Enhancing Gait and Stability in Multiple Sclerosis Patients through Dual-Task Training

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ABSTRACT

Objective: Motor dysfunction-particularly balance and gait impairments-is a common limitation in patients with Multiple Sclerosis (MS), significantly reducing their quality of life. Dual-task (DT) training, which combines cognitive and motor challenges, has emerged as a promising rehabilitation strategy. This study aimed to evaluate the effects of DT training on improving motor function in MS patients.

Methods: In this randomized controlled trial, we examined the impact of an eight-week DT training program on balance and gait in female MS patients. Thirty participants (aged 30–72, including 10 elderly individuals) from the Tehran MS Association were voluntarily enrolled and assessed using the Berg Balance Scale (BBS) and Timed Up and Go (TUG) test before and after the intervention, with informed consent obtained. Participants were randomly assigned to either the control or experimental group. After an initial pre-test, the experimental group underwent DT training for eight weeks, consisting of two weekly sessions (45–60 minutes each). A post-test was then administered. Data were analyzed using paired and independent t-tests at a significance level of $p \leq 0.05$.

Results: MANOVA revealed that DT training led to significant improvements in motor function ($p=0.001$) in the experimental group compared to the control group. Notably, the experimental group demonstrated substantial enhancements in balance and gait ($p<0.001$), suggesting that DT training could be an effective intervention in MS rehabilitation.

Conclusion: The findings indicate that an eight-week DT training program incorporating cognitive-motor tasks can effectively enhance motor function in MS patients, supporting its integration into rehabilitation protocols.

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Introduction

Multiple Sclerosis (MS) is a chronic autoimmune neurodegenerative disorder affecting the central nervous system (CNS), characterized by demyelination of white matter in the brain and spinal cord [1]. As a subtype of demyelinating diseases, MS presents with multiple clinical and histological variations where the immune system mistakenly attacks the CNS, leading to chronic inflammation and neuronal degeneration [1]. This non-communicable, progressive condition manifests through various neurological symptoms that may emerge abruptly or gradually [2].

The disease primarily disrupts communication between the brain and other organs. A key determinant of disease progression is the frequency of relapses - acute clinical episodes typically occurring days to weeks after recovery periods and lasting at least 24 hours [3]. Relapse frequency is generally higher during initial disease stages and diminishes over time. The severity, duration, and recovery quality following relapses are closely associated with lesion locations within the CNS [3].

Motor impairments, particularly balance instability and gait disturbances, affect approximately 85% of MS patients [4]. Concurrent cognitive deficits in attention and executive functions further complicate motor performance during daily activities [5]. These attention and executive function impairments independently correlate with postural instability, disrupted daily functioning, and increased fall risk [6].

The dual-task paradigm, which combines motor and cognitive activities, provides valuable insights into functional impairments in MS. When performing simultaneous tasks (e.g., walking while counting), patients typically show performance degradation in one or both tasks compared to single-task conditions [7]. This phenomenon reflects cognitive-motor interference (CMI) and more accurately reveals functional limitations than single-task assessments [6].

Recent research has increasingly underscored the critical role of cognitive-motor interference (CMI) in individuals with Multiple Sclerosis (MS). For instance, Kalron et al. identified dual-task gait assessments as sensitive indicators of cognitive deterioration and heightened fall risk among MS patients [8]. Benedetti et al. further demonstrated that executive dysfunction is closely linked to deficits in motor planning and elevated dual-task costs, reflecting compromised functional integration [9]. Additionally, Zhou et al. emphasized the importance of attentional control in preserving postural stability under cognitive load, proposing that targeted cognitive training interventions may enhance motor performance and reduce fall susceptibility [10].

Two primary theoretical frameworks explain dual-task interference:

1. Central Resource Theory: Proposes that limited attentional resources must be allocated between concurrent tasks [11]. Kahneman's model suggests this attentional capacity can adapt based on task demands and individual circumstances [12].
2. Bottleneck Theory: Suggests that when tasks require overlapping neural pathways, sequential processing creates a bottleneck, slowing performance [13].

Neuroimaging studies have identified specific brain regions activated during dual-task performance, including the prefrontal cortex, anterior cingulate cortex, and inferior frontal gyrus [14]. Research across various populations (young adults, elderly individuals, and those with neurodegenerative disorders like Alzheimer's and Parkinson's disease) has demonstrated the utility of dual-task parameters for evaluating cognitive-gait interactions and fall risk [6].

McCarthy et al. investigated attention allocation in MS patients, finding significant deficits in divided attention compared to healthy controls [15]. Similarly, Esposito et al. demonstrated that MS patients perform worse on dual cognitive tasks versus single tasks [16]. Recent studies examining cognitive-motor interactions in neurological populations have shown that concurrent cognitive tasks adversely affect gait parameters [17]. These dual-task impairments not only impact daily functioning but may also explain the elevated fall risk in these populations, with implications for assessment and rehabilitation approaches.

Building on this evidence, our study aimed to develop a dual cognitive-motor task protocol for improving gait and balance in MS patients, addressing both motor and cognitive aspects of rehabilitation.

Materials and Methods

Subjects

Thirty women (30–72 years) with MS were recruited from the Tehran MS Association. Inclusion criteria: No prior exercise intervention; No assistive devices; No major visual/hearing impairments; No history of balance-affecting conditions and lack of dependence on wheelchair users. Exclusion criteria for participants included psychiatric medications, neurodegenerative disorders, traumas with a significant impact on cognitive function such as traumatic brain injury (previous surgery, patient's history of affecting balance or walking, symptoms of severe depression, and visual and hearing impairments).

Time Up and Go test

TUG is a simple gait control test that requires only one chair, stopwatch, and one meter to perform the test [18]. A tape is used to indicate a distance of three meters (10 feet) from the chair. In the beginning, the subject must be seated on a chair. Testing begins when the tester uses the word "go or start" and then the stopwatch. The subject moves from the raised chair to the designated distance of three meters, then turns and returns to the chair and finally sits again on the chair as soon as the subject sits on the stopwatch and the time is recorded. If a subject typically uses an auxiliary device such as a walker or a cane to walk, he should use it during the test. The person does not receive any further physical assistance during the test [19].

Berg Balance Scale

The leaf balance test, or BBS, is a clinical test for examining static and dynamic balance, especially neurologic patients [20]. The test is named after Catherine Berg, one of the developers of the test. This test is a standard gold test to check functional balance, which takes about 15 to 20 minutes. This clinical trial consists of 14 balance tests. The minimum score for each test is 0, and the maximum score is 4. The wheelchair will require a wheelchair if the patient's total score is less than or equal to 20. If the patient's total score is more than 20 and less than or equal to 40, the patient will need help walking. Patients with scores above 40 can be independent in walking [21].

Intervention Protocol

The research process was conducted in testing before and after the intervention and two months after the intervention. Tests included balance and walking tests. Initially, 43 patients with multiple sclerosis were identified, and finally, 30 women were selected for further research. All volunteers participated in the study voluntarily. Subjects underwent dual cognitive-motor task training. The intervention consisted of a 16-session period (8 weeks with two sessions per week) that lasted 45 to 60 minutes per session. This amount of training has been associated with optimal effectiveness in previous studies [22]. The training protocol consisted of 10 Functional Walking Assessment (FGA) exercises, including 1- Safe walking, 2- Change in walking speed, 3- Horizontal head rotation, 4- Vertical head rotation. 5- Walking and turning 180, 6- Walking obstacles, 7- Walking with minor support, 8- Walking blindfold, 9- Walking backward, 10- Walking the stairs. The ten items were merged with cognitive tasks (backward counting, multiplying and dividing numbers, counting months, counting coins) [4, 6, 15, 19]. After the intervention, subjects were re-evaluated by leaf and TUG tests.

Statistical analysis

First, the Shapiro-Wilk test was used to check the normality of the data, and the Levene’s Test was used to test the variance. Data analysis was conducted using both descriptive and inferential statistical methods. Descriptive statistics included the calculation of means and standard deviations for relevant variables. Inferential analyses were performed using SPSS version 25, incorporating paired-sample t-tests, independent-sample t-tests, and multivariate analysis of covariance (MANCOVA). Statistical significance was determined at a threshold of $p \leq 0.05$.

Results

Pre-Intervention Comparisons:

Shapiro-Wilk test results showed normal distribution of data (P≥0.05). Also, the results of Levene's Test showed that variances are homogeneous (P≥0.05). No significant differences were found between the experimental and control groups on pretest measures: BBS: p = 0.456 TUG: p = 0.556.

Post-Intervention Outcomes:

Independent t-tests revealed no significant between-group differences at baseline for balance (t(28) = 1.74, p = 0.456) or gait (t(28) = -0.601, p = 0.556). However, post-intervention comparisons showed significant improvements in the experimental group for both balance (t(28) = 5.5, p < 0.001) and gait (t(28) = -6.490, p < 0.001), with higher balance scores and lower (improved) gait times compared to controls (Figures 1 & 2).

Paired t-tests demonstrated significant within-group improvements for the experimental group:

Balance scores increased significantly from pre-test (36.26 ± 2.73) to post-test (32.13 ± 2.79; t(14) = -8.670, p < 0.001) .Gait times decreased significantly from pre-test (11.73 ± 0.88s) to post-test (15.26 ± 0.88s; t(14) = 21.384, p < 0.001)

No significant changes were observed in the control group for either balance (pre: 30.86 ± 3.11 vs post: 30.46 ± 2.41; t(14) = -0.921, p = 0.373) or gait (pre: 15.90 ± 2.13s vs post: 15.60 ± 1.95s; t(14) = 0.000, p = 1.000). After verifying assumptions (Box's M test: p = 0.111; Levene's test for homogeneity of variance), MANCOVA analysis confirmed significant between-group differences in the combined balance-gait measures (F(4,25) = 22.544, p < 0.001, η² = 0.485). Follow-up analyses revealed: Significant between-group differences in post-test balance scores (F(1,28) = 26.319, p < 0.001, η² = 0.601) and significant between-group differences in post-test gait performance (F(1,28) = 42.125, p < 0.001, η² = 0.601).

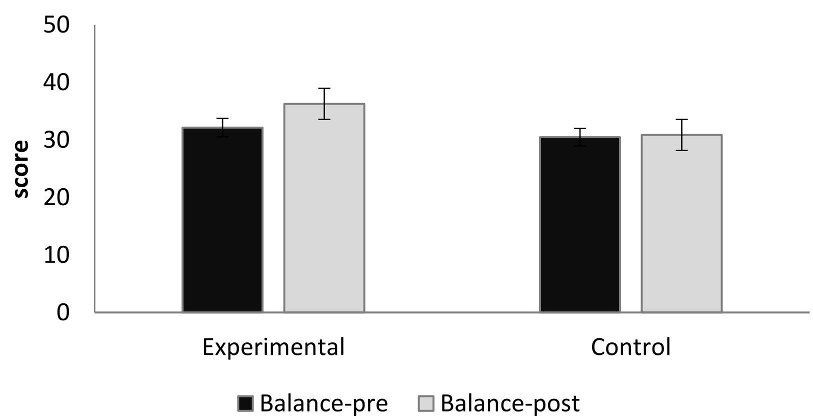

Figure 1. *Comparison of balance and gait scores between experimental and control groups before and after the intervention.*

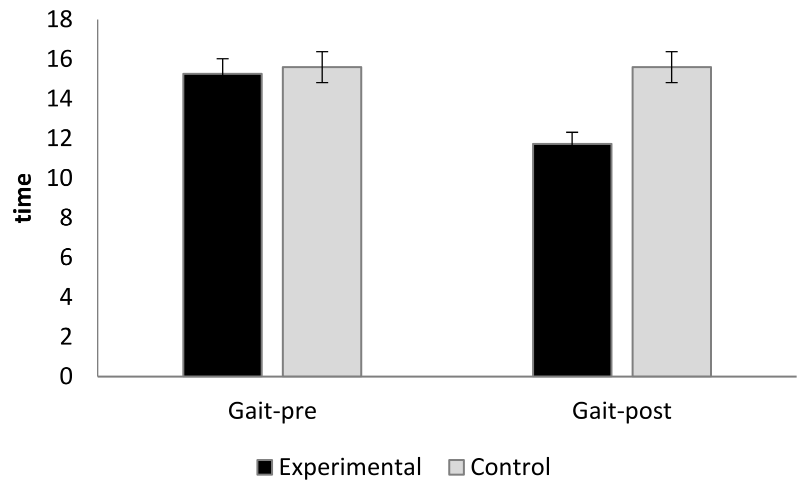

Figure 2. *Comparison of gait times between experimental and control groups before and after the intervention.*

Discussion

The purpose of this study was to evaluate the effect of dual cognitive-motor training intervention on motor function in M.S. patients. According to the research output on the effectiveness of dual-task training on motor performance, both the main effect of the test, the group, the interaction effect of the test, and the group were significant. The independent t-test also showed no significant difference between the mean of motor function error in the control and experimental groups in the pre-test, but there was a significant difference between the two groups. A correlated t-test for comparing the mean of motor performance error in the experimental group showed that post-test error in motor performance is lower than the mean of pre-test error. The findings showed that eight weeks of cognitive-motor dual-task training improved balance and walking speed in M.S. patients. Our findings are in line with [23, 24, 25, 19].

Megan et al. used three dual-task methods on three groups of people with multiple sclerosis. Research results have shown that dual-tasking with a backward seven-count dramatically affects people with multiple sclerosis [26]. Also, in the research of Castiel et al., the relationship of dual-task with quality of life and standing balance was investigated [27]. Their results indicated that cognitive-motor assignments were practical on patients' standing balance and quality of life. Sosnof et al., in a randomized controlled trial, examined the effectiveness of dual cognitive-motor and single motor task exercises on balance in M.S. patients [19]. The results showed that the dual-task group had a significant difference in balance with the single group [19]. The dual-task assignments of the present study were performed in different walking situations, as well as adding more complex cognitive components to the later steps.

On the other hand, the exercises were chosen to keep with the patients' motor abilities and followed the intensity of the difficulty level from the first to the last session. As a result, these exercises lead to more patients being involved in the exercise. This, in turn, improves muscle strength, which can increase postural control.

Balance is needed to perform all the movements throughout the day successfully. The most common methods for measuring equilibrium are descriptive and, therefore, are not suitable for examining the various components of equilibrium [28, 29]. The theory that researchers in studying equilibrium have recently used is system theory. According to this theory, maintaining and controlling the body's position in space results from a connection between the nervous, muscular, and skeletal systems. There have been numerous theories on dual-tasking, the results of which support Newman's theory of action-choice and confirm the effectiveness of dual-tasking in improving balance and walking. Based on the results of this study, it can be stated that dual cognitive-motor training can be a suitable method for the rehabilitation of M.S. patients [24]. According to the present study results, dual tasks that involve the cognitive system of patients can play a significant role in the postural control of patients. Structured progression and engagement across sessions improved adherence and minimized dropout. Dual task rehabilitation is not only feasible but may outperform traditional single-task interventions [22]. Limitations include small sample size and lack of long-term follow-up. Future studies may investigate sustained effects and compare different dual task modalities (e.g., motor-motor vs. cognitive-motor tasks).

Conclusion

This study provides valuable insights into the interplay between cognition and motor function in multiple sclerosis (MS) patients, demonstrating that cognitive-motor dual-task training not only enhances balance and walking speed but also highlights the significant benefits of integrating cognitive and motor challenges due to their interconnected nature. Future research should further explore the extent of memory improvement, compare the effectiveness of dual-task (e.g., cognitive-motor or motor-motor) versus single-task training on motor and memory performance, and investigate the underlying pathophysiology and clinical applications of these exercises. Importantly, the findings support the use of dual-task training in MS rehabilitation, as it improves functional mobility, balance, and independence while reducing fall risk, emphasizing its potential for personalized therapeutic strategies.

Author Contributions

Conceptualization, A. A, M.Sh. and E. AA; methodology, A. A, M. Sh and E.AA.; Data analysis, A.A. and M. Sh; data curation, A.A.; writing—original

draft preparation, A.A.; writing—review and editing, M.Sh.; project administration, M.SH.; All authors have read and agreed to the published version of the manuscript."

Data Availability Statement

Not applicable.

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Ethical considerations

All steps in the study of human participants are comparable to the ethical standards of the Institutional and National Research Committee and its subsequent amendments or ethical standards. This study has been approved by the National Ethics Committee of Biomedical Research, University of Tehran (IR.UT.SPORT.REC.1398.049).

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Conflict of interest

The authors declare no conflict of interest.

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