support.

The results aligned with prior research indicating the advantageous effects of NMES and FES in children with CP. In children with spastic CP, NMES plus strengthening exercises markedly enhanced motor function compared to exercise alone **(Qi et al., 2018).** The results showed that electrical stimulation has the potential to improve muscle performance and functional mobility through increased neuromuscular activation.

In another study, **Katz et al. (2008**) found that CP children showed improvements in functional movement patterns and muscle activity after receiving electrical stimulation. The authors concluded that electrical stimulation could improve voluntary motor recruitment and strengthen weak muscles to improve motor performance. Such findings are in agreement with the present study observation that electrical stimulation can significantly increase the weight bearing capacity of the upper limb.

Garzon and co-authors (2018) also reported that FES of the upper limb improved several subdomains of the QUEST including grasp ability, dissociated movement and weight bearing functions in children with hemiplegic CP. Despite the study focusing on children with hemiplegia rather than SQ, the enhancements in QUEST domains corroborate the notion that recurrent electrically assisted functional activities can enhance upper limb performance in children with neurological impairments.

The baseline equality of the two groups strengthens the internal validity of the study. Comparability was observed between the groups before therapy regarding age, weight, height, spasticity grade, and GMFCS level ($p > 0.05$). Moreover, there were no substantial variations in pre-treatment QUEST scores across groups ($p = 0.95$), indicating that the post-treatment differences were likely attributable to the intervention rather than pre-existing group disparities.

The current findings align with recent assessments of neuromuscular electrical stimulation in the rehabilitation of CP. A scoping study by **Greve et al. (2022**) found that NMES improved motor function, strength of muscles, and functional mobility in people suffering from spastic cerebral palsy. Also, **Ou et al. (2023)**, found that upper-limb NMES interventions were effective in improving motor performance and upper-extremity function in children with CP. Meta-analyses **(Yang et al., 2025; Novak et al., 2013)** suggest that NMES and FES modalities are effective adjuncts to conventional therapy, particularly when protocols are task-specific and integrated into active movement practice. However, there is little study explicitly devoted to children with SQ so this work is an addition to the field.

Some **limitations** should be discussed in the context of the encouraging results of the present study. Some limitations to consider are the limited sample size and the absence of long-term follow-up to determine the retention of benefits.. Moreover, only the weight-bearing domain of QUEST was measured. Other aspects of upper limb function such as gripping, dexterity and activities of daily life were not assessed.

More extensive follow-up, bigger samples, and other outcome measures to evaluate functional independence and quality of life should be considered in future research**.** Further research may include optimum stimulation parameters, length and frequency of treatment to maximise therapeutic benefit. Further studies investigating the effect of combination of task-specific electrical stimulation with other Comprehensive solutions for upper limb rehabilitation in children with cerebral palsy may be better understood with the help of rehabilitation approaches (e.g., virtual reality, robotic-assisted therapy, and constraint-induced movement therapy).

Conclusion Combined effect of TASES and conventional physical treatment has significant effect on the rehabilitation of upper limb weight bearing capacities in children with SQCP. The intervention appears to produce clinically relevant improvements, in addition to those achieved with physical therapy alone, and may be a useful adjunctive treatment method in child neurorehabilitation.

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