

Original Article

Effect of Sensory- Motor Integration Training on Activities of Daily Living in Children with Erb's Palsy: A Randomized Controlled Trial

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Abstract

Objective: This study examined sensory-motor integration training effects on activities of daily living (ADLs) in children with Erb's palsy. **Methods:** A randomized controlled trial enrolled 32 children aged 2–6 years with Narakas Type I Erb's palsy. This assessor-blinded study randomly allocated participants using sequentially numbered, sealed opaque envelopes to control group (60 minutes of an upper-limb rehabilitation program) or study group (45 minutes of the same upper-limb rehabilitation program plus 15 minutes of sensory-motor integration training; total 60 minutes/session). Interventions were delivered three times weekly for 12 weeks. The primary outcome was the Jebsen–Taylor Hand Function Test (JTHFT) Simulated Feeding subtest; secondary outcomes included other JTHFT subtests and grip strength, measured at baseline and week 12. **Results:** Both groups showed significant within-group improvements in grip strength ($p < 0.001$). Post-intervention, the study group demonstrated significantly greater grip strength versus control (5.42 ± 0.81 vs. 3.36 ± 0.46), with a between-group difference of 2.06 units (95% CI: 1.58–2.54) and very large effect size (Cohen's $d = 3.13$; $p < 0.001$). The study group showed greater improvement in feeding performance ($\Delta = 13.93$ s; 60% improvement) than control ($\Delta = 11.27$ s; 51% improvement). **Conclusion:** Combined with an upper limb rehabilitation program, sensory-motor integration training significantly improves functional abilities and daily living skills in children with Erb's palsy. **ClinicalTrials.gov ID:** NCT06324643.

Keywords: Erb's Palsy, Dynamometer, Hand Function, Sensory-Motor Integration, Upper Limb Rehabilitation Program

Introduction

Neonatal Brachial Plexus Injury (NBPI) is a type of peripheral nerve injury that leads to partial or complete weakness of the upper limb, most commonly arising during

labor. This condition occurs in approximately 1.4 per 1,000 live births worldwide and has been linked to obstetric risk factors such as macrosomia, shoulder dystocia, and the use of instrumental delivery¹. Although many neonates recover spontaneously, approximately 10–18% continue to experience persistent functional limitations.

The most common form of NBPI is Erb's palsy, which is typically caused by injury to the upper trunk (C5–C6) and, less frequently, C7. It is characterized by motor impairments, such as a flattened shoulder, reduced ability to bend the elbow, and limited wrist extension, primarily due to the compromised function of muscles such as the deltoid, biceps brachii, supraspinatus, and coracobrachialis². According to clinical observations, children with Erb's palsy frequently have the distinctive “waiter's tip” posture, which consists of wrist flexion, elbow extension, forearm

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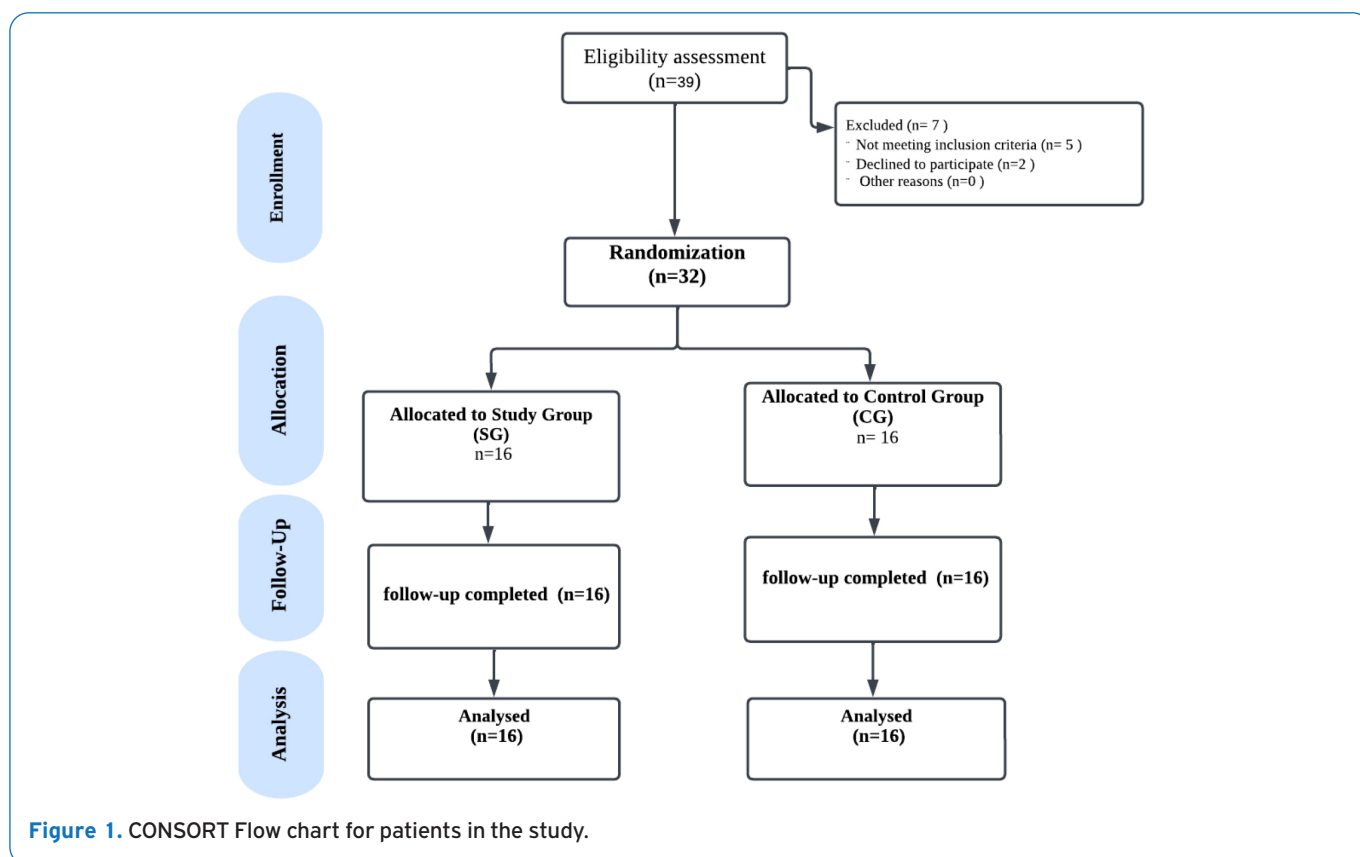


Figure 1. CONSORT Flow chart for patients in the study.

pronation, and shoulder adduction with internal rotation³.

These neuromuscular impairments lead to lasting restrictions in both active and passive joint motion, muscle contractures, and sensory disturbances, thereby limiting the upper limb function. Consequently, children with NBPI frequently struggle to perform activities of daily living (ADLs), which adversely affects their autonomy, psychosocial health, and overall quality of life⁴⁻⁵.

Sensory-motor integration training is increasingly being applied in pediatric neurorehabilitation to optimize functional recovery by stimulating multisensory processing and motor control. It employs tactile, proprioceptive, and vestibular inputs to encourage adaptive responses and improve coordination, attention, and motor planning. Integrated within the central nervous system, these inputs shape motor output and behavior, supporting the execution of meaningful and goal-oriented tasks⁶⁻⁷.

Considering the ongoing motor and sensory deficits in children with Erb's palsy and the scarcity of research on sensory-motor rehabilitation within this population, this study goal was to assess the impact of sensory-motor integration training on improving activities of daily living (ADLs). The intervention combines sensory stimulation with functional motor practice to promote greater independence

and efficiency in performing daily tasks. We hypothesized that combining sensory-motor integration training with functional motor practice would enhance ADL performance compared to functional motor practice alone in children with Erb's palsy. By addressing this knowledge gap in pediatric neurorehabilitation, this study evaluated a potentially valuable therapeutic modality, recognizing the importance of innovative approaches to foster functional independence in this population.

Methods

Study Design and Participants

This study utilized a two-arm, parallel, randomized controlled trial (RCT) design incorporating pre- and post-intervention assessments. Thirty-two male and female children aged 2–6 years were recruited from Kafr El-Sheikh University's outpatient clinic and randomly allocated into two equal groups (n = 16 per group). Inclusion required a diagnosis of Narakas Type I obstetric brachial plexus palsy, specifically involving the C5-C6 nerve roots. Participants needed to have a functional Range of Motion (ROM) in their wrists and fingers, as well as functional strength in the distal muscles, which was defined as achieving a grade of 3

or higher on the Manual Muscle Testing scale. This ensured that all included children possessed the anti-gravity motor control necessary to attempt the functional tasks required during the study. All participants demonstrated significant baseline functional impairment. These included decreased grip strength and a marked slowness in fine motor tasks such as grasping small objects, manipulating tools, and handwriting, which hindered their ability to achieve age-appropriate activities of daily living (ADLs). Additionally, the capacity to obey verbal directions, normal muscular tone, and intact visual and auditory capacities were all required for inclusion. All included children had unilateral Erb's palsy, and the affected hand was the limb undergoing assessment, with baseline characteristics such as affected side and hand dominance documented in Table 2. Children with a history of surgical intervention, cognitive problems, congenital defects, complete sensory loss, shoulder subluxation or dislocation, or Erb's engram were excluded. Data collection and procedures were carried out from May to October 2024.

Randomization and Allocation

A total of thirty-nine children with obstetric brachial plexus palsy were screened for eligibility. Five participants did not satisfy the predetermined inclusion criteria and were consequently excluded from the study and two participants declined to participate. Thirty-two children who met the eligibility criteria were recruited and randomly assigned to either the control or intervention group with a 1:1 allocation ratio.

A computerized random number generator (Microsoft Excel RAND function) was used to produce an allocation sequence for the randomization process. To ensure appropriate separation of trial roles, an independent statistician (not involved in participant enrollment or outcome assessment) generated the allocation sequence. A second investigator, blinded to the allocation sequence, enrolled eligible participants sequentially according to the randomization order. Group assignment was communicated to participants and treating therapists only at the time of initial intervention.

To prevent selection bias, treatment allocation was concealed using sequentially numbered, opaque, sealed envelopes. These envelopes were managed by an independent researcher who was not involved in the subsequent phases of the trial. The assignments were only revealed following the completion of baseline measurements and just before the start of the intervention, ensuring that the group assignment remained unpredictable to both the investigators and participants.

Due to the pragmatic nature of the interventions employed in this investigation, participants and treating therapists necessarily remained aware of the treatment group assignment throughout the study period. However, to minimize detection bias and maintain methodological rigor, outcome assessors performing post-intervention

measurements and biostatisticians conducting data analyses remained masked to group allocation. The participant flow diagram, including enrollment, randomization, and follow-up, is presented in Figure 1 in accordance with the Consolidated Standards of Reporting Trials (CONSORT) 2010 guidelines.

Sample size

The sample size was determined using G*Power software (version 3.1.9.2). Based on a t-test analysis with an alpha level of 0.05, a power of the test = 0.80, and effect size = 0.9, a total of 32 participants (16 per group) was required to ensure statistical significance.

Procedures

Method of evaluation

The primary outcome (JTHFT Simulated Feeding subtest) and secondary outcomes (other JTHFT subtests and grip strength) were measured at baseline and week 12.

1. Assessment of grip strength using a digital handheld dynamometer:

To assess the maximal isometric grip strength of both the extrinsic and intrinsic hand musculature, a calibrated Jamar digital dynamometer (Model 5030J1) was used. The device was adjusted individually to the level of the participants' proximal interphalangeal joints. The participants maintained a standardized seated position: arms adducted, elbows flexed at 90°, forearms in a neutral position, and wrists in slight extension (0°–30°) with minimal ulnar deviation (0°–15°). Standardized verbal encouragement was provided throughout each trial to ensure peak performance. For each muscle group, the maximum force (kg) was captured across three consecutive trials, and the resulting mean was adopted for subsequent statistical evaluation, consistent with established protocols for this pediatric population⁹.

2. The Jebsen-Taylor Hand Function Test (JTHFT) was used to assess the manual dexterity and functional hand performance of children diagnosed with Erb's palsy. The JTHFT, a standardized tool for assessing hand function, evaluates fine and gross motor skills through seven timed tasks resembling daily life activities, measured in seconds using a digital stopwatch⁹. These tasks included sentence writing, page turning, placing small objects, stacking checkers, spoon feeding, transferring empty cans, and transferring weighted cans (~0.45 kg). We used timed performance (in seconds) for within- and between-group comparisons. The writing subtest was adapted to a scribbling task using a thick-grip marker to accommodate the developmental level of participants aged 2–3 years¹⁰. This adaptation focuses on the motor component of grasping and moving a writing utensil rather than standardized letter formation. All participants successfully performed the task; consequently, no missing data or infeasible tasks were recorded.

Table 1. Session duration in both study and control groups.

Component	Control Group (min)	Intervention Group (min)
Upper Limb Rehabilitation Program	60	45
Sensory-Motor Integration Training	0	15
Total Session Duration	60	60

Treatment procedures

Control Group Protocol

The control group received an upper limb rehabilitation program consisting of 60-minute sessions administered three times weekly over a 12-week period. The control intervention was designed to address impairments in upper-extremity function using evidence-based therapeutic techniques. Each session encompassed five core therapeutic components delivered sequentially.

1. Proximal Stability Enhancement: Weight-bearing activities targeting scapular and glenohumeral joint stability to establish a foundation for distal upper extremity control.

2. Neuromuscular Facilitation: Joint approximation techniques to modulate muscle tone and promote coordinated muscle activation patterns.

3. Sensory Preparation: Tactile stimulation to normalize sensory processing and prepare tissues for functional movement.

4. Functional Motor Training: Task-specific reaching, grasping, and releasing activities designed to improve functional grasp patterns and hand dexterity in ecologically relevant contexts.

5. Contracture Prevention: Passive and active-assisted stretching exercises targeting muscles prone to contracture formation, particularly in the anterior upper extremity, are performed.

Intervention Group Protocol (Study Group)

To control for non-specific therapeutic effects (attention, therapist interaction time, environmental enrichment), the intervention group received an upper limb rehabilitation program plus sensory-motor integration training with frequency (three times weekly for 12 weeks). The intervention was divided into two sequential components Table 1¹.

Upper Limb Rehabilitation Program Component (45 minutes)

Participants in the intervention group received the same five conventional components delivered within 45 minutes, followed by 15 minutes of sensory-motor integration training (total session time 60 minutes).

Sensory-Motor Integration Training Component (15 minutes)

Following the standard therapy component, participants received supplemental sensory-motor integration training emphasizing the integration of sensory feedback with motor output during functional tasks. This component utilized graduated sensory stimuli of varying proprioceptive, tactile, and sensory complexity. Specific training activities included: (a) discrimination tasks utilizing objects of systematically varied shapes, sizes, and surface textures; (b) tactile localization exercises requiring identification of touch stimuli delivered to the hand and upper extremity; and (c) object recognition tasks requiring identification of objects through tactile exploration without visual input.

Progression and Fidelity

Progression rules were based on functional improvement; task difficulty increased once the child achieved 80% accuracy over three consecutive sessions, progressing from “eyes open” to “eyes closed” tasks¹². The sensory-motor component was tailored to each child while adhering to the ten core fidelity elements of Sensory Integration (SI) therapy as outlined by¹³, which encompass strategies essential for delivering authentic SI-based interventions:

- (1) Structure the environment to allow for active engagement.
- (2) Ensure the child's physical safety during all activities.
- (3) Provide rich and varied sensory opportunities.
- (4) Support the child in achieving and facilitating the maintenance of alertness and readiness for task performance.
- (5) Tailor tasks to ensure the delivery of a just-right challenge.
- (6) Ensure the success of the activities.
- (7) Promote self-regulation of behaviour.
- (8) Foster a playful setting.
- (9) Collaborate with the child in choosing activities.
- (10) Developing and maintaining a strong therapist-child relationship.

These 10 elements are organized into 3 categories:

- (1) Modifying the environment and offering sensory-rich opportunities throughout the session.
- (2) Promoting adaptive responses by presenting appropriately challenging tasks.

Table 2. General characteristic of both study and control groups.

Hand dominance	Study group	Control group	T-Statistic	p-value
	mean \pm SD	mean \pm SD		
Age (years)	3.8 \pm 0.87	3.6 \pm 0.76	0.721	0.477
Height (cm)	102.38 \pm 8.35	102.25 \pm 8.99	0.041	0.968
Weight (kg)	14.75 \pm 2.62	15.06 \pm 2.02	0.378	0.708
Sex (M: F), n (%)	8 (50): 8 (50)	(4 : 12)	2.133*	0.144
Affected side (Right: Left), n (%)	8 (50) : 8 (50)	(7 : 9)	0.126*	0.723
Hand dominance (Affected: Non-affected), n (%)	9 (56): 7 (44)	(8 : 8)	0.126*	0.723

*Data are presented as mean \pm standard deviation (SD) for continuous variables and number (percentage) for categorical variables. Independent t-test was used for continuous variables. *Chi-square (χ^2) test was used for categorical variables. p-values < 0.05 were considered statistically significant.*

(3) Enhancing the therapeutic relationship between the child and therapist.

All sessions were conducted by senior pediatric physical therapists (minimum of 5 years of experience) trained in the protocol. They received specific training on the standardized tasks used in this study to ensure inter-rater reliability and protocol adherence.

Co-interventions and Adherence

Parents were instructed to avoid any new medical or rehabilitative interventions (e.g., Botox or additional therapy) during the 12-week study period. Compliance was verified through bi-weekly interviews with parents, and adherence was monitored via a daily attendance log.

Statistical Analysis

Data analysis was structured around the primary outcome (JTHFT Simulated Feeding subtest) and secondary outcomes (other JTHFT subtests and grip strength). Statistical analysis was performed using SPSS version 27 for Windows. Data normality was verified via the Shapiro-Wilk test. Baseline demographic characteristics (age, height, and weight) were compared between groups using descriptive statistics and unpaired t-tests, while the Chi-square test was employed for gender distribution. For the primary and secondary outcomes including the Jebsen-Taylor Hand Function Test subtests and grip strength-within-group and between-group comparisons were analyzed using paired and unpaired t-tests, respectively. However, the 'Checkers' subtest was analyzed using the Mann-Whitney U test for between-group post-treatment comparisons and the Wilcoxon Signed-Ranks test for within-group changes, as the data necessitated non-parametric analysis. The results are reported as mean \pm standard deviation, with significance set at $p < 0.05$. No formal adjustment for multiplicity

was performed for secondary outcomes; therefore, these results are considered exploratory. All randomized participants completed follow-up and were analyzed.

Results

General Characteristics

The recruitment and flow of participants are illustrated in Figure 1. Initially, 39 children were screened for eligibility, of whom seven were excluded: five did not meet the predefined inclusion criteria, and two declined to participate. The remaining 32 participants were enrolled and randomly allocated into two equal groups ($n = 16$ per group). All 32 participants finished the entire intervention period and were included in the final analysis. The average age was 3.6 ± 0.76 years for the control group and 3.8 ± 0.87 years for the study group. A descriptive evaluation of participants' age, height, and weight indicated no significant differences between the study and the control groups at the baseline (Table 2).

Grip strength

Figure 2 (Grip Strength) and Table 3 show the changes in grip strength following the intervention. At baseline, no statistically significant differences were observed between the two groups ($p = 0.112$), with mean values of 2.03 ± 0.59 kg for the study group and 2.4 ± 0.68 kg for the control group. Following the 12-week program, both groups demonstrated significant within-group improvements. The post-intervention mean values increased to 5.42 ± 0.81 kg (a 167% increase) for the study group and 3.36 ± 0.46 kg (a 40% increase) for the control group. Furthermore, post-intervention analysis revealed that the study group demonstrated a statistically significant superior improvement ($p < 0.05$).

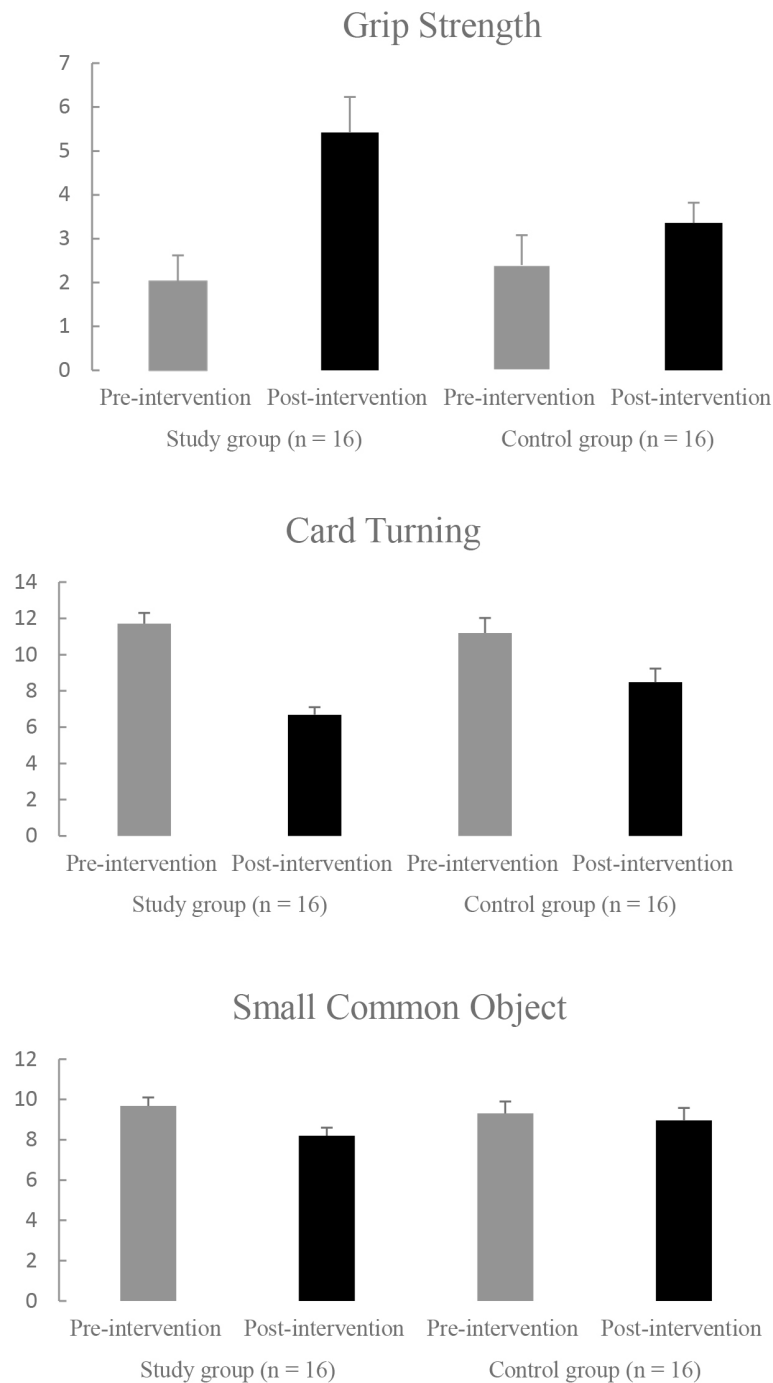


Figure 2. Comparison of mean values of Grip Strength (kg), Card Turning, and Small Common Object (seconds).

Taylor Hand Function Test (JTHFT)

At the baseline, there were no significant differences in the JTHFT writing subtest between the study group (82.52 ± 4.2 seconds) and the control group (79.59 ± 4.82 seconds) ($p = 0.077$). Following the 12-week training,

both groups showed significant improvement; the study group's completion time decreased by 23% (reaching 63.7 ± 5.34 seconds), while the control group showed a 15% improvement (reaching 67.93 ± 4.81 seconds) as shown in Figure 3. Post-intervention analysis in Table 3 indicated

Table 3. Between-group comparison of grip strength and Jebsen–Taylor Hand Function Test outcomes.

Outcome	Time	Study group (n = 16)	Control group (n = 16)	Mean Difference (MD)	95% CI	Cohen's <i>d</i>	<i>p</i> -value
		Mean ± SD	Mean ± SD		(LL, UL)		
Grip strength (kg)	Pre	2.03 ± 0.59	2.40 ± 0.68	-0.37	-0.83, 0.09	0.58	0.112
	Post	5.42 ± 0.81	3.36 ± 0.46	2.06	1.58, 2.54	3.13	< 0.001
	Δ (Post–Pre)	3.39	0.96	—	—	—	—
	% improvement	167%	40%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—
JTHFT – Writing (s)	Pre	82.52 ± 4.20	79.59 ± 4.82	2.93	-0.33, 6.19	0.65	0.077
	Post	63.70 ± 5.34	67.93 ± 4.81	-4.23	-7.90, -0.56	0.83	0.025
	Δ (Post–Pre)	18.82	11.66	—	—	—	—
	% improvement	23%	15%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—
Card turning (s)	Pre	11.71 ± 0.59	11.19 ± 0.83	0.52	0.00, 1.04	0.72	0.052
	Post	6.68 ± 0.42	8.48 ± 0.75	-1.80	-2.23, -1.36	2.96	< 0.001
	Δ (Post–Pre)	5.03	2.71	—	—	—	—
	% improvement	43%	24%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—
Small common objects (s)	Pre	9.68 ± 0.42	9.31 ± 0.59	0.37	0.00, 0.74	0.72	0.051
	Post	8.20 ± 0.40	8.96 ± 0.62	-0.76	-1.14, -0.38	1.46	0.0003
	Δ (Post–Pre)	1.48	0.35	—	—	—	—
	% improvement	15%	4%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—
*Simulated feeding (s)	Pre	23.08 ± 1.20	22.26 ± 1.08	0.82	0.00, 1.64	0.72	0.052
	Post	9.15 ± 0.57	10.99 ± 0.80	-1.84	-2.34, -1.34	2.65	< 0.001
	Δ (Post–Pre)	13.93	11.27	—	—	—	—
	% improvement	60%	51%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—
Checkers (s)	Pre	9.94 ± 0.74	9.56 ± 0.54	0.38	-0.09, 0.85	0.59	0.115
	Post	5.98 ± 0.86 Median (IQR)= 6.2 (0.26)	7.23 ± 0.49 Median (IQR)= 7.21 (0.26)	-1.01	-1.51, -0.51	—	< 0.001
	Δ (Post–Pre)	3.96	2.33	—	—	—	—
	% improvement	40%	24%	—	—	—	—
	<i>p</i> -value	0.0004	0.0004	—	—	—	—
Large light objects (s)	Pre	8.53 ± 0.31	8.60 ± 0.78	-0.07	-0.49, 0.36	0.12	0.733
	Post	4.21 ± 0.56	6.10 ± 0.83	-1.89	-2.40, -1.38	2.67	< 0.001
	Δ (Post–Pre)	4.32	2.50	—	—	—	—
	% improvement	51%	29%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—
Large heavy objects (s)	Pre	11.69 ± 0.54	11.26 ± 0.64	0.43	0.00, 0.86	0.73	0.051
	Post	6.79 ± 0.50	8.23 ± 0.58	-1.44	-1.83, -1.05	2.66	< 0.001
	Δ (Post–Pre)	4.90	3.03	—	—	—	—
	% improvement	42%	27%	—	—	—	—
	<i>p</i> -value	< 0.001	< 0.001	—	—	—	—

*Indicates the primary outcome of the study. Data are presented as mean ± standard deviation (SD). Mean Difference (MD) represents between-group differences at each time point. Δ (Post–Pre) represents within-group absolute change. Cohen's *d* interpreted as: small (0.2), medium (0.5), large (0.8), very large (>1.2). Independent *t*-tests were used for between-group comparisons except for the Checkers post-treatment comparison, which used the Mann–Whitney *U* test; within-group comparisons used paired *t*-tests except for Checkers, which used the Wilcoxon signed-rank test. *p* < 0.05 considered statistically significant. JTHFT: Jebsen–Taylor Hand Function Test; CI: confidence interval; Lower Bound (LL) and Upper Bound (UL); IQR: Interquartile range.

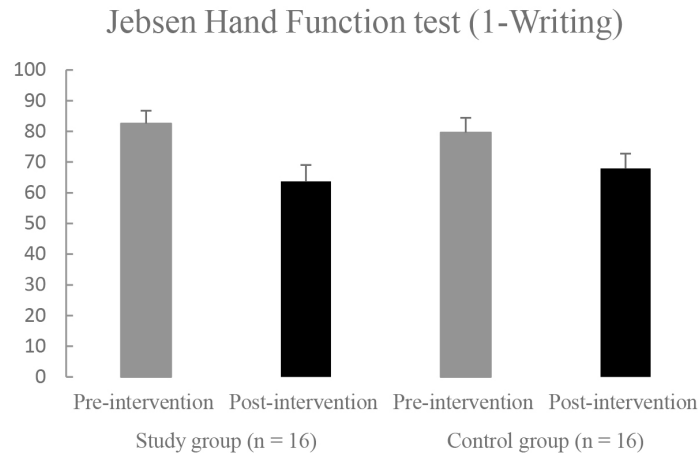


Figure 3. Comparison of mean values of Jebsen Hand Function test (1-Writing) (seconds) in both groups.

that the improvements observed in the study group were statistically significant in comparison to the control group ($p < 0.05$).

Regarding the JTHFT Card Turning subtest, no significant change was found at baseline between the study group (11.71 ± 0.59 seconds) and the control group (11.19 ± 0.83 seconds) ($p = 0.052$). Following the 12-week intervention, (Figure 2, Card Turning) shows that the study and control groups demonstrated significant within-group improvements ($p < 0.05$). The post-intervention completion time decreased to 6.68 ± 0.42 seconds (a 43% improvement) for the study group and 8.48 ± 0.75 seconds (24% improvement) for the control group. As shown in Table 3, the study group exhibited a statistically significant clinical gains over the control group post-intervention ($p < 0.001$).

Figure 2 (Small Common Object) and Table 3 present the results for the Small Common Object subtest (JTHFT). At the baseline, no significant difference was observed between the study group (9.68 ± 0.42 seconds) and the control group (9.31 ± 0.59 seconds) ($p = 0.051$). Following the 12-week intervention, intra-group comparisons revealed that both cohorts exhibited statistically significant improvements across all measured outcomes ($p < 0.05$). The post-intervention completion time decreased to 8.20 ± 0.40 seconds (15% improvement) for the study group and 8.96 ± 0.62 seconds (4% improvement) for the control group. Post-intervention analysis showed that in comparison to the control group, the study group demonstrated a statistically significant benefit ($p = 0.0003$).

Figure 4 (Simulated Feeding) and Table 3 present the results for the Simulated Feeding subtest (JTHFT). At pre-treatment, there was no significant difference between the study group (23.08 ± 1.20 seconds) and the control

group (22.26 ± 1.08 seconds) ($p = 0.052$). Following the 12-week intervention, two groups demonstrated significant within-group improvements ($p < 0.05$). The post-intervention completion time decreased to 9.15 ± 0.57 seconds (60% improvement) for the study group and 10.99 ± 0.80 seconds (51% improvement) for the control group. Post-intervention analysis revealed that the study group had a statistically significant superiority over the control group ($p < 0.001$).

Figure 4 (Checkers) and Table 3 display the results for the Stacking Checkers subtest (JTHFT). At the baseline, there were no significant differences between the study group (9.94 ± 0.74 seconds) and the control group (9.56 ± 0.54 seconds) ($p = 0.115$). Following the 12-week intervention, two groups demonstrated significant within-group improvements ($p < 0.05$). The post-intervention completion time decreased to 5.98 ± 0.86 seconds (a 40% improvement) for the study group and 7.23 ± 0.49 seconds (a 24% improvement) for the control group. Post-intervention analysis showed that the study group had a statistically significant benefit over the control group ($p < 0.001$).

The findings for the Large Light Object subtest (JTHFT) are illustrated in Figure 4 (Large Light Object) and Table 3. Pre-treatment, no significant differences were found between the study group (8.53 ± 0.31 s) and the control group (8.6 ± 0.78 s) ($p = 0.733$). Following the 12-week intervention, two groups demonstrated significant within-group improvements ($p < 0.05$). The post-intervention completion time decreased to 4.21 ± 0.56 s (a 51% improvement) for the study group and 6.1 ± 0.83 s (a 29% improvement) for the control group. Statistical analysis confirmed a significant advantage for the study group over the control group post-treatment ($p < 0.001$).

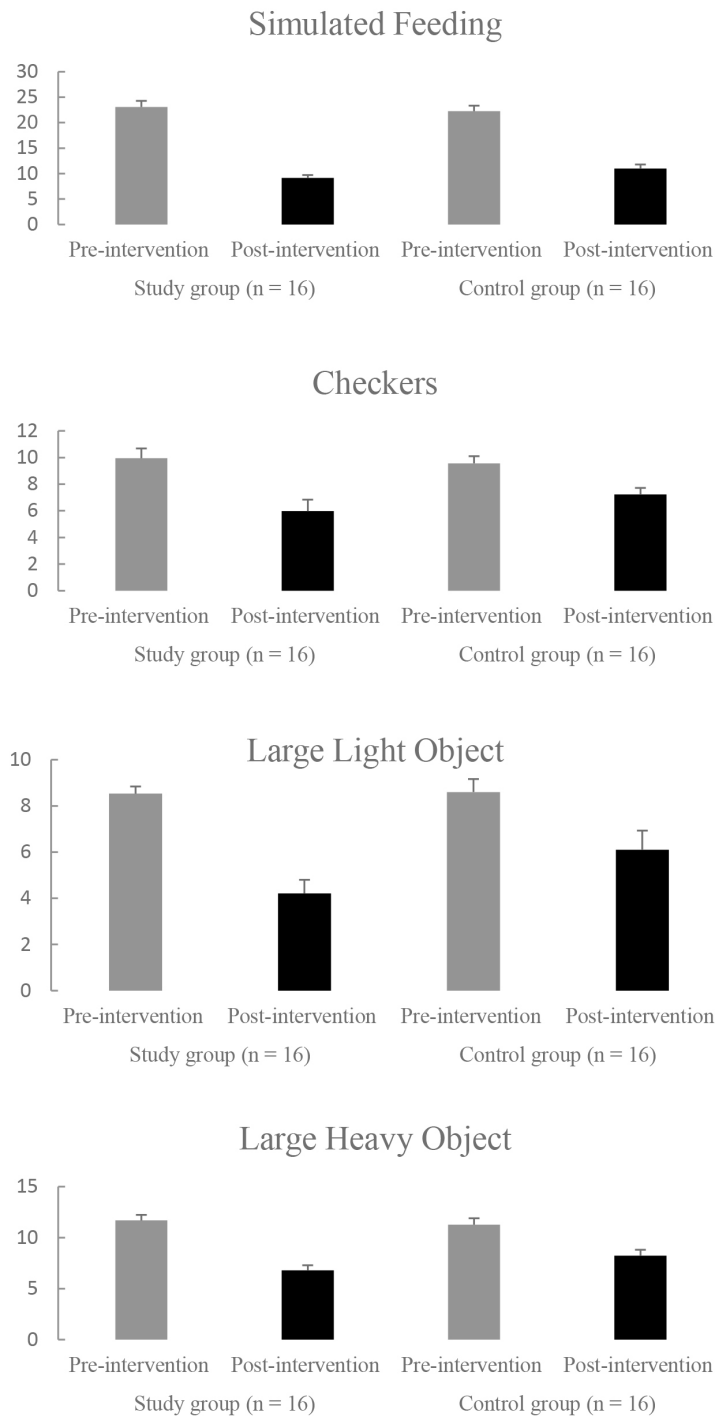


Figure 4. Comparison of mean values of Simulated Feeding, Checkers, Large Light Object, and Large Heavy Object (seconds) in both groups.

Figure 4 (Large Heavy Object) and Table 3 present the findings for the Large Heavy Object subtest (JTHFT). At the baseline, no significant difference was observed between the study group (11.69 ± 0.54 s) and the control group ($11.26 \pm$

0.64 s) ($p = 0.051$). Following the 12-week intervention, the both groups showed significant within-group improvements ($p < 0.05$). The post-intervention completion time decreased to 6.79 ± 0.50 s (a 42% improvement) for the study group

and 8.23 ± 0.58 s (a 27% improvement) for the control group. Post-intervention analysis revealed a statistically significant advantage for the study group over the control group ($p < 0.001$).

Discussion

To our knowledge, this study represented the first attempt to examine the application of sensory-motor integration training in children diagnosed with Erb's palsy. Due to the limited available literature on this specific condition, evidence from studies involving other pediatric neurological disorders was referenced to support the rationale and design of our research. The aim of this study was to investigate the potential effects of sensory-motor integration training on everyday activity performance in the children with Erb's palsy.

Our findings suggested a statistically significant improvement on ADL tasks for children with Erb's palsy. Upper Limb Rehabilitation Program plus sensory-motor integration training demonstrated superior outcomes compared to upper limb rehabilitation program in this sample. These findings indicated that integrating sensory-based interventions contributed to meaningful improvements in everyday activities in children affected by Erb's palsy.

Regarding grip strength (secondary outcome), the current results showed that the percentage of improvements in study group was 167% while in control group was 40%. The observed improvements in grasp and manipulation could be partially attributed to enhanced tactile sensory input, which provided information about an object's texture, shape, and size, thereby potentially contributing to the development of internal representations of its characteristics. Such representations enabled the child to appropriately scale the muscle force required to lift an object, with this force adjustment occurring in anticipation of the action based on sensory and motor memory. Post-treatment, children in the study group performed tasks more quickly than those in the control group, likely due to the sensory stimulation that facilitated accurate orientation to object properties and improved discrimination between objects. This, in turn, enhanced anticipatory control and hand function. Our findings were in line with the findings of ¹⁴.

The present findings are in line with previous studies.¹⁵ investigated interventions directed at multiple muscle groups, including the deltoid muscle, external rotators, biceps brachii, forearm supinators, and wrist extensors. In contrast¹⁶, emphasized abduction and external rotators, whereas¹⁷ focused on the external rotator and shoulder flexor. Despite targeting different muscle groups, all three studies reported improvements in muscle strength. A study conducted on 30 children with cerebral palsy reported that combining sensory-integration therapy with conventional physical therapy resulted in greater improvements in gross motor skills compared to physical therapy alone. The differences observed between their findings and the present

study ascribed to the relatively brief intervention duration of eight weeks and the inclusion of children with cortical visual impairment in their cerebral palsy cohort¹⁸. Sensory-motor training enhances children's adaptive behaviors by providing a stronger foundation for organization, planning, problem-solving, and self-monitoring¹⁹. Understanding this finding requires consideration of the principle that learning is shaped by motor development, including balance between gross and fine motor skills and general coordination²⁰⁻²¹.

Regarding the primary outcome (JTHFT Simulated Feeding), the study group improved by 60% while the control group improved by 51%. For other secondary JTHFT outcomes, the study group showed higher improvement than the control group in Writing (23% vs 15%), Card Turning (43% vs 24%), Small Common Objects (15% vs 4%), Checkers (40 % vs 24%), Large Light Objects (51% vs 29%), and Large Heavy Objects (42% vs 27%).

Previous studies have demonstrated that SI/SBI interventions enhance motor development and movement skills²²⁻²⁴. Evidence from previous research indicates that sensory-motor training contributes to the improvement of motor skills in children²⁵. Additionally²⁶, showed that children experience less disorder symptoms when they receive sensory integration therapy. In contrast, a review of 25 studies on interventions reported mixed outcomes. Specifically, only three studies supported the effectiveness of sensory integration therapy, eight examined the benefits of combining sensory integration with other therapeutic approaches, while 14 concluded that sensory integration therapy alone was not effective²⁷.

Based on the scores before and after therapy, throughout the 12-week sensory integration therapy (SIT) program, there may influence in gross motor performance; this influence may have been predicted given that the premise of SIT relies on preparation and putting new functional skills into practice²⁸. Previous studies have reported the use of sensory integration therapy programs to enhance motor performance. However, the degree of improvement may vary depending on whether the intervention involves exercise alone or SIT. Since SIT is specifically designed to address both postural stability and gross motor development, it is expected to produce the most pronounced effects on postural control²⁹. The Sensory Integration Therapy (SIT) framework facilitates optimal neurodevelopment by enhancing the child's capacity to process and synthesize diverse afferent inputs. This includes the effective integration of visual, proprioceptive, auditory, and perceptual information, which are essential for coordinated functional responses. The child's intrinsic motivation is an important consideration when planning SIT interventions, as it drives the selection of therapeutic activities. Children naturally gravitate towards experiences that fit their developmental needs, and through active engagement and exploration, they gradually improve their ability to organise sensory information³⁰. Overall, the study discovered that sensory-motor training is a valuable and engaging intervention, with the potential to improve hand function activities as well as grip strength.

Limitations

Multiple limitations in the present study warrant acknowledgment. First, the inherent clinical heterogeneity among children with Erb's palsy presented an inevitable challenge; variations in individual clinical characteristics may have affected the uniformity of treatment outcomes. Second, the 12-week intervention period may be insufficient to fully evaluate the sustained, long-term impact of sensory integration therapy on motor development and functional performance. Third, the risk of multiplicity remains a concern due to the multiple subtests of the JTHFT, which increases the probability of Type I errors. Furthermore, a potential age-related bias may exist, as the feasibility and task completion in JTHFT can vary across different developmental stages. Therefore, further investigation is warranted using larger, more homogenous cohorts over prolonged durations. Incorporating long-term follow-up periods is essential to ascertain the durability of the observed improvements and to establish a more robust framework for the clinical application of these results in diverse pediatric populations.

Conclusion

Sensory-motor integration training and upper limb rehabilitation programs both are effective interventions for children with Erb's palsy. However, the integration of sensory-motor integration training led to better grip strength, with a significant impact on functional outcomes and improving in activities of daily living. These findings highlight the potential benefits of incorporating sensory-motor integration training as an adjunctive therapeutic approach within pediatric rehabilitation programs for children with Erb's palsy. Future research goal is to further examine the sustainability and long-term impact of such interventions, ideally with a more homogeneous sample and extended follow-up periods to enhance the generalizability of the findings.

Ethics approval

Ethical approval for this study was obtained from the Research Ethics Committee of the Faculty of Physical Therapy at Kafr El-Sheikh University (KFSIRB200-147). This study adhered to the ethical standards of the Declaration of Helsinki (1964) and its later amendments.

Consent to participate

Written informed consent was obtained from the parents or legal guardians of all participants before enrollment.

Author's contributions

S.E.A., A.E.S., O.A.E., S.Y.E., and M.I.A. collaborated to conceptualise. S.E.A., A.E.S., O.A.E., and S.Y.E. worked together to establish the methodology. S.E.A., A.E.S., O.A.E., and S.Y.E. carried out formal analysis and investigation. They also handled resource allocation and data curation. S.E.A., A.E.S., O.A.E., S.Y.E., and M.I.A. wrote the original draft of the paper, which was then reviewed and

revised by the same group. S.E.A., A.E.S., O.A.E., S.Y.E., and M.I.A. collaborated on visualisation projects. M.I.A. acquired the funds. All authors read and approved the final version of the manuscript.

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