Original Article

Effectiveness of Neuromuscular Physical Therapy with Cognitive-Motor Dual Task Training in Reducing Fall Risk in Older Adults with Mild Cognitive Impairment

Allied Medical Research Journal
Vol:3 No.1: 85-92

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ABSTRACT

Background: A study investigating the effectiveness of neuromuscular physical therapy combined with cognitive-motor dual-task training could provide valuable insights into optimizing fall prevention strategies. Such research would help establish evidence-based protocols that maximize functional outcomes and improve the quality of life for older adults at risk of falls.

Methods: A quasi-experimental study with pre- and post-intervention assessments was conducted to evaluate the effectiveness of combining neuromuscular physical therapy with cognitive-motor dual-task training in reducing the risk of falls among older adults with mild cognitive impairment (MCI).

Results: The effects of interventions were determined by comparing the average values of outcome measures taken at baseline and after 12 weeks of intervention and the findings provide significant improvement where the values of Tinetti Performance-Oriented Mobility Assessment at baseline were 22.63±3.27 that was significantly ($p<0.001$) improved to 27.21±3.11 after twelve weeks of intervention. In addition to that value of cognitive functioning as observed at baseline was 21.36±2.12 was also significantly ($p<0.001$) improved to 25.66±3.21 after intervention.

Conclusion: The 12-week intervention program combining neuromuscular physical therapy and cognitive-motor dual-task training significantly improved functional mobility, cognitive function, and dynamic balance in older adults with mild cognitive impairment. The results indicate that the intervention was effective in enhancing balance and reducing fall risk, as evidenced by the improvements in Tinetti Performance-Oriented Mobility Assessment (POMA), Montreal Cognitive Assessment (MoCA), and Timed Up and Go (TUG) test scores.

Keywords: Cognition, Elderly, Mobility, Postural Balance.

Received: August 15, 2024**; Revised:** November 5, 2024**; Accepted:** December 14, 2024
Corresponding Email: jitendar_valecha@yahoo.com
DOI: https://doi.org/10.59564/amrj/03.01/016

INTRODUCTION

The annual prevalence of falls among older adults is a significant public health concern, particularly for those with cognitive impairment[1]. Studies show that nearly 60% of older adults with cognitive impairment experience falls each year, a rate twice as high as that of cognitively healthy, community-dwelling older adults[2]. This heightened risk is further exacerbated by the fact that older adults with cognitive impairment are five times more likely to be institutionalized following a fall compared to their non-falling peers[3]. The consequences of falls in this population are also more severe, with a 2- to 3-fold increased risk of hip fractures, slower recovery rates, and higher

mortality[4]. Research indicates that older adults with dementia experience up to eight times greater incidence of falls compared to their cognitively healthy counterparts[5]. Cognitive impairment affects critical functions such as judgment, attention, and spatial awareness, making it harder for individuals to navigate their environment safely[5]. Additionally, physical and functional impairments, such as reduced balance, muscle weakness, and slower reaction times, are common in this population, further increasing fall risk[6]. Behavioral disturbances, such as impulsivity or agitation, and psychosocial factors like anxiety or depression, also contribute to this heightened vulnerability[7]. These factors, combined with age-related changes in vision, hearing, and mobility, create a complex interplay that predisposes older adults with cognitive impairment to falls and related injuries[7].

Despite the clear need for targeted interventions, fall prevention strategies for older adults with cognitive impairment remain underdeveloped. Most fall prevention trials have excluded individuals with cognitive impairment, resulting in a lack of evidence-based interventions tailored to this population[8]. As the global prevalence of dementia is expected to double by 2050, affecting over 152 million older adults, there is an urgent need for research and interventions that specifically address the unique challenges faced by older adults with cognitive impairment to reduce falls and their devastating consequences[9]. Neuromuscular physical therapy plays a crucial role in reducing the risk of falls among older adults, particularly those with cognitive impairment or neurological conditions such as stroke. This form of therapy focuses on improving motor function, balance, coordination, and strength through targeted exercises and repetitive motor training[10]. By leveraging principles of motor learning, such as adaptation and skill acquisition, neuromuscular physical therapy helps older adults regain functional movement patterns or develop compensatory strategies to perform daily activities safely. For older adults, this approach can improve gait stability, reduce postural sway, and enhance overall mobility, thereby lowering the likelihood of falls[11].

Dual-task training is a neurorehabilitation approach that involves performing two tasks simultaneously, such as a motor task combined with a cognitive task (motor-cognitive) or two motor tasks (motor-motor)[12]. This method challenges the brain to distribute attention between tasks, improving cognitive-motor integration and enhancing the ability to manage multiple demands at once. For older adults, particularly those with mild cognitive impairment (MCI), dual-task training can be highly effective in reducing the risk of falls[13-15]. The integration of dual-task training into fall prevention programs is particularly beneficial for older adults with MCI, as they often experience deficits in attention, executive function, and motor control[16]. By simultaneously engaging cognitive and motor systems, dual-task training promotes neuroplasticity and strengthens the neural pathways involved in multitasking. This can lead to improved coordination, faster reaction times, and better postural control, all of which are essential for reducing fall risk[17].

Despite the benefits of dual-task training, there is a need for further research to explore its effectiveness when combined with other interventions, such as neuromuscular physical therapy. Neuromuscular physical therapy focuses on improving strength, balance, and motor control, while dual-task training enhances cognitive-motor integration[18-19]. Combining these approaches could provide a synergistic effect, addressing both the physical and cognitive risk factors for falls in older adults with MCI. A study investigating the effectiveness of neuromuscular physical therapy combined with cognitive-motor dual-task training could provide valuable insights into optimizing fall prevention strategies. Such research would help establish evidence-based protocols that maximize functional outcomes and improve the quality of life for older adults at risk of falls.

METHODOLOGY

Study Design

A pilot randomized controlled trial was conducted to evaluate the effectiveness of combining neuromuscular physical therapy with cognitive-motor dual-task training in reducing the risk of falls among older adults with MCI.

Study Setting

The study was conducted in a community-based rehabilitation center equipped of Jamshoro, Sindh with resources for neuromuscular rehabilitation and dual-task training, including balance mats, treadmills, cognitive task materials, and safety equipment to prevent falls during training.

Sample Size

A sample size was calculated based on the findings of previous study titled as "The Effect of Dynamic Neuromuscular Stabilization Exercises on Balance and Fear of Falling in Female Elderly"20. The pre-post mean values of static balance from the experimental were taken that were 10.62±1.27 (pre) and 12.91±1.44 (post). By keeping the confidence interval of 95% and a bond of error of 5% a sample size of n=32 was calculated based on the following formula:

$$n = (Z\alpha/2+Z\beta)2 *2*\sigma2 / d2$$

Inclusion Criteria

- Adults aged 65 years and older.
- Diagnosed with MCI based on a Montreal Cognitive Assessment (MoCA) score of 18–25.
- Ability to walk independently or with minimal assistance (e.g., cane or walker).
- Willingness to participate in a 12-week intervention program.
- No severe visual or auditory impairments hindering participation.

Exclusion Criteria

- Severe cognitive impairment or dementia (MoCA score <18).
- History of severe neurological or musculoskeletal conditions (e.g., Parkinson's disease, severe arthritis).
- Recent history of falls with severe injuries (e.g., fractures) within the past 6 months.
- Inability to commit to the 6-day-per-week training schedule.

Intervention Protocol

The intervention lasted for 12 weeks, with participants engaging in training sessions 6 days per week. The program alternated between neuromuscular physical therapy and cognitive-motor dual-task training, with each type of training conducted on 3 separate days per week.

Neuromuscular Physical Therapy

Frequency: 3 days per week.

Intensity:

- *Strength training:* Moderate intensity (50-70% of 1RM for lower limb muscles).
- *Balance training:* Moderate, challenging but safe (able to maintain balance with minimal external support).
- *Gait training:* Moderate intensity (55-70% of maximum heart rate) with variable speeds and obstacles.

Time: 45–60 minutes including:

- Warm-up: 5–10 minutes (light aerobic activity and dynamic stretching).
- Main session: 30–40 minutes.
- Cool-down: 5–10 minutes (light stretching and breathing exercises).

Type:

Strength training:

- *Leg presses:* 3 sets of 10–12 repetitions to improve lower limb strength.
- *Step-ups:* 3 sets of 10 repetitions per leg.
- *Resistance band exercises:* 3 sets of 12 repetitions (leg curls, hip abduction/adduction).

Balance training:

- *Single-leg stands:* 3 sets of 30 seconds per leg to enhance stability.
- *Tandem walking:* 3 sets of 10 steps forward and backward.
- *Balance board exercises:* 3 sets of 60 seconds.

Gait training:

- *Treadmill walking:* 3 sets of 5 minutes at varying speeds (slow, moderate, and fast) with 1-minute rests to improve walking patterns.
- *Obstacle navigation:* 3 sets of 5 minutes, focusing on step-over and side-stepping movements.

Progression:

Gradually increase resistance and duration every 2 weeks based on patient tolerance and clinical assessment.

Cognitive-Motor Dual-Task Training

Frequency: 3 days per week.

Exercises:

- Walking while counting backward or naming objects to challenge attention and gait simultaneously.
- Stepping over obstacles while solving simple arithmetic problems to enhance coordination and cognitive processing.
- Carrying a tray with objects while responding to verbal cues to simulate real-world multitasking scenarios.

Duration: 45–60 minutes per session, with progressive increases in task complexity.

Outcome Measures

- **Tinetti Performance-Oriented Mobility Assessment (POMA)**
  Test Performance: The participant was observed while sitting, standing, turning, and walking a short distance. Balance and gait were assessed through posture, step length, trunk stability, and turning ability[21].
  Scoring: The maximum score was 28 (16 for balance, 12 for gait).
  - 25–28: Low fall risk.
  - 19–24: Moderate fall risk.
  - <19: High fall risk.

  Clinical Relevance: This test predicted fall risk, evaluated functional mobility, and helped design fall prevention strategies[21].

- **Montreal Cognitive Assessment (MoCA)**
  Test Performance: The participant completed tasks assessing memory, visuospatial ability, attention, language, abstraction, and orientation. The test took about 10 minutes to administer[22].
  Scoring: The total score was 30 points.
  - ≥26: Normal cognitive function.
  - 18-25: Mild cognitive impairment (MCI).
  - 10-17: Moderate cognitive impairment
  - <10 Severe Cognitive Impairment

  Clinical Relevance: This test detected early cognitive impairment and was particularly useful in conditions like Alzheimer's, Parkinson's disease, and vascular dementia[22].

- **Timed Up and Go (TUG) Test**
  Test Performance: The participant started seated in a chair, stood up, walked 3 meters, turned around, walked back, and sat down while being timed[23].
  Scoring:
  - <10 seconds: Normal mobility.
  - 10–20 seconds: Good mobility, independent in daily activities.
  - >20 seconds: Impaired mobility, increased fall risk.

  Clinical Relevance: This test assessed dynamic balance, functional mobility, and fall risk, commonly used for older adults or those with neurological or musculoskeletal conditions[23].

Data Analysis

Descriptive statistics, including mean and standard deviation, were calculated for demographic and baseline characteristics. Paired t-tests was applied to determine pre-post difference at a confidence interval CI of 95% a $p<0.05$ was considered statistically significant.

Ethical Considerations

Informed consent was obtained from all participants after providing detailed information about the study's purpose, procedures, risks, and benefits. Participant data were anonymized and stored securely, with access limited to the research team. Safety measures, including supervision by trained therapists and the use of assistive devices, were implemented to prevent falls or injuries during training sessions.

RESULTS

Demographic descriptions of the participants had revealed that the mean age of the participants was 68.53±2.36 years with n=18 (56.25%) male and 14 (43.75%) females. In addition to that cognitive variables were also assessed and the findings revealed that at baseline the value of cognitive functions as measured using a MoCA score was 21.36±2.12 (Table-1).

Table-1 Demographic Characteristics of Participants measured at baseline

Variables	Mean value at baseline	Standard Deviation
Age	68.53	2.36
Cognition (MoCA)	21.36	2.12
Gender wise distribution		
Gender	**Number**	**Percentage**
Male	18	56.25%

Female	14	43.75%

The effects of interventions were determined by comparing the average values of outcome measures taken at baseline and after 12 weeks of intervention and the findings provide significant improvement where the values of Tinetti Performance-Oriented Mobility Assessment at baseline were 22.63±3.27 that was significantly (p<0.001) improved to 27.21±3.11 after twelve weeks of intervention. In addition to that value of cognitive functioning as observed at baseline was 21.36±2.12 was also significantly (p<0.001) improved to 25.66±3.21 after intervention (Table-2).

Table#2 Paired T-Test to Determine Pre-Post Effect of Intervention on Functional Mobility and Cognitive Function

Variables	Mean±SD (Baseline)	Post±SD (Post)	t-test	t-crit	p-value
POMA	22.63±3.27	27.21±3.11	1.96	0.34	<0.001
MoCA	21.36±2.12	25.66±3.21	1.63		<0.001

Dynamic Balance of the participants were also estimated and the findings revealed that dynamic balance was significantly improved p<0.001 after 12 weeks of intervention where the values at baseline were 21.7±2.44 seconds that was reduced to 16.12±2.56 seconds (Table-3).

Table-3 Paired T-Test to Determine Pre-Post Effect of Intervention on Dynamic Balance

Variables	Mean±SD (Baseline)	Post±SD (Post)	t-test	t-crit	p-value
TUG	21.7±2.44	16.12±2.56	1.66	0.34	<0.001

The graphical representation illustrating the effects of 12 weeks of intervention on cognitive function, functional mobility and dynamic balance shown in Figure-1:

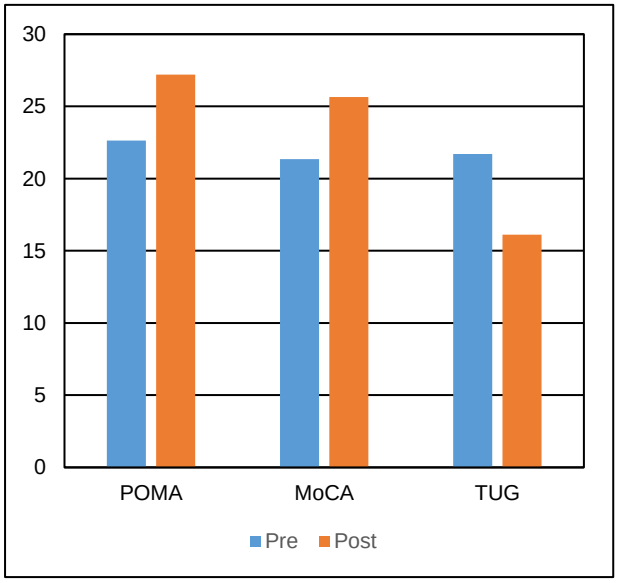

Fig-1. Effects of 12 weeks of intervention on cognitive function, functional mobility and dynamic balance

DISCUSSION

The findings of this study demonstrated significant improvements in cognitive function, functional mobility, and dynamic balance following a 12-week intervention combining neuromuscular physical therapy and cognitive-motor dual-task training. At baseline, participants exhibited mild cognitive impairment, with a mean MoCA score of 21.36±2.12, indicating the need for targeted cognitive stimulation alongside physical rehabilitation. After the intervention, this score significantly improved to 25.66±3.21 (p<0.001), reflecting enhanced cognitive processing and attention. Similarly, functional mobility, as measured by the POMA, showed a marked improvement from 22.63±3.27 to 27.21±3.11 (p<0.001), reducing participants' fall risk and supporting the efficacy of the neuromuscular training protocol. Additionally, dynamic balance, assessed using the TUG test, revealed a significant reduction in time from 21.7±2.44

seconds at baseline to 16.12±2.56 seconds post-intervention ($p<0.001$), indicating greater mobility and stability. These results suggest that integrating physical and cognitive exercises into rehabilitation programs for older adults can yield meaningful functional gains, thereby enhancing overall quality of life and reducing the likelihood of falls and cognitive decline. In another study, the effect of motor-cognitive dual-task training (mCdtt) and motor-motor dual-task training (mMdtt) on balance, fear of falling, walking functionality, and muscle strength in older adults was explored. Interestingly, the findings revealed that although the 8-week mCdtt and mMdtt programs did not significantly differ in their impact on these clinical outcomes, both training approaches effectively improved balance ability[24]. This aligns with the results of the present study, where a 12-week intervention combining neuromuscular physical therapy and cognitive-motor dual-task training led to significant improvements in functional mobility, cognitive performance, and dynamic balance[24]. Notably, while the other study observed no significant difference between the two forms of dual-task training, our findings suggest that integrating physical and cognitive exercises more comprehensively over a longer duration can yield greater functional gains[24]. This contrast highlights the potential advantage of a longer intervention period and suggests that sustained, progressive cognitive-motor engagement may be key to maximizing clinical outcomes in older adults. In a similar study, the effect of neuromuscular rehabilitation, specifically proprioceptive neuromuscular facilitation (PNF), was investigated for improving balance and muscle health among older adults with a high risk of falls[25]. Over six months, the intervention group receiving PNF training alongside standard care demonstrated significant improvements in balance function, as reflected in higher Berg Balance Scale scores, faster TUG test times, and increased 30-Second Chair Stand Test counts ($p<0.05$)[25]. Additionally, bone density showed a notable increase in the intervention group compared to the control group, though lower limb muscle mass differences were not substantial. These findings align with the results of the present study, where a 12-week neuromuscular physical therapy and cognitive-motor dual-task training program led to significant enhancements in functional mobility, dynamic balance, and cognitive performance[25]. Interestingly, while both studies confirmed improvements in balance and fall prevention, our study further highlighted the cognitive benefits of integrating motor and cognitive tasks, suggesting that a combined approach may offer broader functional gains. In a systematic review conducted to determine the effects of neuromuscular training on physical performance in older adults, significant improvements were observed across several key domains[26]. The review reported notable gains in postural balance, flexibility, cardiorespiratory fitness, and both upper and lower limb strength. Additionally, neuromuscular training was found to enhance functional autonomy, contributing to a reduced risk of falls and greater independence in daily activities[26].

These empirical findings underscore the effectiveness of neuromuscular interventions in promoting overall physical well-being among older adults, although the review emphasized the need for more high-quality studies for more generalizability in the findings[26]. A notable strength of this study is its well-structured, community-based rehabilitation setting, which provided a safe and controlled environment equipped with specialized resources for neuromuscular and dual-task training. The 12-week intervention, with a rigorous 6-day-per-week schedule, allowed for consistent engagement and progressive improvements, as evidenced by significant gains in functional mobility (POMA), cognitive function (MoCA), and dynamic balance (TUG). The inclusion of standardized outcome measures adds to the study's reliability and clinical relevance. However, a potential weakness is the relatively small sample size (n=32), which may limit the generalizability of the findings. Additionally, the exclusion of participants with severe cognitive or musculoskeletal impairments, while necessary for safety, may overlook the intervention's efficacy in more vulnerable populations. Future studies with larger, more diverse cohorts and a longer follow-up period could provide a clearer picture of the long-term benefits and sustainability of these interventions.

CONCLUSION

The 12-week intervention program combining neuromuscular physical therapy and cognitive-motor dual-task training significantly improved

functional mobility, cognitive function, and dynamic balance in older adults with mild cognitive impairment. The results indicate that the intervention was effective in enhancing balance and reducing fall risk, as evidenced by the improvements in POMA, MoCA, and TUG test scores. The substantial improvements in cognitive function and balance suggest that the dual-task training approach, combining physical and cognitive challenges, can be an effective strategy for improving overall quality of life and reducing fall risk in older adults. However, further research with larger sample sizes and long-term follow-up is recommended to confirm these findings and explore the sustainability of the benefits.

Acknowledgments
None.

Author Contributions
Mudassar Rooh ul Muazzam conceptualized and designed the research. **Munaish Kumar** and **Jai Vansi** were involved in data collection and participant recruitment. **Jeetandar** and **Ravi Kumar Katta** contributed to data analysis and interpretation. **Humaira Azhar** assisted in manuscript drafting and critical revisions. All authors reviewed and approved the final version of the manuscript.

Ethical Approval
This study received approval from the Institutional Ethical Review Committee (No. LUMHS/IEC/2025-163) Liaquat University of Medical and Health Sciences, Jamshoro, Sindh.

Grant Support and Funding Disclosure
None.

Conflict of Interests
None.

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