Effect of Hybrid Assistive Neuromuscular Dynamic Therapy and Constraint Induced Movement Therapy in the Upper Extremity Functions in Hemiparetic Patients

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Abstract

Purpose: - Stroke is a leading cause of long term disability in adults, often resulting in weakness or paralysis on one side of the body, known as hemiparesis. Upper limb hemiparesis significantly limits a person's ability to perform movements, affecting overall independence. Recovery of arm and hand function is typically slower. While various rehabilitation methods aim to improve motor function, many individuals continue to experience persistent difficulties due to limited movement control, spasticity and reduced sensory feedback. Innovative approaches are needed to enhance motor recovery and support functional independence in stroke survivors.

Materials and methods:- A total of 28 participants with post-stroke hemiparesis were randomly assigned into two groups: Group A (control group) received only Constraint Induced Movement Therapy, while Group B (experiment group) received both Hybrid Assistive Neuromuscular Dynamic Therapy and Constraint Induced Movement Therapy. Outcome measures included the Fugl-Meyer Hand Assessment, Action Research Arm Test (ARAT), and Stroke Rehabilitation Assessment of Movement (STREAM), evaluated at baseline (Day1), 2nd week, 4th week, 6th week.

Results: - Both groups showed significant improvements over six weeks ($p< 0.05$), but Group B had greater gains. Group A improved modesty across all the functions measures, while Group B showed larger increases in Fugl-Meyer, ARAT, and STREAM scores ($p<0.0001$). Between group analysis confirmed significantly better outcomes in Group B, supporting the effectiveness of constraint induced movement therapy combined with hybrid assistive neuromuscular dynamic therapy.

Conclusion: - The combination of Hybrid Assistive Neuromuscular Dynamic Therapy with Constraint Induced Movement Therapy is more effective than Constraint Induced Movement Therapy alone in improving upper extremity function in hemiparetic stroke patients. This dual approach reduces spasticity, enhances neuroplasticity and promotes greater task performance, suggesting that integrating assistive neuromuscular technologies into conventional therapy can significantly advance stroke rehabilitation outcomes.

Keywords: -Stroke Rehabilitation, Hemiparesis, Constraint Induced Movement Therapy, Hybrid Assistive Neuromuscular Dynamic Therapy, Upper extremity recovery, Neuroplasticity**.**

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Introduction

Stroke is one of the most important causes of long term neurological disability worldwide. It is defined as a sudden loss of brain function resulting from either an obstruction of blood flow (ischemic stroke) or bleeding into the brain tissue (haemorrhagic stroke). The outcome depends on the size and site of the lesion, but in most cases, survivors are left with impairments that reduce independence and quality of life. Among these, hemiparesis, or weakness affecting one side of the body, is the most frequent clinical presentation after stroke. It is a leading cause of disability-adjusted life years lost, particularly in low- and middle-income countries where access to acute stroke care and rehabilitation remains limited. Feigin et al. reported that nearly 12 million new cases occur globally each year, with approximately 6.5 million deaths and a high prevalence of survivors living with chronic disability [1]. The middle cerebral artery (MCA) is the most commonly affected vascular territory, and ischemic infraction in this region often leads to hemiparesis and impairments in motor control of the upper extremity.

Several modifiable and non-modifiable risk factors contribute to stroke occurrence. Age, gender, and genetics are non-modifiable contributes, while hypertension, diabetes, obesity, atrial fibrillation, smoking, alcohol consumption, and sedentary lifestyle are major modifiable risk factors (1, 2). The presence of multiple comorbidities further increases the likelihood of severe functional deficits post-stroke occurrence but also influence the severity on impairment and potential. Hemiparesis results in weakness of the arm, hand, leg, or combination, depending on the vascular territory affected. Upper limb hemiparesis is particularly disabling due to its impact on motor function and fine coordination. Patients typically present with muscle weakness, abnormal synergy patterns, and impaired coordination, sensory loss, and sometimes shoulder subluxation (2, 3). Importantly, recovery of the proximal arm (shoulder and elbow) is more achievable, whereas the distal joints (wrist and fingers) demonstrates slower and less predictable recovery (3).

Motor recovery after stroke depends heavily on the process of neuroplasticity. Neuroplasticity refers to the ability of the brain to reorganize its neural connections following injury (4). Stroke damages corticospinal pathways that control voluntary movements, particularly in the distal limb. Repeated practice and task-specific training stimulate alternate neural pathways to assume motor control (3, 4). However, many patients develop the learned non-use phenomenon, described by Taub et al., where the affected limb is unconsciously neglected, and reliance shifts entirely to the unaffected limb (6).

Another major issue is spasticity, a form of increased muscle tone caused by loss of inhibitory control from the damaged motor cortex (3). Spasticity interferes with voluntary control, causes abnormal postures, and leads to secondary complications such as contractures. Properly designed interventions are needed to reduce spasticity, encourage repetitive use of the weaker limb, and promote neuroplasticity for optimal recovery.

Rehabilitation of the upper limb after stroke typically involves a combination of physiotherapy, occupational therapy, neuro-facilitation techniques, strengthening exercises, and functional electrical stimulation (2, 7). Robotic devices and virtual reality-based therapies have also been introduced in the past two decades to supplement conventional therapy (7). Despite these advancements, recovery of upper limb function remains limited in many patients, especially at the level of the hand. Conventional therapy often does not provide sufficient repetitions or intensity to drive cortical reorganization (8).

CIMT is an evidence-based technique developed to overcome learned non-use (6). In this method, the unaffected arm is restrained, forcing the patient to perform tasks with the affected arm. Repetitive, task-specific practice encourages cortical reorganization, thereby improving voluntary motor control (9, 10). Studies have shown that CIMT can significantly improve arm function and increase the real-world use of the weaker limb (9). However, a limitation of CIMT is that it requires patients to have some voluntary control at baseline. Patients with very limited distal activity or severe weakness may not benefit as much, as they are unable to initiate or complete tasks independently (10).

Technological advancements have led to the development of robotic and assistive devices that support movement. HANDT is based on principles similar to the Hybrid Assistive Limb (HAL) system studied by Takebayashi et al. (11). It works by detecting small voluntary signals from the muscles and assisting the limb in completing the intended movement. This support allows patients with poor voluntary control to participate actively in therapy. Importantly, HANDT provides both movement assistance and sensory feedback, which are key to motor learning and cortical reorganization (11, 12).

Studies on robotic and assistive therapies have demonstrated improvements in muscle tone, range of motion, and functional use of the affected limb (7, 11). Feedback mechanisms built into such devices also increase motivation and engagement, factors known to influence rehabilitation outcomes (12, 13).

Although CIMT and HANDT have proven effective individually, there is little evidence on their combined use. CIMT promotes active use and neuroplastic changes by overcoming learned non-use, but it has limited benefit for severely weak patients (9, 10). HANDT assists patients with minimal voluntary control, enabling participation and repetition of tasks that would otherwise be impossible (11). By combining the two, patients can benefit from both approaches—CIMT ensures active engagement of the weaker limb, while HANDT supports and enhances movement when voluntary effort is insufficient.

Most prior studies have either evaluated CIMT or robotic-assisted therapy separately. Very few studies have investigated the synergistic effect of combining CIMT with HANDT on upper limb function in hemiparetic patients. Moreover, recovery of distal upper limb function, such as wrist and hand movements, remains under-researched despite being crucial for functional independence. This study aims to fill this gap by exploring whether combining these two therapies results in superior improvements compared to CIMT alone.

Materials and Methods

A total of twenty-eight individuals with hemiparesis following stroke were enrolled in the study and randomly assigned into two equal groups. Group A, serving as the control group, underwent Constraint Induced Movement Therapy (CIMT), whereas Group B, the experimental group, received CIMT in combination with Hybrid Assistive Neuromuscular Dynamic Therapy (HANDT). Participants were eligible if they experienced a first-ever ischemic stroke, were between 30 and 70 years of age, and demonstrated a minimum level of voluntary wrist and finger extension. Patients with significant cognitive impairment or spasticity exceeding grade 2 were excluded to ensure safe and effective participation.

The intervention for both groups was administered five days per week over a total period of six weeks. Functional outcomes were evaluated at four different time points: baseline (prior to the intervention), at the 2nd week, 4th week, and at the completion of the 6th week. Standardized assessment tools were used to capture motor recovery and functional improvements, including the Fugl-Meyer Hand Assessment, the Action Research Arm Test (ARAT), and the Stroke Rehabilitation Assessment of Movement (STREAM). This structured design was aimed at examining the comparative effectiveness of CIMT alone versus CIMT combined with HANDT in enhancing upper limb function in post-stroke patients.

Intervention

The intervention program was structured to support upper limb recovery in stroke patients with hemiparesis. Participants were divided into two groups for comparison. Group A (control group) received routine physiotherapy along with Constraint-Induced Movement Therapy (CIMT). In this approach, the stronger arm was restricted so that the weaker arm was forced to perform therapeutic tasks. Activities included reaching forward and sideways, grasping and releasing small objects, pegboard placement, and lifting light objects to stimulate voluntary movement. Group B (experimental group) followed the same plan, but with the addition of Hybrid Assistive Neuromuscular Dynamic Therapy (HANDT). The HANDT device provided assisted and repetitive movements that supported patients in practicing actions such as arm lifting, wrist extension, and finger opening and closing, even in those with limited control. Both groups received therapy for six weeks, with emphasis on repeated practice, task-based training, and feedback to enhance brain reorganization, decrease stiffness, and regain motor coordination. Effectiveness was assessed using the Fugl-Meyer Hand Assessment, Action Research Arm Test (ARAT), and Stroke Rehabilitation Assessment of Movement (STREAM).

Fig1- elevation and depression of scapula

Fig-2 Quadripod weight shifts

Fig 3- Protraction and Retraction of Scapula

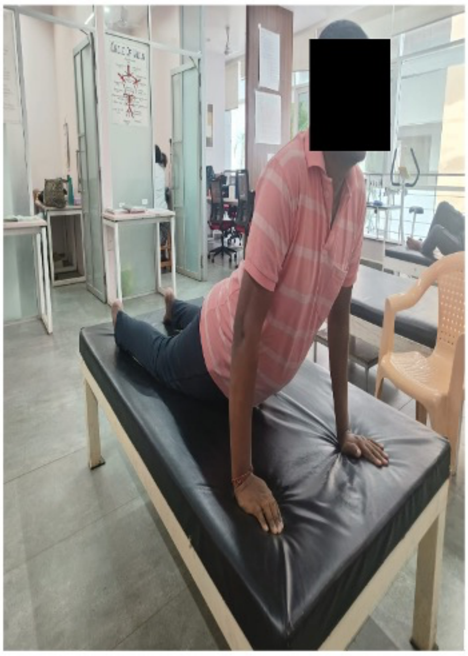


Fig 4- Prone on hands

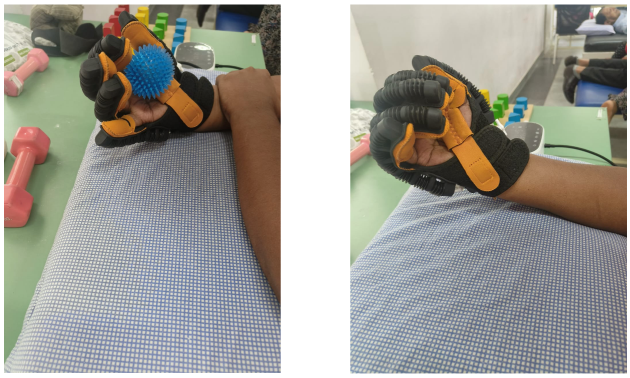
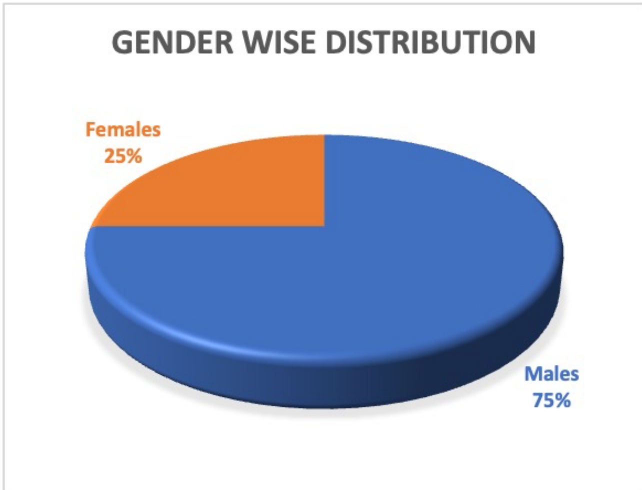


Fig 7-8:- HAND Therapy

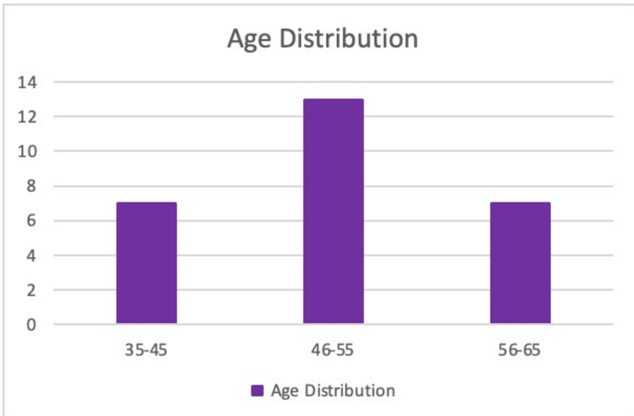
Results

Graph No. 1- Gender Distribution



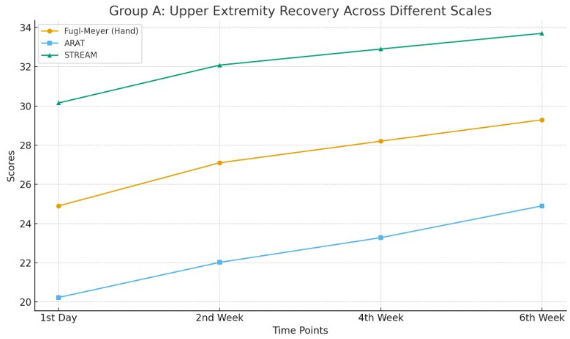
Interpretation: In the above table and graph shows that 75% are males and 25% are females of the total population participated in the study.

Graph No. 2- Age distribution



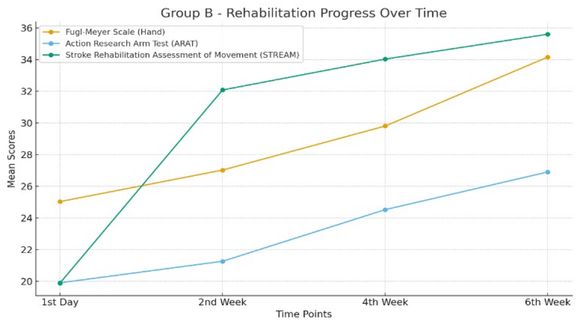
Interpretation: In the above table and graph shows that subjects in the age group between 35-45 years are 7, 46-55 years are 13, and 56-65 years are 8.

Graph No. 3: Rehabilitation Progress over Time for group A



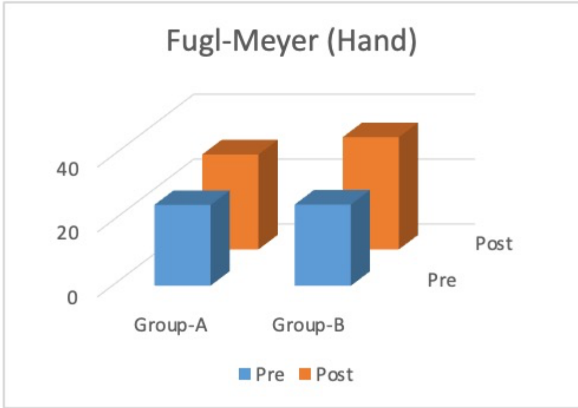
Interpretation: The combined table and graph show that Group A improved gradually across all three outcome measures (Fugl-Meyer, ARAT, and STREAM) from the 1st day to the 6th week. Although the improvements were statistically significant, the overall progress was moderate, suggesting that conventional therapy with CIMT helped enhance function but recovery remained limited compared to more advanced interventions.

Graph No.4: Rehabilitation Progress over Time for group B



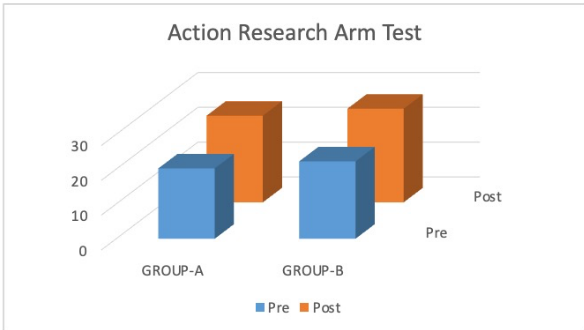
Interpretation: The merged graph clearly demonstrates that all three outcome measures (Fugl-Meyer Scale, Action Research Arm Test, and STREAM) showed progressive improvement from the 1st day to the 6th week in Group B. The Fugl-Meyer scale shows steady motor recovery in the hand. The ARAT scores indicate functional improvement in upper limb activities. The STREAM scores reveal substantial gains in overall movement and motor control, especially evident between the 1st day and 2nd week. The p-value (0.0001) across all tests indicates that these changes are statistically highly significant, confirming that Group B experienced both clinical and functional recovery over the intervention period.

Graph No.5- Fugl-Meyer (HAND) Scale between group A and group B



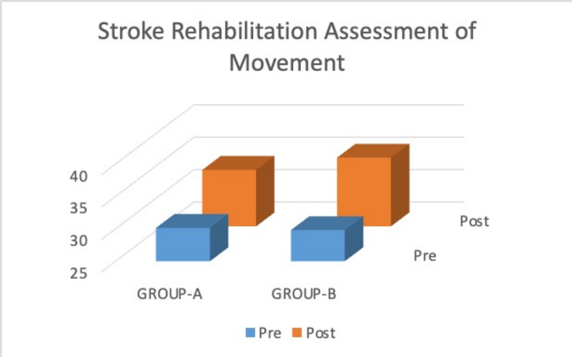
Interpretation: The above table interprets the results of Fugl-Meyer (Hand) scale between experimental group and control group. There was statistically significant difference in terms of p value among both the groups. However, clinically in terms of mean group B the experimental group shows more marked improvement post assessment than group A the control group.

Graph No.6- Action Research Arm Test between group A and group B



Interpretation: The above table interprets the results of Action Research Arm Test between experimental group and control group. There was statistically significant difference in terms of p value among both the groups. However, clinically in terms of mean group B the experimental group shows more marked improvement post assessment than group A the control group.

Graph No.7- Stroke Rehabilitation Assessment of Movement between group A and group B



Interpretation: The above table interprets the results of Fugl-Meyer (Hand) scale between experimental group and control group. There was statistically significant difference in terms of p value among both the groups. However, clinically in terms of mean group B the experimental group shows more marked improvement post assessment than group A the control group.

Discussion

Hemiparesis, meaning weakness on one side of the body, is among the most frequent complications of stroke. Upper limb is particularly disabling because fine motor control and coordination are required for functional recovery [1, 2]. Abnormal motor synergies, reduced strength, and spasticity further complicate rehabilitation. Therapy therefore focuses on neuroplasticity, spasticity management, and motor control restoration [3, 4].

This study compared two rehabilitation strategies: Constraint- Induced Movement Therapy (CIMT) with conventional care (Group A) and CIMT Combined with Hybrid Assistive Neuromuscular Dynamic Therapy (HANDT) (Group B). Both groups improved significantly across outcome measures, but the experimental group demonstrated superior functional recovery.

Neuroplasticity is central to recovery, as the brain reorganizes connections after injury [4, 5]. In Group A, CIMT facilitated cortical reorganization by limiting use of the unaffected arm, forcing the weaker arm into repeated practice [6]. Such forced-use principles have long been shown to reduce learned non-use and enhance recovery [14]. Yet, CIMT is less effective in patients with little voluntary activity.

Group B benefitted from HANDT, which supported incomplete movements by amplifying weak muscle activity. This allowed even severely impaired patients to engage in repetitive, task-oriented training. Importantly, sensory and visual feedback reinforced learning, accelerating cortical reorganization [11, 12]. Recent studies confirm that feedback-rich training increases activation in motor areas and improves outcomes beyond conventional exercise [15].

Spasticity, a common complication post-stroke, limits voluntary movement by increasing resistance in muscles [3]. Group A achieved some reduction through CIMT-driven activity, but improvement was restricted by voluntary control capacity. Group B, in contrast, showed greater reductions because HANDT guided smooth, biomechanically correct motions. Repeated low-resistance movements normalize tone and reduce abnormal reflexes [7]. Similar findings have been reported in robotic-assisted trials, where controlled repetition reduced hypertonia and improved joint flexibility [16].

Motor control—the regulation of movement timing, force, and coordination—is often impaired after stroke [8]. Group A improved gradually through forced practice, though gains were limited by baseline strength. Group B, supported by HANDT, exhibited greater improvements in regulating movement speed and direction. By minimizing compensatory strategies such as trunk leaning or shoulder elevation, HANDT ensured higher-quality practice, consistent with principles of motor learning [8, 17].

Our findings align with earlier work. Liao et al. (2012) found CIMT superior to bilateral training in improving arm use [9], while Wu et al. (2007) showed CIMT reduced compensatory trunk strategies [10].

Takebayashi et al. (2020) confirmed robotic-assisted therapy using HAL improved functional recovery by detecting and assisting weak voluntary movements [11]. Likewise, Subramanian and Levin (2011) emphasized that feedback-rich training enhances motor relearning [12].

Other studies support these conclusions. Kwakkel et al. (2008) highlighted that high-intensity, task-specific practice is critical for upper limb recovery [18]. Mehrholz et al. (2018) found robotic therapy significantly improved arm function compared with conventional methods [16]. Recent meta-analyses also confirm that combining conventional therapy with technology-based interventions accelerates motor gains [19].

Another important factor was patient motivation. Group B participants reported higher engagement, likely due to the novelty and feedback of the device. Maclean et al. (2002) stressed that motivation strongly influences rehabilitation adherence and outcomes [13]. Similarly, Ballester et al. (2016) demonstrated that reward-based feedback and interactive training improve long-term therapy participation [20].

Conclusion

While CIMT alone remains effective for addressing learned non-use, its benefits are limited in patients with severe weakness. HANDT complements CIMT by providing assistance, feedback, and smoother motor practice, leading to enhanced neuroplasticity, spasticity reduction, and motor control improvements. This study demonstrates that integrating advanced assistive technology with traditional rehabilitation provides a more effective pathway for upper limb recovery in hemiparetic patients.

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