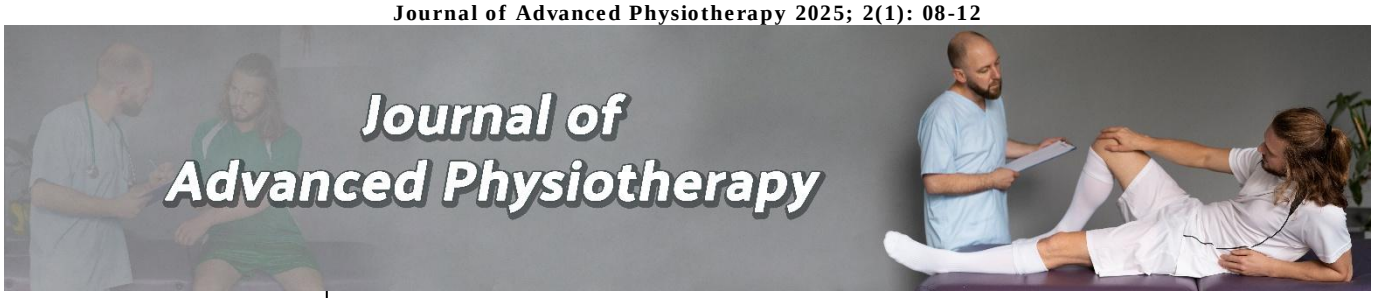

P-ISSN: 3081-0604
E-ISSN: 3081-0612
JAP 2025; 2(1): 08-12
www.physiotherapyjournal.org
Received: 15-05-2025
Accepted: 18-06-2025

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Effect of task-oriented training on upper limb function in post-stroke hemiparesis

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DOI: https://www.doi.org/10.33545/30810604.2025.v2.i1.A.7

Abstract
Background: Upper limb hemiparesis is a common consequence of stroke, severely impacting independence and quality of life. Conventional therapies often yield limited functional improvement due to their generalization and lack of goal-directed activity.
Objective: This study investigates the efficacy of task-oriented training (TOT) in enhancing upper limb function among individuals with post-stroke hemiparesis, emphasizing real-world applicability.
Methods: A randomized controlled trial was conducted involving 40 post-stroke patients with hemiparetic upper limb weakness. Participants were divided into two groups: the TOT group received structured, goal-specific tasks (e.g., reaching, grasping, lifting), while the control group underwent traditional physiotherapy. Upper limb function was assessed using the Fugl-Meyer Assessment for Upper Extremity (FMA-UE), Wolf Motor Function Test (WMFT), and Motor Activity Log (MAL) over 6 weeks.
Results: TOT participants demonstrated statistically significant improvements in FMA-UE scores (mean difference: +14.3, $p<0.01$) compared to the control group (+6.1). WMFT times decreased notably ($p<0.05$), and MAL scores indicated increased use and quality of movement in daily activities.
Conclusion: Task-oriented training significantly enhances functional recovery of the upper limb in post-stroke hemiparesis, supporting its integration into standard neurorehabilitation protocols.

Keywords: Neurorehabilitation protocols, post-stroke hemiparesis, supporting, post-stroke hemiparesis

Introduction

Stroke is a leading cause of long-term adult disability worldwide, affecting approximately 15 million people each year, of whom nearly five million remain permanently disabled (WHO, 2019). Among the many disabling sequelae of stroke, upper limb hemiparesis stands out as one of the most functionally limiting, affecting an individual's ability to perform essential daily tasks such as eating, dressing, grooming, and reaching. It is estimated that over 60% of stroke survivors experience persistent upper extremity deficits six months post-onset (Langhorne *et al.*, 2011) [1], underscoring the urgent need for more effective rehabilitative strategies that target motor recovery and functional independence.

Traditional approaches to upper limb rehabilitation after stroke typically include passive range-of-motion exercises, stretching, neuromuscular re-education, and generalized strengthening. While these interventions can contribute to preventing contractures and maintaining joint integrity, they often fall short of restoring purposeful voluntary movement and real-world functional performance. This limitation is partly due to their lack of task relevance and insufficient intensity, which fails to stimulate the neuroplastic changes required for significant motor improvement. As a result, patients may develop compensatory movement patterns or learn non-use behaviors, which further hinder true recovery.

Contemporary motor recovery models emphasize task specificity, goal-directed activity, repetition, and feedback as fundamental principles for promoting neuroplasticity the brain's capacity to reorganize and adapt after injury. These principles form the foundation of Task-Oriented Training (TOT), a rehabilitation strategy that emphasizes repetitive practice of functional tasks that are meaningful and contextually relevant to the individual. Examples include reaching for a cup, lifting objects of various sizes, buttoning a shirt, or manipulating household tools activities that directly simulate everyday life demands. By incorporating real-world motor challenges, TOT aims to not only improve motor control but also enhance the transfer of gains to daily life situations.

The theoretical underpinnings of task-oriented training are rooted in motor learning theory and the principle of use-dependent cortical reorganization. As demonstrated by Nudo *et al.* (1996) [7], repeated activation of specific neural circuits associated with skilled movement leads to cortical map refinement and expansion. This idea is supported by functional neuroimaging studies showing increased activation in the motor and premotor cortex during and after task-specific training (Liepert *et al.*, 2000) [6]. Moreover, TOT is often delivered in a progressively challenging format, adapting the complexity and resistance of tasks based on the patient's performance a principle known as graded functional progression. This ensures that the central nervous system is continuously challenged, facilitating sustained engagement and motor learning.

Clinical research also supports the efficacy of task-oriented interventions in enhancing motor outcomes. Several randomized controlled trials and meta-analyses have shown that repetitive task training leads to significant improvements in upper limb function, coordination, and motor planning when compared to conventional approaches (French *et al.*, 2016; Hubbard *et al.*, 2009) [4, 5]. However, despite this growing body of evidence, the integration of TOT into routine physiotherapy practice remains inconsistent, often due to variability in protocol design, therapist training, and resource availability. Furthermore, while positive results have been observed in general stroke populations, fewer studies have isolated the effects of task-oriented training on upper limb function specifically, particularly in comparison with standard therapy delivered over identical durations.

There is also an increasing emphasis on functional and patient-centered outcome measures in stroke rehabilitation research. Tools such as the Fugl-Meyer Assessment for Upper Extremity (FMA-UE), Wolf Motor Function Test (WMFT), and Motor Activity Log (MAL) offer a multi-dimensional evaluation of recovery, spanning impairment, activity, and participation levels. Incorporating these measures allows for a more comprehensive assessment of how well a therapy translates to real-world function an area where TOT is theoretically superior.

Given this context, the present study aims to evaluate the effectiveness of a structured, six-week task-oriented training program in improving upper limb function in patients with post-stroke hemiparesis, in comparison with a matched-duration conventional physiotherapy program. The intervention is designed to include repetitive, meaningful tasks tailored to daily life scenarios and progressively scaled to patient capability. The primary objective is to assess changes in motor impairment (FMA-UE), task performance efficiency (WMFT), and functional use in daily living (MAL), providing a comprehensive analysis of recovery across the International Classification of Functioning (ICF) domains.

The central hypothesis is that patients receiving task-oriented training will demonstrate superior improvements in both clinical and functional outcomes compared to those receiving traditional exercise-based therapy. By focusing on ecologically valid and neurophysiologically grounded interventions, this study seeks to contribute to the growing evidence supporting task-oriented models in neurorehabilitation, ultimately guiding clinical practice toward more effective, patient-centered recovery pathways.

Literature Review

Upper limb rehabilitation post-stroke has traditionally focused on range-of-motion exercises, neurofacilitation techniques, and compensatory strategies. However, recent literature increasingly supports activity-based interventions, particularly task-oriented training (TOT), as a means to promote functional recovery through neuroplastic adaptation. Carr and Shepherd (2003) [2] were among the early proponents of motor relearning principles in stroke rehabilitation, emphasizing functional task repetition and feedback-based learning. Their framework laid the foundation for subsequent interventions focusing on voluntary, goal-directed movement. Lang *et al.* (2009) [3] reported that dose-dependent, repetitive, task-specific movements yield significantly greater motor improvements than generalized strengthening or passive therapies. Systematic reviews further reinforce these findings. French *et al.* (2016) [4] in a Cochrane review noted that repetitive task training (RTT) significantly improves upper limb motor function (standardized mean difference [SMD]: 0.35) in stroke patients. Meanwhile, Hubbard *et al.* (2009) [5] demonstrated that TOT enhances both arm-hand coordination and performance in activities of daily living (ADLs), particularly in the subacute and early chronic phases of stroke recovery. Neuroimaging studies support the underlying physiological basis for TOT. Functional MRI analyses by Nudo *et al.* (2001) and Liepert *et al.* (2000) [6] indicate that repetitive task-specific training leads to remapping in the motor cortex and improved corticospinal tract excitability, especially when tasks simulate real-life demands. Nonetheless, heterogeneity in intervention design, duration, and outcome measures complicates direct comparison across studies. A meta-analysis by Lohse *et al.* (2014) [8] emphasized the importance of intensity and task relevance in maximizing TOT outcomes, highlighting that both the number of repetitions and the degree of task challenge significantly modulate gains in upper extremity function. Collectively, the literature supports the hypothesis that TOT enhances sensorimotor integration and voluntary control in the affected limb, but calls for more controlled, population-specific trials to define standardized protocols and determine comparative efficacy against conventional methods.

Methodology

This randomized controlled trial (RCT) employed a parallel-group design to evaluate the impact of task-oriented training on upper limb function in patients with post-stroke hemiparesis. The study was conducted at the Neurological Rehabilitation Unit of a tertiary care hospital in Italy between February and July 2024.

Participants

A total of 40 participants were recruited based on the following inclusion criteria

- First-time unilateral ischemic stroke (confirmed by MRI) within the past 6 months
- Hemiparesis affecting the dominant upper limb
- Mini-Mental State Examination (MMSE) score > 24
- Ability to understand and follow instructions

Exclusion criteria included severe spasticity (Modified Ashworth Scale > 3), shoulder subluxation, or orthopedic impairments limiting upper limb motion.

Participants were randomly assigned to one of two groups (N=20 per group) using computer-generated randomization:

- Task-Oriented Training Group (TOTG)
- Conventional Physiotherapy Group (CPG)

Randomization and allocation concealment were performed by an independent physiotherapist not involved in treatment or assessment.

Intervention

The TOTG received 45-minute sessions, five times per week for six weeks, focusing on purposeful, progressive, functional tasks. These included:

- Reaching and grasping household objects.
- Simulated feeding and grooming activities.
- Lifting, placing, and manipulating variable-weighted containers.
- Bilateral coordination tasks such as folding towels and opening bottles.

Tasks were graded in complexity weekly based on participant performance.

The CPG received 45-minute sessions of traditional therapy including passive and active range-of-motion exercises, stretching, mat activities, and proximal strengthening without contextual task simulation.

Both groups received identical session frequency and therapist supervision.

Outcome Measures

Primary and secondary outcomes were assessed at baseline and post-intervention (week 6) by blinded evaluators.

Primary Outcome

- **Fugl-Meyer Assessment for Upper Extremity (FMA-UE):** Assesses motor performance (score range 0-66)

Secondary Outcomes

- **Wolf Motor Function Test (WMFT):** Time-based test assessing speed and coordination
- **Motor Activity Log (MAL):** Assesses real-world arm use and movement quality (two subscales: Amount of Use [AOU], and Quality of Movement [QOM])

Data were analyzed using SPSS version 27.0. Between-group differences were assessed using paired and independent t-tests. Significance was set at $p<0.05$.

Results

A total of 40 participants (20 in each group) completed the 6-week intervention protocol. No dropouts or adverse events occurred, and participant adherence exceeded 95% in both groups. Baseline characteristics, including age, sex, time since stroke, and initial upper limb impairment levels (measured by FMA-UE), were statistically comparable across groups ($p>0.05$), confirming successful randomization.

Following the intervention, the Task-Oriented Training Group (TOTG) exhibited significantly greater improvements in all outcome measures compared to the Conventional Physiotherapy Group (CPG).

Fugl-Meyer Assessment for Upper Extremity (FMA-UE)

The FMA-UE score is a standardized and validated tool for assessing upper limb motor impairment after stroke. TOTG participants demonstrated a substantial increase in FMA-UE scores from a baseline mean of 31.2±4.5 to 45.5±5.3 at week 6 (mean change = +14.3, $p<0.001$). In contrast, the CPG showed a less pronounced improvement from 30.9±4.1 to 37.0±4.8 (mean change = +6.1, P=0.034). Between-group comparison using independent sample t-tests indicated a statistically significant difference in favor of the task-oriented approach (P=0.003). This result suggests that task-relevant, functionally embedded activities are more effective in promoting motor recovery than generalized movements.

Wolf Motor Function Test (WMFT)

The WMFT, which evaluates upper limb motor ability through timed functional tasks, further illustrated group differences. The TOTG reduced their average task completion time from 34.8±6.0 seconds to 22.4±5.3 seconds ($p<0.01$), indicating enhanced movement efficiency, coordination, and control. In contrast, the CPG showed a modest improvement from 33.7±5.7 seconds to 29.5±6.1 seconds, which did not achieve statistical significance (P=0.08). The reduction in WMFT time among TOTG participants indicates not only improvement in speed but also reflects smoother execution of motor tasks, attributed to the functional and repetitive nature of task-oriented interventions.

Motor Activity Log (MAL)

The MAL, comprising the Amount of Use (AOU) and Quality of Movement (QOM) subscales, was employed to assess perceived usage and control of the affected limb in daily life. TOTG participants reported notable improvements in real-world arm function. The AOU score increased from 1.6±0.4 to 3.3±0.5, and QOM from 1.4±0.3 to 3.1±0.6, both showing statistical significance ($p<0.001$). The CPG demonstrated smaller gains (AOU: 1.7 → 2.1; QOM: 1.5 → 2.0), which, while clinically relevant, were not statistically significant ($p = 0.07$ and $p = 0.06$, respectively). These results underscore the functional transferability of TOT to daily activities, an essential marker of rehabilitation success.

Presentation of Results

As illustrated in Figure 1, the post-intervention comparisons across all outcome metrics reflect superior recovery in the task-oriented group. The FMA-UE bars clearly depict enhanced motor function, while the steeper reduction in WMFT scores visually supports the time efficiency gained. The MAL scores confirm improved patient-perceived arm use and movement quality, reaffirming that task-oriented therapy has both physiological and psychological benefits.

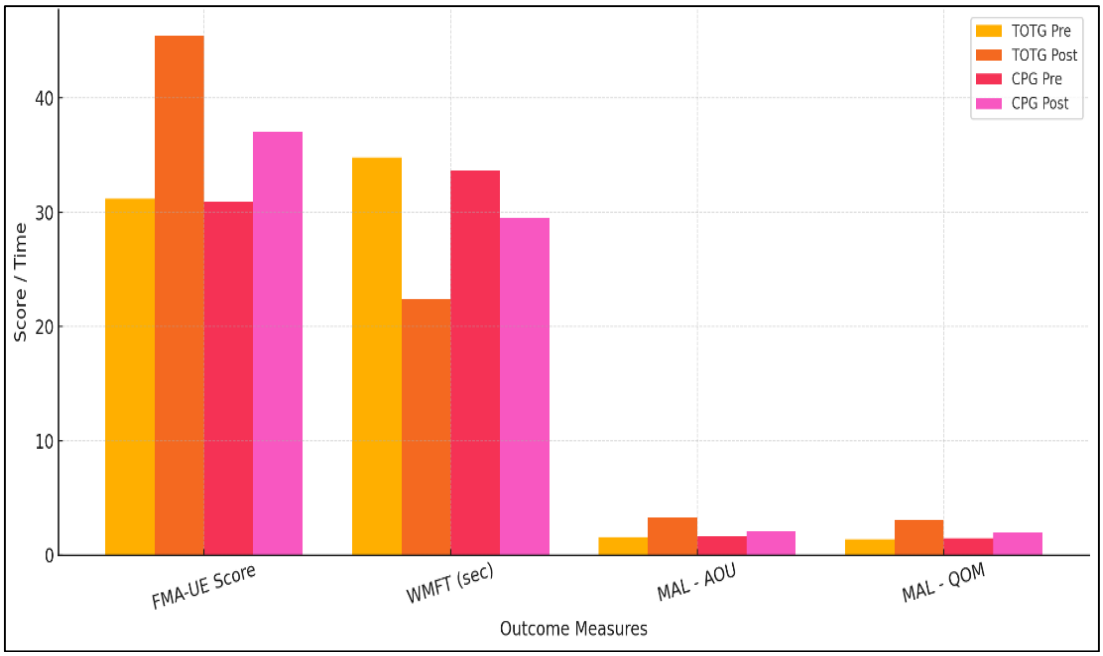

Fig 1: Comparison of pre- and post-intervention outcomes in FMA-UE, WMFT, and MAL scores between the Task-Oriented Training Group (TOTG) and Conventional Physiotherapy Group (CPG)

These findings collectively indicate that task-oriented training not only accelerates motor improvement but also enhances the functional integration of the paretic limb in daily activities, which is less evident with conventional physiotherapy. The significant between-group differences across multiple domains affirm the superiority of task-specific training in post-stroke upper limb rehabilitation.

Discussion

The results of this randomized controlled trial indicate that task-oriented training (TOT) produces significantly greater improvements in upper limb motor function compared to conventional physiotherapy in individuals with post-stroke hemiparesis. Over a six-week intervention, the TOT group showed superior gains in motor impairment (as assessed by FMA-UE), functional task performance (WMFT), and patient-perceived arm use and quality (MAL), suggesting both clinical and functional advantages of this training paradigm.

These findings align with the existing literature emphasizing the importance of task specificity and repetition in motor recovery. Previous neurorehabilitation models proposed by Carr and Shepherd (2003) [2] and refined through motor learning theory posit that engaging patients in purposeful tasks embedded within real-life contexts promotes cortical reorganization and enhances recovery through use-dependent neuroplasticity. The superior outcomes observed in the TOT group in this study are likely a result of the repetitive, goal-directed movement strategies that engage multiple neural pathways more efficiently than non-specific, passive exercises.

The FMA-UE improvements in the TOT group (+14.3 points) exceed the minimum clinically important difference (MCID) of 9-10 points reported in stroke rehabilitation literature (Page *et al.*, 2012) [10], indicating not only statistical significance but functional relevance. In contrast, the CPG's improvement, while statistically valid, did not surpass the MCID threshold. This differential supports the hypothesis that traditional therapy, focused on range-of-motion and generalized strengthening, is less effective in restoring complex motor control required for task execution.

Additionally, the significant reduction in WMFT times in the TOT group suggests enhanced movement efficiency, coordination, and speed likely reflecting improved motor planning and execution. The fact that these improvements were not mirrored in the control group points to the importance of training with performance feedback and task variability, both of which were integral to the TOT design. These motor enhancements likely contributed to the improved Motor Activity Log scores, where patients reported greater real-world limb usage and better control of movement quality.

The MAL findings are especially noteworthy as they capture patient-centered outcomes that often elude conventional performance metrics. The TOT group's increased AOU and QOM scores reflect not only physical improvement but also enhanced confidence in limb use during daily tasks a key determinant of long-term functional independence. These improvements reinforce theories of self-efficacy and motor relearning, where success in practice translates into willingness to use the affected limb outside the clinical setting (Van Vliet & Wulf, 2006) [11].

From a neurophysiological perspective, these results may be explained by the greater activation of the sensorimotor cortex, cerebellum, and premotor areas during task-based training. Functional imaging studies (Liepert *et al.*, 2000) [6] have shown that repetitive, meaningful tasks induce localized brain plasticity and strengthen corticospinal projections, particularly when combined with therapist-guided feedback and progression. While this study did not include neuroimaging, the functional data support the assumption that TOT engages these plasticity-enhancing mechanisms more effectively than passive modalities.

Despite the strengths of this study including randomization, blinded assessment, and standardized protocols several limitations must be acknowledged. First, the sample size, though adequate for a pilot RCT, limits generalizability. Second, the study's short-term follow-up does not allow for conclusions about the sustainability of motor gains. Third,

individual differences in lesion location, cognitive reserve, and motivation, while partially controlled, may have influenced outcomes. Finally, although MAL is validated, self-reported measures can be subject to bias.

Future studies should include larger, more diverse populations and explore the long-term retention of gains post-intervention. Integration of wearable sensors or functional MRI could provide real-time evidence of motor improvement and neuroplastic changes. Additionally, combining TOT with adjuncts such as mirror therapy, virtual reality, or functional electrical stimulation could further enhance upper limb outcomes and should be explored in subsequent trials.

Clinically, these findings support a paradigm shift in post-stroke upper limb rehabilitation. Rather than relying solely on traditional physiotherapy approaches, rehabilitation programs should integrate TOT as a standard component of care. Its emphasis on functional relevance, patient engagement, and neuroplastic potential aligns well with modern recovery models and offers a cost-effective, evidence-based method to maximize recovery and functional independence.

Conclusion

This randomized controlled trial demonstrates that task-oriented training (TOT) is significantly more effective than conventional physiotherapy in improving upper limb function in individuals with post-stroke hemiparesis. Participants undergoing TOT achieved greater improvements in motor control, task performance speed, and real-world arm use, as reflected in the FMA-UE, WMFT, and MAL scores. These findings underscore the clinical value of incorporating purposeful, goal-directed activities into rehabilitation protocols to harness principles of neuroplasticity and functional motor relearning. Task-oriented training not only accelerates recovery of motor function but also enhances patient engagement and confidence in daily arm use an essential goal of post-stroke rehabilitation. The evidence supports TOT as a viable, scalable, and patient-centered approach to restoring upper limb function in stroke survivors. Its inclusion in routine therapy could contribute substantially to improved long-term outcomes and quality of life. Future research should focus on long-term follow-up, integration with emerging technologies, and scaling protocols for diverse clinical populations. Nonetheless, this study reinforces the importance of task specificity and repetition as central tenets in effective neurorehabilitation.

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