

Comparison of Hand Arm Bimanual Intensive Therapy and Action Observation Therapy on Upper Extremity Functions in Children with Spastic Cerebral Palsy – An Experimental Study

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ABSTRACT

BACKGROUND: Cerebral palsy (CP) is a non progressive disorder which occur due to insult to the developing brain. The resulting impairments to upper extremities may demonstrate abnormal muscle tone with posturing into wrist flexion, ulnar deviation, elbow flexion and shoulder internal or external rotation in addition to reduced strength, as well as tactile and proprioceptive disturbances. Treatments targeting upper extremity function in children with CP aim to improve functional abilities, promote functional independence and/or reduce disabling muscle tone. HABIT (Hand Arm Bimanual Intensive Therapy) focuses on functional activities without the use of restraints, along with concurrent encouragement of bimanual hand use through positive feedback and knowledge of performance. Action Observation Therapy (AOT), in which the patient is asked to carefully observe actions presented through a video-clip or performed by an operator, in order to try and imitate them after the observation.

NEED AND AIM OF THE STUDY: Children with cerebral palsy display deficit in motor planning and execution that impact the timing and co-ordination of joint movements in upper extremity. Therefore, this study aims to address this research gap by comparing the HABIT and AOT interventions to provide evidence based guidance for improving upper extremity function in spastic cerebral palsy children.

METHODOLOGY: Total of 30 spastic cerebral palsy children with age 4 to 8 years and both male and female with the criteria of 1 and 1+ grade of spasticity on MAS, able to follow command as well those able to perform minimal or initiation of the hand movements are included in the study. The Quality of Upper Extremity Skill Test (QUEST) and Melbourne Assessment-2 was taken to measure the Upper extremity function.

RESULT: The findings of this study demonstrated significant improvements in both groups across all domains of QUEST and MA2 within the group level. However, no statistically significant differences were found between the groups in post-intervention comparison, indicating that both interventions were equally beneficial in improving upper limb functional abilities except in the grasp domain of the QUEST in the HABIT group.

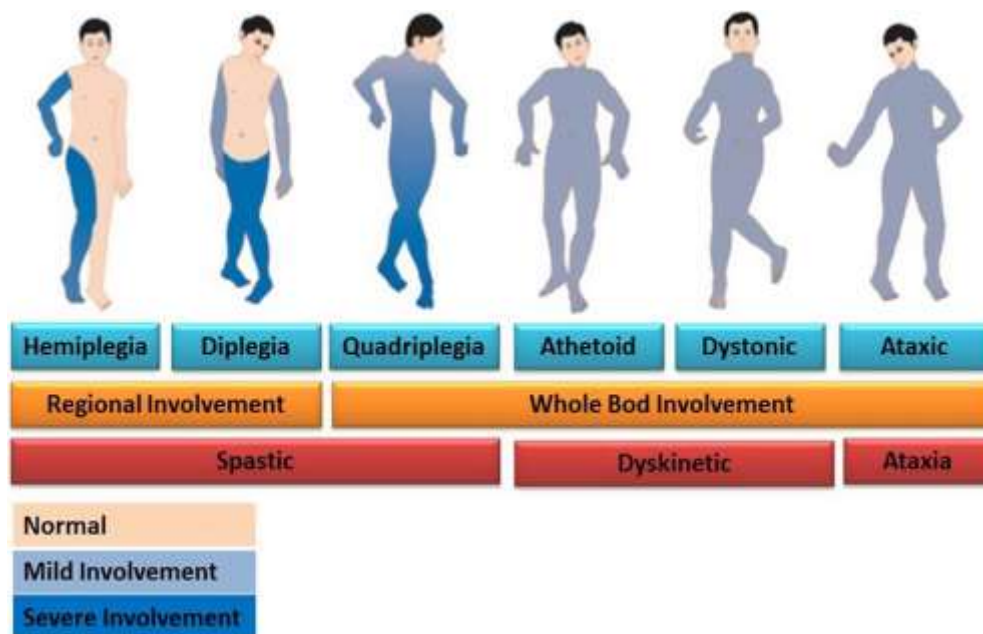
CONCLUSION: Both intervention groups showed significant improvement in upper limb function on QUEST and MA-2, indicating that both treatment are effective.

KEY WORDS: HABIT, AOT, Upper extremity function, spastic cp

Introduction :

Cerebral Palsy (CP) is a non-progressive disorder resulting from an insult to the developing brain occurring during the pre-natal, peri-natal or post-natal period. Cerebral palsy has multiple etiologies that can affect different parts of the brain, thus contributing to the broad range of clinical findings.⁽¹⁾⁽²⁾

Cerebral palsy is a group of disorder characterized by abnormal muscle tone, posture and movement. In clinical practice, it is useful to classify cerebral palsy based on predominant motor system involvement such as spastic hemiplegia, spastic diplegia, spastic quadriplegia, extrapyramidal or dyskinetic, and ataxic.⁽¹⁾⁽²⁾



Classification of CP

The upper limb involvement is usually more pronounced than the lower limb. The resulting impairments to upper extremities may demonstrate abnormal muscle tone with posturing into wrist flexion, ulnar deviation, elbow flexion and shoulder internal or external rotation in addition to reduced strength, as well as tactile and proprioceptive disturbances. All the previous impairments can result in abnormal development of hand skills and consequently affect functional independence and quality of life as well as skilled independent finger movement. Length of the muscle plays an important role in the amount of muscle tension, so decrease in muscle length beyond resting level due to spasticity leads to decrease in the maximum force exerted by the muscles, which in turn affect grasping. The best capacities of upper limb function can differ between two hands in the children with unilateral CP. Meanwhile, children with bilateral CP have a wide range of gross motor and upper limb functions, but the discrepancy in upper limb functions between two hands has not been evident. Most children with unilateral CP were independent in bimanual activities, while there was a large variation in bimanual performance and gross motor function in children with bilateral CP.⁽³⁾⁽¹⁾

Several therapeutic interventions are used in the management of CP. The techniques used in the treatment of CP are conventional approaches (including traditional physiotherapy and occupational therapy, neurodevelopment treatment, hippotherapy, etc.) and recent or current approaches (including electrical stimulation technique). The most commonly used therapeutic interventions are occupational therapy and traditional physiotherapy and have been shown to benefit in the treatment of CP. Treatments targeting upper limb function in children with CP aim to improve functional abilities, promote functional independence and/or reduce disabling muscle tone.⁽¹⁾

Hand-Arm Bimanual Intensive Training (HABIT), which is a specific type of bimanual therapy, was introduced by Charles and Gordon in 2006. HABIT focuses on functional activities without the use of restraints, along with concurrent encouragement of bimanual hand use through positive feedback and knowledge of performance. HABIT improves coordination of both arms by using structured tasks in bimanual play and daily activities. The basic principle of HABIT concerns maintaining the intensity of constraint therapy and improving the deficiency of bimanual coordination (including temporal and spatial coordination) based on the principles of motor learning and neuroplasticity. Training is based on motor learning theory (practice specifically types of practice and feedback) and neuroplasticity (the potential of the brain to change by repetition, increasing movement complexity, motivation and reward) through tasks that require the equal use of both arms in bimanual skills⁽³⁾⁽⁴⁾.

AOT is based on the well-established principle that observation of actions activates the same cortical structures that are active during the actual performance of the task. The brain imaging experiments have shown that during learning a novel, complex motor task through observation of a model (observational learning), areas within the mirror neuron system become active from the observation of meaningful actions followed by their execution (action observation treatment) may become a rehabilitative strategy to accelerate the process of functional recovery in patients with motor impairment.⁽⁵⁾

So, the children with cerebral palsy display deficit in motor planning and execution that impact the timing and co-ordination of joint movements in upper extremity. However, limited literature is available directly comparing the effects of HABIT and AOT on upper extremity function in children with spastic cerebral palsy. Therefore, this study aims to address this research gap by comparing these two interventions to provide evidence based guidance for improving upper extremity function in spastic cerebral palsy children.

Methodology:

The ethical clearance was obtained from the Institutional Ethical Committee (SSPC/IEC/116/2024) prior to the study. Total of 30 spastic cerebral palsy children with age 4 to 8 years and both male and female was randomly allocated into two groups, Group A: 15 children (Hand Arm Bimanual Intensive Therapy + Conventional Physiotherapy Intervention) and Group B: 15 children (Action Observation Therapy + Conventional Physiotherapy Intervention). This was an experimental study in which the simple random sampling was used with the study duration of one year.

Inclusion criteria :

- Parents giving consent for their child to be part of study.
- Children diagnosed with spastic cerebral palsy
- Age between 4 to 8 years
- Both male and female

- Spasticity ranged between 1 and 1+ grades according to Modified Ashworth scale
- Able to follow commands
- Ability to achieve minimal or initiation of active hand movement (Manual Ability Classification System (MACS) Level 2 and more)
- Sufficient co-operation and cognitive understanding to participate (Mini Mental Examination for Children (MMC) score > 25)

Exclusion criteria :

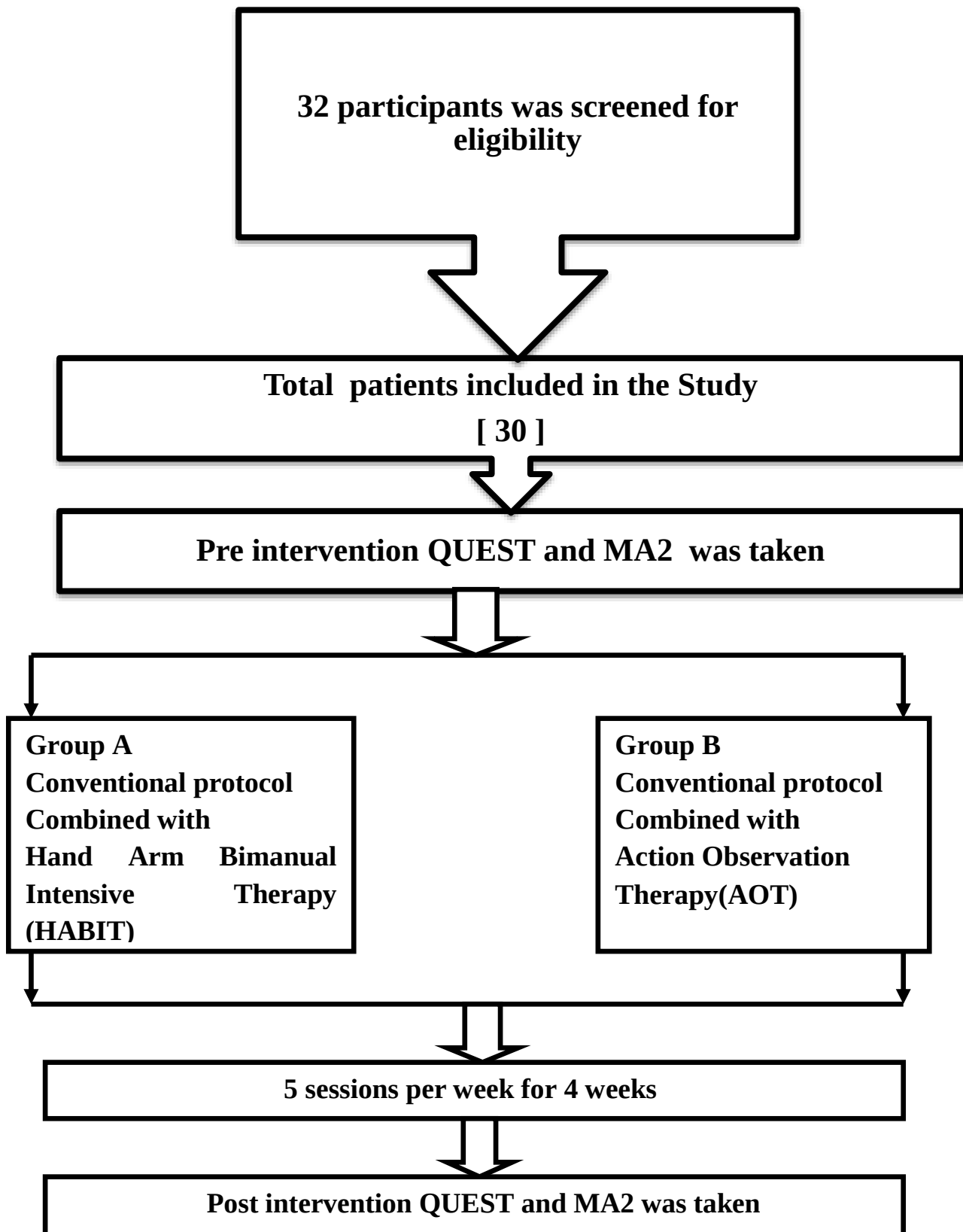
- Visual or auditory impairment
- Previous orthopedic surgery in the upper extremity
- Fixed upper extremity deformities
- Botulinum toxin injections in the upper extremity within 6 months prior to study entry.
- Suffering from other diseases that interfere with training .

Outcome Measures**Quality Of Upper Extremity Skills Test (QUEST):**

The QUEST (Quality of Upper Extremity Skills Test) was developed to specifically overcome the limitations of measures of hand function currently available. It is designed to be used with children who exhibit neuromotor dysfunction with spasticity and has been validated with children 18 months to 8 years of age. The QUEST manual contains psychometric and administration information. It is a 34-item criterion-referenced observation test, with higher scores indicating increased levels of achievement on harder items and the assumption that easier items can be credited as performed. There are four domains: dissociated movement, grasp, weight bearing, and protective extension. The domain score is a summed item score converted into a standardized percentage and the total score is the average of domain scores. QUEST is the highly reliable (ICC>0.90) and valid tool for assessing upper limb function in cerebral palsy.⁽⁶⁾⁽⁷⁾

Melbourne Assessment 2 (MA2):

The Melbourne Assessment 2 (MA2) is a standardized, criterion-referenced instrument for assessing quality of unilateral upper-limb movement in children of 2.5-15 years with neurological impairment.⁽²⁷⁾ Through 14 functional tasks - reaching, grasping, releasing and manipulating simple objects - the MA2 derives 30 scored items organized into four subscales: range of motion, accuracy of reach/placement, dexterity, and fluency. Scoring is based on video-recorded performance, yielding a separate score for each subscale. The MA2 has demonstrated excellent test-retest, inter-rater and intra-rater reliability (ICC ~ 0.92-0.98), as well as responsiveness to change after therapy interventions, making it a reliable and valid tool for clinical and research use to track upper-limb motor performance over time and identify targeted intervention areas.⁽⁸⁾



Conventional protocol

- Stretching of tight muscles of upper limb and lower limb
- Weight bearing activity of upper limb and lower limb
- Manual dexterity exercise
- Grasp – release activity
- Pack board activity
- Teaching of ADLs
- Functional task practice

Hand Arm Bimanual Intensive Therapy (HABIT) protocol

Activity	Description
Dough activities	Roll large ball of dough between the two palms or roll two equal size of dough by both hands at the same time on the table
Ball activities	Throwing or catching different sized balls (start with large ones)
Cubes activities	Transferring cube from non-affected to the affected hand and towering cubes. Started with 3 cubes till 6 cubes (first tower with the uninvolved limb and then with the involved)
Bottle and marble activities	Put marbles into bottle. First the affected hand stabilized the bottle and the child performed the task with the no affected hand. Task difficulty was increased by using the non-affected hand in putting marbles.
Stacking rings	Child held the rings starting with large one and stack with the non-affected hand and put rings on with the affected hand.
Stringing beads	Stabilize the rope first with the affected hand and the less affected hand stringing beads. Task difficulty was increased as the non-affected hand holds the rope and the affected hand performs the task. First large beads and thick cord were used progressing to small beads and thin cord.
Manipulation activities	Alternate banging and clapping movement Fastening clothing button and unbutton buttons, open and close zip. Twist the lid of jar Twist and press a lock and its key Cutting of paper by scissors





[1.Dough activities, 2.Ball activities, 3.Cubes activities, 4.Bottle and marble activities, 5.Stacking rings, 6.Stringing beads, 7.Manipulation activities]

Action Observation Therapy (AOT) protocol

The child is instructed to carefully observe the movement, focusing how the task was initiated, controlled and completed. After the observation, the children attempts to replicate the same movement, either independently or with facilitation as required.

- Grasping and moving an object in the horizontal plane
- Grasping and moving an object in the vertical plane
- Using a pencil
- Eating a candy
- Eating an ice-cream
- Manipulating a cube with both hands
- Playing with two small cars
- Reading a book
- Using an hourglass
- Opening and closing a jar
- Opening a house (game) with a key
- Drawing with a pencil, after sharpening it
- Playing with Lego
- Playing a piano with both hands



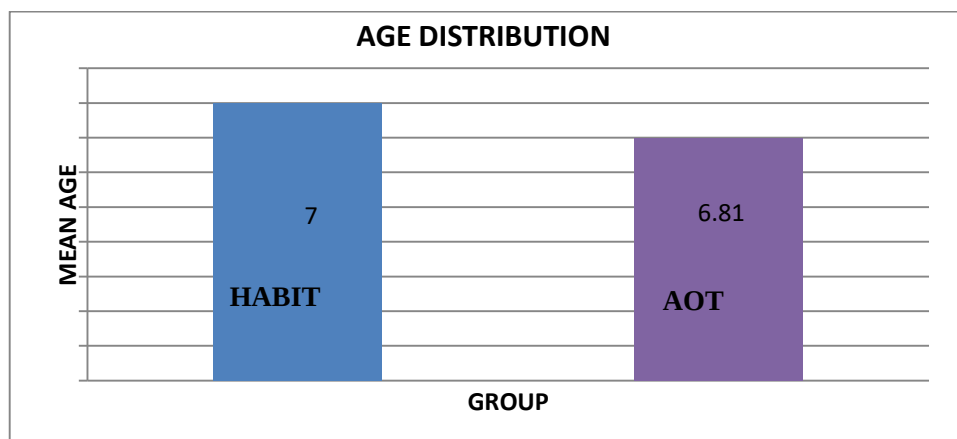


[1.Using a pencil, 2.Manipulating a cube with both hand, 3.Playing with two small car, 4.Reading a book, 5.Using an hourglass, 6.Opening and closing a jar,7. Playing with Lego, 8.Playing a piano with both hands]

Statistical Analysis:

Data of 30 children were analyzed using statistical package of social science version 16 (spss.16) and Microsoft excel 2007. Before applying statistical tests, data was screened for normal distribution using Shapiro-Wilk test. The Shapiro-Wilk test indicated that all outcome variables were normally distributed ($p > 0.05$); therefore, parametric tests were used for within and between group analysis.

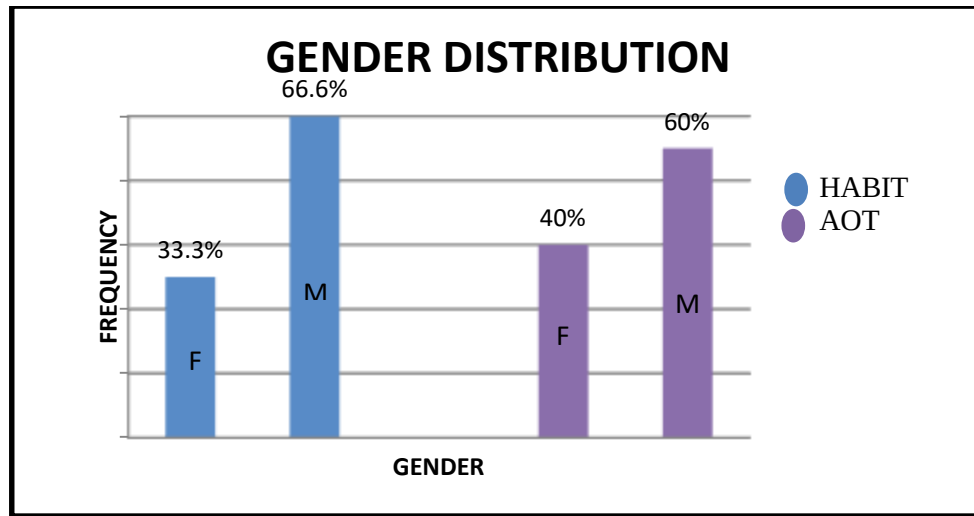
Group	No.	Mean	SD
HABIT	15	7	0.85
AOT	15	6.81	1.18



There were 15 participants in both the groups with the mean age of 7 in the HABIT group and 6.81 in the AOT group.

Group	Gender	Frequency	Percentage
HABIT	FEMALE	5	33.3
	MALE	10	66.6
AOT	FEMALE	6	40

	MALE	9	60
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There were 15 participants in both the groups, among that 5 female and 10 male in HABIT group and 6 female and 9 male in AOT group. There were 33.3% female and 66.6% male in HABIT group and 40% female and 60% male in AOT group.

MEAN AND SD OF PRE AND POST QUALITY OF UPPER EXTREMITY SKILL TEST IN WITHIN GROUP ANALYSIS IN HABIT GROUP:

Domains	Mean±SD (Pre)	Mean±SD (Post)	p-value	t-value
Dissociated movement	70.62±6.02	76.40±5.76	0.001	-9.807
Grasp	63.70±7.94	70.18±8.47	0.001	-8.959
Weight bearing	63.90±6.12	70.96±6.32	0.001	-14.940
Protective extension	66.56±5.67	73.05±6.39	0.001	-9.986

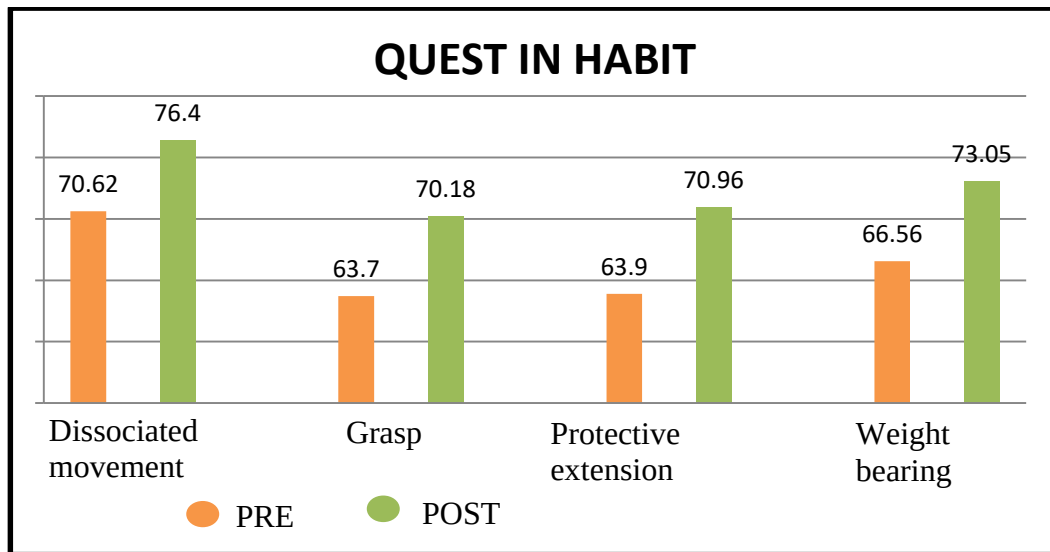


Table and Graph shows the statistically significant increase in upper extremity function in children of HABIT group as the p-value is 0.001. To analyze the difference in within group after 4 weeks of intervention paired t-test was applied. The mean value of the pre and post test for Dissociated movement is 70.62 and 76.40, Grasp is 63.70 and 70.18, Weight bearing is 63.90 and 70.96 and Protective extension is 66.56 and 73.05 in the QUEST for the HABIT group.

MEAN AND SD OF PRE AND POST MELBOURNE ASSESSMENT-2 IN WITHIN GROUP ANALYSIS IN HABIT GROUP:

Domains	Mean±SD (Pre)	Mean±SD (Post)	p-value	t-value
ROM	41.91±3.85	49.97±6.09	0.001	-8.804
Accuracy	40.60±5.44	47.62±5.38	0.001	-14.68
Dexterity	39.22±6.33	45.88±6.71	0.001	-11.45
Fluency	40.09±4.37	46.13±4.98	0.001	-24.76

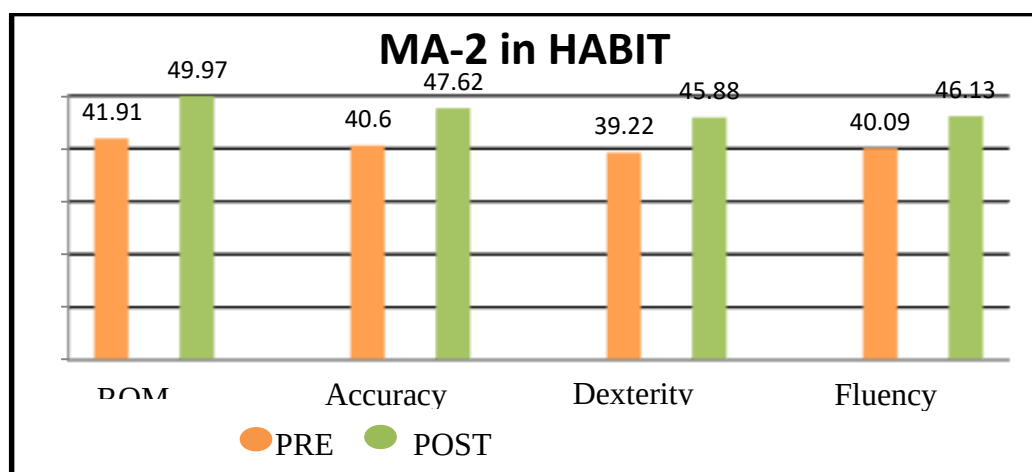


Table and Graph shows the statistically significant increase in upper extremity function in children of HABIT group as the p-value is 0.001. To analyze the difference in within group after 4 weeks of

intervention paired t-test was applied. The mean value of the pre and post test for ROM is 41.91 and 49.97, Accuracy is 40.60 and 47.62, Dexterity is 39.22 and 45.88 and Fluency is 40.09 and 46.13 in the MA-2 for the HABIT group.

The within group analysis after the 4 week for the HABIT group in both the outcomes, QUEST and MA-2 shows the significant improvement as the p value is <0.05.

MEAN AND SD OF PRE AND POST QUALITY OF UPPER EXTREMITY SKILL TEST IN WITHIN GROUP ANALYSIS IN AOT GROUP:

Domains	Mean±SD (Pre)	Mean±SD (Post)	p-value	t-value
Dissociated movement	69.19±5.32	73.85±5.15	0.001	-8.548
Grasp	65.83±6.11	70.17±6.43	0.001	-9.192
Weight bearing	60.34±7.20	66.24±7.72	0.001	-14.02
Protective extension	69.88±5.33	75.80±5.49	0.001	-23.29

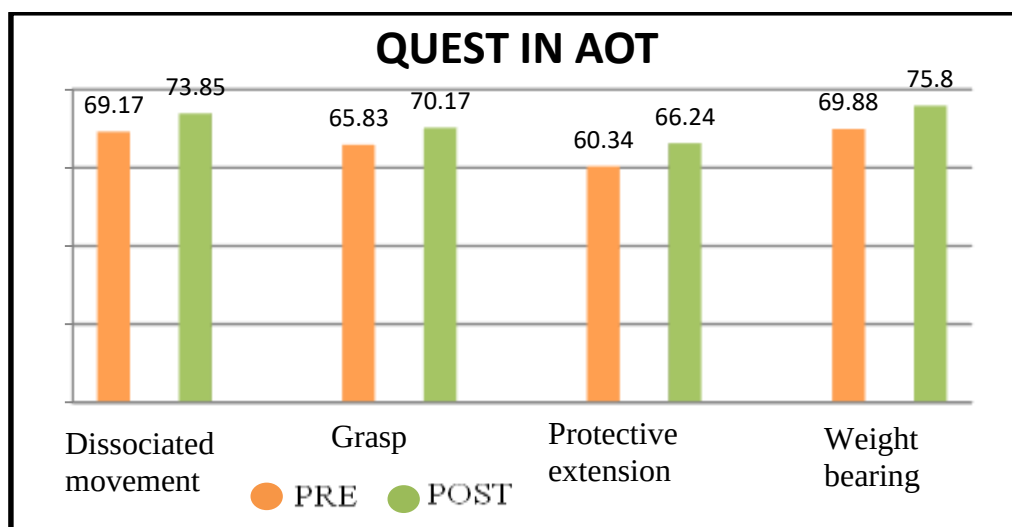


Table and Graph shows the statistically significant increase in upper extremity function in children of AOT group as the p-value is 0.001. To analyze the difference in within group after 4 weeks of intervention paired t-test was applied. The mean value of the pre and post test for Dissociated movement is 69.19 and 73.85, Grasp is 65.83 and 70.17, Weight bearing is 60.34 and 66.24 and Protective extension is 69.88 and 75.80 in the QUEST for the AOT group.

MEAN AND SD OF PRE AND POST MELBOURNE ASSESSMENT-2 IN WITHIN GROUP ANALYSIS IN AOT GROUP:

Domains	Mean±SD (Pre)	Mean±SD (Post)	p-value	t-value
ROM	43.00±4.70	49.96±4.47	0.001	-12.65
Accuracy	39.98±4.06	46.50±4.87	0.001	-13.66
Dexterity	33.51±5.35	39.82±6.27	0.001	-9.07
Fluency	38.77±6.40	44.36±6.11	0.001	-9.85

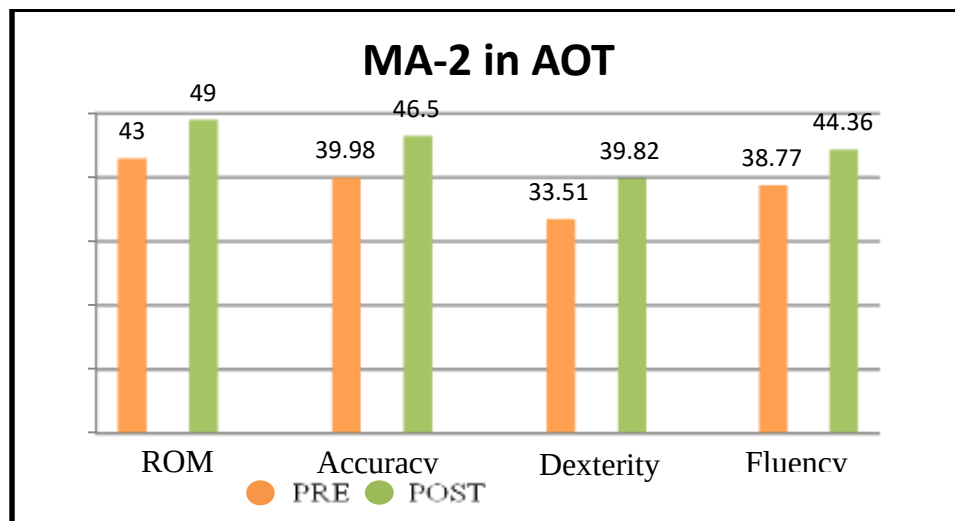


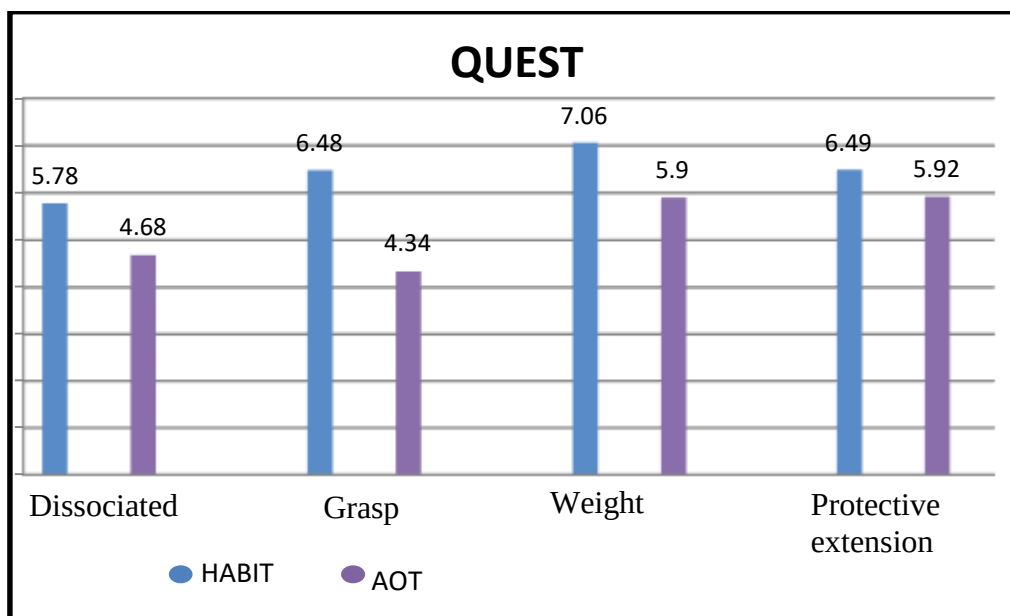
Table and Graph shows the statistically significant increase in upper extremity function in children of AOT group as the p-value is 0.001. To analyze the difference in within group after 4 weeks of intervention paired t-test was applied. The mean value of the pre and post test for ROM is 43.00 and 49.96, Accuracy is 39.98 and 46.50, Dexterity is 33.51 and 39.82 and Fluency is 38.77 and 44.36 in the MA-2 for the AOT group.

The within group analysis after the 4 week for the AOT group in both the outcomes, QUEST and MA-2 shows the significant improvement as the p value is <0.05.

MEAN AND SD OF THE QUALITY OF UPPER EXTREMITY SKILL TEST FOR BETWEEN GROUP:

Domains	HABIT (Mean±SD)	AOT (Mean±SD)	p-value	t-value
Dissociated movement	5.78± 2.28	4.78± 2.12	0.182	1.36
Grasp	6.48± 2.80	4.34± 1.82	0.020	2.47
Weight bearing	7.06± 1.83	5.90± 1.63	0.079	1.82

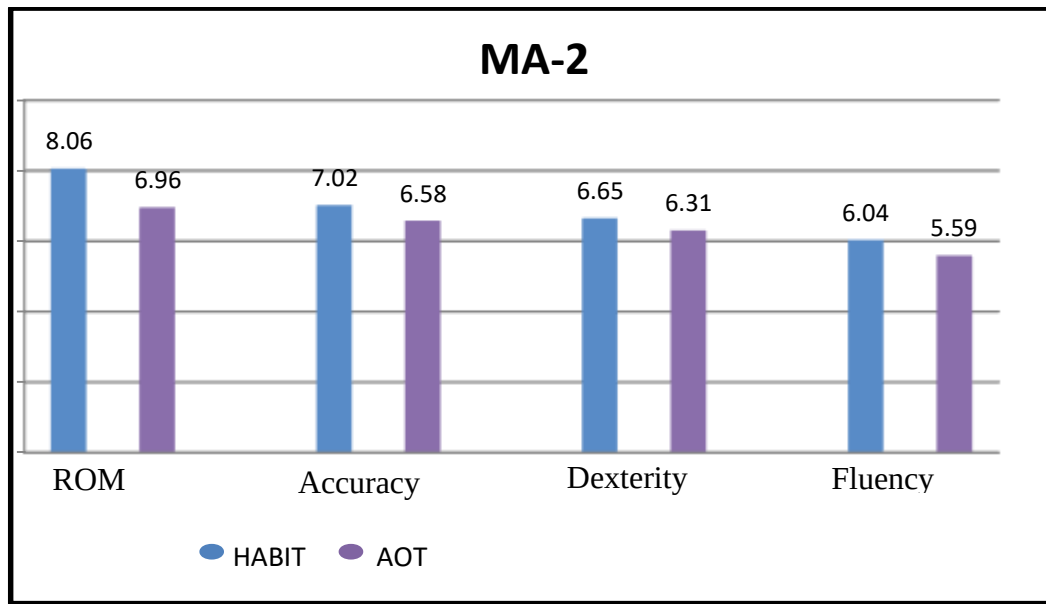
Protective extension	6.49± 2.51	5.92± 0.98	0.418	0.82
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To analyze the between group difference the independent t-test was applied. It shows that there is no statistically significant difference in Dissociated movement, Weight bearing and Protective extension for both the group as the p value is >0.05 however the grasp in the HABIT group showed significant statistically difference as the p value is <0.05 compared to AOT group.

MEAN AND SD OF THE MELBOURNE ASSESSMENT-2 FOR BETWEEN GROUP:

Domains	HABIT (Mean±SD)	AOT (Mean±SD)	p-value	t-value
ROM	8.06± 3.54	6.96± 2.12	0.312	1.03
Accuracy	7.02± 1.85	6.58± 1.86	0.522	0.64
Dexterity	6.65± 2.24	6.31± 2.69	0.710	0.37
Fluency	6.04± 0.94	5.59± 2.19	0.475	0.72



To analyze the between group difference the independent t-test was applied. It shows that there is no statistically significant difference in ROM, Accuracy, Dexterity and Fluency in between group analysis of both the group as the p value is >0.05 .

Discussion:

The present study suggests that Hand Arm Bimanual Intensive Training (HABIT) is effective to improve upper extremity function performance, coordination and enhancement of the affected hand in the functional daily activities. HABIT is based on the bimanual, task-specific and intensive practice which promote the motor recovery by the engaging the both hemisphere and reinforcing the functional motor patterns. HABIT emphasizes the simultaneous use of both upper extremities in meaningful task, thereby activating the bilateral cortical networks. The neurophysiological studies suggests that bimanual high repetition and task specific intervention enhances active problem solving and coordinated actions which decreases the difficulty in daily care activities. Previous studies have also reported that HABIT improves bimanual coordination, grasp-release ability and functional task performance compared to unimanual activity training.

The unimanual training approaches such as Constraint-induced Movement Therapy (CIMT), when compared with HABIT allows the use of affected limb to facilitate the movement of affected limb through bilateral coupling, where HABIT allows bilateral coupling, facilitatory movement of affected limb through coordinated use of both upper extremities.

The present study also suggests about the Action Observation Therapy (AOT) is the technique which improves the functional performance and activity participation in spastic cerebral palsy children. AOT intervention suggests that observation based motor learning which is grounded in the concept of mirror neuron system, which is activated both execution of an action and during observation of the same action performed by others. By repeatedly observing goal-directed and meaningful actions, children activates the neural networks involved in motor control, thereby it facilitate the motor performance during execution of complex task.

When comparing the both the interventions, HABIT appears to have greater impact on activity and participation level as it involves the real-life bimanual tasks. Conversely the AOT may serve as an

effective strategy that enhances the physical practice by improving neural readiness and movement anticipation.

Although, HABIT may be superior for improving functional independence, whereas AOT may be more effective in enhancing motor planning and movement quality.

This findings highlights the distinct but synergistic roles of HABIT and AOT in the neurorehabilitation of children with spastic cerebral palsy. While HABIT remains gold standard for driving functional independence through high-intensity, task-specific practice, AOT offers a unique neurological advantage by priming the motor cortex and movement anticipation.

The evidence suggests a tiered benefit, HABIT excels at achieving tangible participation-level outcomes in real-world environments, whereas AOT provides a foundational boost to motor planning and neural readiness.

Therefore, a multimodal approach that integrates the cognitive-motor priming of AOT with the intensive physical execution of HABIT may offer a more comprehensive therapeutic pathway, addressing both the quality of movement and the child's overall ability to perform daily activities.

Ultimately, the integration of these two modalities could bridge the gap between mental motor representation and physical functional execution, leading to superior clinical outcomes for children with cerebral palsy.

Conclusion:

This study clarifies the distinct roles that Hand Arm Bimanual Intensive Therapy (HABIT) and Action Observation Therapy in the rehabilitation of children with spastic cerebral palsy. While HABIT stands out as an essential method for increasing functional independence through high-intensity, real-world task practice, AOT provides a critical neurological advantage by preparing the motor cortex and child's ability to anticipate movement. Combining AOT with HABIT may therefore provide a comprehensive approach to optimize motor recovery in children with spastic cerebral palsy.

Clinical implication:

Since both interventions found equally effective in between group analysis, clinically either of any intervention can be used according to the child cooperation, cognitive level and clinical setting. Both interventions can be integrated into routine neuro-rehabilitation program, allowing flexibility in treatment planning without compromising functional outcomes. The findings support the use of task-specific, neuroplasticity based interventions to improve upper extremity function in children with spastic cerebral palsy. Therapists may consider a combined or sequential application of HABIT and AOT to maximize functional gains, especially in children with varying motor and cognitive abilities.

Limitations:

The study was limited by a relatively small sample size, which may affect the generalizability of the findings to the broader population of children with different types or severities of cerebral palsy.

The current data focuses on immediate or short-term improvements; however, the long-term retention of functional gains and neural adaptations remains to be fully established.

In AOT, the child plays a passive observer role, and the degree of engagement during this phase can vary significantly between participants, potentially impacting the consistency of results.

While HABIT focuses on real-life tasks, the transition of these skills into diverse home and school environments without therapist supervision was not exhaustively measured.

Future recommendations:

Further research can explore the effectiveness of these interventions across various age ranges and cerebral palsy classifications such as hemiplegic, diplegic, etc.

Adding measures such as EEG, fNIRS or neuroimaging could help understand cortical reorganization and motor learning mechanisms associated with these therapies.

Future research should include activity and participation level outcomes such as school tasks, ADLs, Quality of life in addition to impairment-based measures.

Studies may evaluate the feasibility and effectiveness of home based programs using video-based programs using video-based AOT, virtual reality or tele-rehabilitation models.

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