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Effectiveness of Executive Function-Based Cognitive Rehabilitation on Brain Fog, Working Memory, and Problem-Solving in Patients with Breast Cancer: A Pilot Randomized Controlled Trial

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ABSTRACT

Background: Cognitive difficulties associated with cancer are among the most frequent and enduring effects of breast cancer and its treatment. This pilot study evaluated the effectiveness of an executive function-based cognitive rehabilitation on brain fog, working memory, and problem-solving performance in women with breast cancer undergoing chemotherapy.

Methods: A randomized controlled pilot study with a pretest-posttest design was conducted among 14 women with breast cancer who were randomly assigned to an intervention group (n = 7) or a control group (n = 7). Baseline cognitive functioning was assessed using the Neuropsychiatry Unit Cognitive Assessment Tool (NUCOG). Outcome measures included the Working Memory subtests of the Wechsler Memory Scale-III, the N-Back Task, the Tower of London Task, and the Brain Fog Scale. The intervention consisted of 15 individual sessions of executive function-based cognitive rehabilitation incorporating executive strategy training, compensatory techniques, and guided application of cognitive skills to everyday activities. Data were analyzed using univariate analyses of covariance (ANCOVAs).

Results: Compared with the control group, participants receiving the intervention showed significant improvements in working memory and problem-solving performance, together with significant reductions in brain fog (all $P < .05$). No significant between-group difference was observed in N-Back response time.

Conclusion: Executive function-based cognitive rehabilitation was associated with improvements across multiple dimensions of cancer-related cognitive impairment. These preliminary findings support further evaluation of this multidimensional intervention in larger studies of patients with breast cancer.

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INTRODUCTION

Breast cancer is still the most frequently diagnosed cancer in women globally, accounting for an estimated 2.4 million new diagnoses and 693 660 deaths each year.[1] As survival rates continue to improve, the focus of cancer care has shifted beyond survival toward optimizing patients' quality of life and functional well-being.[2] Despite these advances, a cancer diagnosis and its treatment remain highly stressful experiences that are frequently accompanied by considerable psychological distress.[3]

Psychological distress, together with treatment-related adverse effects, may increase cognitive vulnerability and contribute to cancer-related cognitive impairment (CRCI).[4,5,6] CRCI commonly involves difficulties in memory, information processing speed, attention, and executive functioning.[7] Unlike many treatment-related adverse effects, these cognitive deficits may persist for years after treatment completion.[8] In patients with breast cancer, particularly those exposed to chemotherapy, cognitive difficulties may affect working memory, problem-solving, and everyday functioning.[9,10]

Among the cognitive domains affected by CRCI, working memory and executive functions are consistently identified as 2 of the most vulnerable domains.[11,12] Chemotherapy has been associated with reduced working memory capacity and slower information processing, limiting patients' ability to temporarily maintain and manipulate information required for everyday cognitive activities.[13,14] Because

working memory provides the cognitive resources necessary for executive processes, impairments in this domain frequently compromise higher-order functions such as planning, decision-making, and problem-solving.[9,10,14] Impairments in these domains may therefore contribute to everyday cognitive difficulties commonly described by patients as "chemo brain" or "brain fog," including forgetfulness, mental slowing, reduced concentration, and difficulties managing routine tasks.[15,16]

Brain fog is a complex and clinically relevant cognitive complaint characterized by mental cloudiness, forgetfulness, slowed thinking, mental fatigue, and difficulties with attention and concentration.[17] In patients with cancer, particularly during and after chemotherapy, disruptions in executive functioning and fatigue may contribute to the persistence of these complaints.[18] Given their potential persistence and negative impact on quality of life, cognitive rehabilitation (CR) and cognitive training have been proposed as promising nonpharmacological approaches for addressing cognitive difficulties in patients with cancer.[16,19]

Growing evidence supports the use of CR interventions to improve cognitive functioning in patients with cancer. Interventions incorporating structured cognitive training and compensatory strategies have demonstrated beneficial effects on working memory, attention, processing speed, and executive functioning.[20,21,22,23] However, findings across studies have not been consistent, with some trials reporting improvements in objective cognitive performance, whereas others have found benefits primarily in subjective cognitive functioning or no significant between-group differences.[22,23] This variability may reflect differences in intervention content, targeted cognitive domains, outcome measures, and the extent to which cognitive strategies are practiced in everyday contexts.

Executive functions represent a potentially important target within CR because they coordinate multiple higher-order cognitive processes, including planning, monitoring, cognitive flexibility, and problem-solving.[24] Accordingly, interventions that combine executive-function training with compensatory strategies may have the potential to produce broader and more transferable cognitive benefits than approaches focused primarily on isolated cognitive skills. Nevertheless, evidence regarding executive function-based CR in women with breast cancer remains limited. In particular, few studies have examined an intervention specifically targeting executive functions while simultaneously evaluating conceptually related outcomes such as brain fog, working memory, and problem-solving.

Therefore, this pilot randomized controlled trial aimed to evaluate the preliminary effectiveness of an executive function-based CR on brain fog, working memory, and problem-solving in women with breast cancer. The intervention integrated structured cognitive training with executive strategy instruction, compensatory techniques, problem-solving practice, and application of these strategies to everyday situations. Given the pilot nature of the study, the findings were intended to provide preliminary evidence regarding the potential benefits of this approach and to inform the design of future, larger randomized controlled trials.

METHODS

Study design

This pilot randomized controlled trial employed a parallel-group, pretest–posttest design with a 1:1 allocation ratio to evaluate the preliminary effectiveness of executive function-based CR on brain fog, working memory, and problem-solving in patients with breast cancer. The study was conducted at oncology clinics and hospitals in Rafsanjan, Kerman Province, Iran, between September 2022 and February 2023. No changes were made to the trial protocol after commencement.

Participants

Eligible women attending the oncology clinics and hospitals in Rafsanjan, Kerman Province, Iran, were approached consecutively for recruitment. Breast cancer diagnosis was confirmed by a board-certified oncologist based on histopathological findings and review of participants' medical records. All participants were undergoing active chemotherapy at the time of enrollment and continued to receive their scheduled chemotherapy cycles as part of routine oncological care throughout the study period.

Eligibility was determined through a clinical screening interview. Inclusion criteria were: (a) women aged 20 to 50 years; (b) histopathologically confirmed breast cancer; (c) absence of major comorbid medical conditions other than breast cancer; (d) absence of neurological disorders or previous brain injury; (e) absence of any current major psychiatric disorder requiring clinical treatment and no current use of psychotropic medications; (f) no previous participation in structured CR or cognitive training programs; (g) presence of at least 8 of the 19 symptoms assessed by the Brain Fog Scale; and (h) provision of written informed consent.

A total of 14 eligible participants were enrolled and randomly assigned to the executive function-based CR group (n = 7) or the waitlist control group (n = 7). The mean age was 43.43 years (SD = 3.25) in the intervention group and 43.42 years (SD = 2.87) in the control group.

Measures

All outcome measures were administered at pretest (approximately 1 week before the intervention commenced) and posttest (within 1 week after completion of the intervention), except for the Neuropsychiatry Unit Cognitive Assessment Tool (NUCOG), which was administered only at baseline as a cognitive screening measure. Neuropsychological assessments were administered by trained research assistants who were blinded to group allocation.

Neuropsychiatry Unit Cognitive Assessment Tool

(NUCOG): Developed by Walterfang *et al.*, the NUCOG was administered at baseline to assess global cognitive functioning and to screen participants before study enrollment. The instrument consists of 21 items assessing 5 cognitive domains, including attention, visuospatial function, memory, executive function, and language. Walterfang *et al.* reported a validity coefficient of 0.91, a reliability coefficient of 0.96, and interrater reliability of 0.91.[25] In the Persian validation study, internal consistency was satisfactory (Cronbach α = 0.919), and convergent validity, assessed through the Pearson correlation between total NUCOG scores and the Mini-Mental State Examination, was 0.92.[26] In the present study, the internal consistency of the NUCOG was Cronbach α = 0.60.

Brain Fog Scale (BFS): Developed by Ross *et al.* (2013), the BFS assesses subjective symptoms of brain fog. It consists of 19 items rated on a 5-point Likert scale ranging from 0 to 4. The total score is the sum of all items, ranging from 0 to 76, with higher scores indicating more brain fog symptoms. The BFS also includes a separate item asking participants to rate the severity of their brain fog on a scale from 0 to 100, with higher ratings indicating greater severity.[17] The Persian version was developed and validated by Mirzaei and Tavakoli (2025), who reported a one-factor structure and excellent internal consistency (Cronbach α = 0.97).[27] In the present study, Cronbach α for the BFS was 0.98.

Wechsler Memory Scale–Third Edition (WMS-III): Developed by David Wechsler, the WMS-III assesses memory functions. In the present study, the Letter–Number Sequencing and Spatial Span subtests were used to assess verbal and visuospatial working memory, respectively.[28] In Iran, Ashayeri *et al.* (2002) investigated the psychometric properties of the WMS-III and reported test–retest reliability coefficients of 0.75 in healthy individuals and 0.89 in patients with neuropsychiatric disorders. They also reported a Cronbach α coefficient of 0.87 for the total scale and 0.79 for the Working Memory Index.[29] In the present study, the internal consistency of the working-memory measures was Cronbach α = 0.92.

N-Back Task: To evaluate working memory, participants performed a visual 2-back task. On each trial, they viewed a sequence of stimuli and pressed predefined response keys whenever the current stimulus was the same as the one presented 2 trials previously. Performance was assessed using the number of incorrect responses, number of no-response trials, percentage of correct responses, and response time. These indices were recorded automatically during task administration. Kane *et al.* (2007) reported Cronbach α coefficients ranging from 0.54 to 0.84 for N-Back measures.[30] In Iran, Amani *et al.* reported a Cronbach α coefficient of 0.78 in a sample of 130 patients with cancer.[31]

Tower of London (TOL): Developed to assess problem-solving ability. In the present study, a computerized version of the task was administered, in which participants were required to reproduce target arrangements of colored balls across 3 vertical pegs while following predefined task rules and completing the task as efficiently as possible. Performance was evaluated using several indices, including total time, delay time, execution time, number of errors, and total score.[32] Culbertson and Zillmer (1998) reported a convergent validity coefficient of 0.41 with the Tower of Hanoi test.[33] Lezak *et al.* (2004) reported a reliability coefficient of 0.79 for the TOL.[34] In the present study, the Cronbach α coefficient of the TOL was 0.74.

Intervention

The executive function-based CR intervention was specifically developed for women with breast cancer undergoing chemotherapy. The intervention integrated restorative cognitive training, compensatory strategy instruction, psychoeducation, and guidance informed by Baddeley and Hitch's working memory model and the Five-Step Problem-Solving Model.

The intervention consisted of 15 weekly individual face-to-face sessions, each lasting approximately 60 minutes. Following recruitment from the participating oncology clinics and hospitals, eligible participants attended the psychology clinic, where all intervention sessions were delivered individually. Participants in both groups continued to receive their routine oncological care, including ongoing chemotherapy as prescribed by their oncologists, throughout the study period. Participants allocated to the waitlist control group received routine oncological care only during the study period and were offered the CR intervention after completion of the postintervention assessment.

Each session followed a standardized 6-component structure consisting of:

- Brief psychoeducation regarding executive functioning and chemotherapy-related cognitive changes;
- Review of the previous session and homework assignments;
- Reflection on the application of cognitive strategies in everyday situations;
- Executive function-based working memory training;
- Structured problem-solving exercises using everyday situations relevant to women undergoing chemotherapy; and
- Summary of the session, therapist feedback, instruction in compensatory cognitive strategies, and individualized homework assignments.

Working memory training included progressively more difficult verbal and visuospatial exercises targeting attentional control, updating, cognitive flexibility, dual-task coordination, and information manipulation. Problem-solving training focused on identifying problems, generating alternative solutions, selecting appropriate responses, and evaluating outcomes using functional real-life scenarios. Throughout the intervention, participants were also taught internal compensatory strategies, including mental rehearsal, visualization, semantic organization, and chunking, as well as external compensatory strategies, including notebooks, calendars, reminder lists, written cues, and smartphone reminders, to facilitate the transfer of cognitive skills into everyday functioning. All

intervention activities and homework assignments were completed using standardized paper-and-pencil worksheets.

Task difficulty was progressively increased throughout the first 10 sessions according to each participant's performance and mastery of previously acquired skills. The remaining 5 sessions emphasized consolidation of cognitive gains, reinforcement of executive strategies, and maintenance of learned cognitive skills. Although task difficulty was individualized, the therapeutic content, session structure, progression schedule, and therapist instructions remained identical across participants.

To ensure treatment fidelity, the content and implementation procedures of all intervention sessions were reviewed by specialists in cognitive psychology and clinical neuropsychology before the intervention commenced. Before each treatment session, the therapist reviewed the corresponding session guide together with the prescribed therapeutic activities to ensure consistent implementation. Participants' attendance, completion of session activities, and adherence to the intervention were documented using a standardized session checklist throughout the intervention. All sessions were delivered individually by the same therapist under the continuous supervision of specialists in cognitive psychology and clinical neuropsychology.

Procedure

Participant recruitment and screening were conducted between September 2022 and February 2023. Figure 1 presents the CONSORT flow diagram of participant progression throughout the trial. No participants were lost between randomization and the postintervention assessment, and all randomized participants completed both the baseline and postintervention assessments.

Eligible participants completed the baseline outcome assessments before randomization. Patients allocated to the intervention group received the 15-session executive function-based CR while continuing their routine oncological care, including active chemotherapy. All participants in the intervention group completed all 15 scheduled sessions (100% adherence). The control group continued to receive routine oncological care alone. The postintervention assessment was conducted within 1 week after completion of the final intervention session, while participants were still receiving chemotherapy. Participants in the control group were offered the CR after completion of the postintervention assessment.

Randomization and blinding. After baseline assessment and confirmation of eligibility, participants were randomized 1:1 to the intervention or waitlist control group. The allocation sequence was generated by an independent researcher using a random number table. Each participant was assigned a unique study code before allocation, and group assignment was performed by a clinic staff member who was not involved in participant recruitment, outcome assessment, or intervention delivery. The staff member used the pregenerated randomization sequence and had access only to the coded participant list required for assignment, without access to baseline cognitive scores or other clinical information that could influence allocation. Thus, allocation was concealed from personnel involved in outcome assessment. Outcome assessors administering the neuropsychological tests and the statistician performing the analyses remained blinded to group allocation. Owing to the nature of the intervention, blinding of participants and the therapist was not feasible.

Sample size. No formal sample size calculation was performed because this was a pilot study designed to evaluate feasibility, acceptability, and preliminary effect sizes to inform the design of a future definitive randomized controlled trial.

Control group. Participants in the control group received routine oncological care only and were offered the executive function-based CR after completion of the postintervention assessment (waitlist control). They did not receive any structured cognitive training or compensatory strategy instruction during the study period.

Statistical analysis

Analyses were conducted using IBM SPSS Statistics version 26. Means and standard deviations were calculated to describe participants' demographic characteristics and study variables. Baseline cognitive functioning was assessed for all participants using the NUCOG. In addition, pretest scores for all outcome measures were examined to determine whether any significant between-group differences existed prior to the intervention. Prior to hypothesis testing, the assumptions of normality and homogeneity of variances were assessed using the Shapiro–Wilk and Levene tests, respectively. The effects of the intervention on postintervention outcome measures were evaluated using separate univariate analyses of covariance (ANCOVAs), with the postintervention score for each outcome as the dependent variable, group as the between-subjects factor, and the pretest score as the covariate. Statistical significance was set at a 2-tailed $P < .05$. To control the familywise error rate across the 14 univariate ANCOVAs, P values were adjusted using the Holm–Bonferroni procedure.

RESULTS

All participants were married women, were premenopausal at the time of enrollment, had a history of breast cancer surgery, and were undergoing active chemotherapy at the time of enrollment. Regarding time since diagnosis, 6 participants in the control group had been diagnosed within the previous year (4 for less than 6 months and 2 between 6 months and 1 year), whereas 1 participant had been diagnosed for more than 1 year. In the intervention group, 4 participants had been diagnosed within the previous year (2 for less than 6 months and 2 between 6 months and 1 year), while 3 participants had been diagnosed for more than 1 year. The mean age was 43.43 years (SD = 3.25) in the intervention group and 43.42 years (SD = 2.87) in the control group. In both groups, 6 participants (85.7%) had a high school diploma and 1 participant (14.3%) had a bachelor's degree.

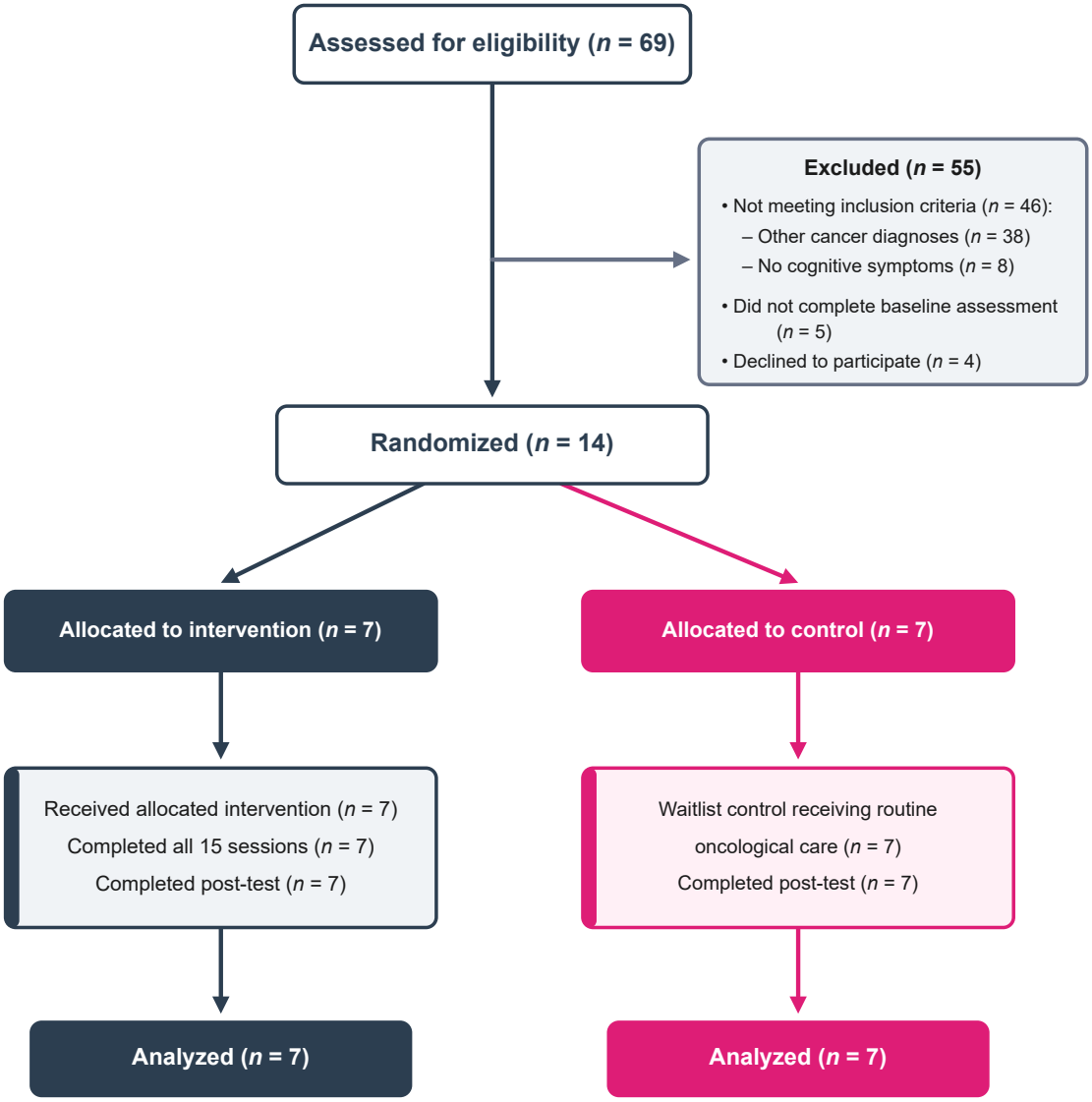


Figure 1. CONSORT (Consolidated Standards of Reporting Trials) Diagram of Progress Through Phases of the Randomized Trial

Baseline cognitive screening using the NUCOG showed that memory and attention were the lowest-performing domains across both groups.

Table 1 shows mean and SD of brain fog, working memory, and problem-solving scores at pretest and posttest.

After controlling for pretest scores, separate univariate analyses of covariance (ANCOVAs) were conducted to compare posttest outcome measures between the intervention and control groups. Prior to the analyses, the assumptions of normality (Shapiro–Wilk test) and homogeneity of variances (Levene test) were examined. Most outcome variables were normally distributed. Significant deviations from normality were observed only for the Tower of London execution time and the WMS-III visual working memory subtest in the intervention group, and for the Brain Fog Scale in the control group (all $P < .05$). Levene test indicated homogeneity of variances for the Tower of London execution time, the N-Back no-response score, the total and subscale scores of the WMS-III working memory assessment, and the Brain Fog Scale. Homogeneity of variances was not met for the remaining outcome measures. However, given the pilot nature of the study and equal group sizes, these minor violations were considered when interpreting the findings. The results of the separate univariate ANCOVAs for each outcome measure are presented in Table 2.

As shown in Table 2, significant between-group differences were observed in most Tower of London indices, WMS-III working memory measures, and Brain Fog Scale outcomes after Holm–Bonferroni adjustment. After Holm–Bonferroni correction, no significant between-group differences were observed for N-Back no-response trials (adjusted $P = .08$) or N-Back response time (adjusted $P = .24$).

Table 1. Pretest and posttest outcomes in the intervention and control groups

Outcome	Intervention group		Control group	
	Pretest	Posttest	Pretest	Posttest
Tower of London				
Total time (s)	491.71 (63.86)	195.29 (69.61)	581.42 (255.16)	726.29 (272.33)
Delay time (s)	143.28 (47.57)	95.71 (27.14)	217.42 (106.53)	356.29 (198.12)
Execution time (s)	280.43 (35.64)	99.57 (58.94)	355.00 (174.28)	370.71 (129.37)
Number of errors	12.86 (5.17)	4.57 (1.71)	21.29 (10.99)	28.71 (11.95)
Total score	29.57 (1.27)	34.29 (0.75)	26.57 (5.71)	23.00 (4.83)
N-back test				
Incorrect answer	46.86 (21.84)	13.86 (4.45)	52.71 (17.90)	52.29 (15.64)
No answer	37.14 (17.29)	24.86 (12.50)	38.71 (15.01)	40.29 (12.89)
Correct percentage	28.57 (9.05)	67.57 (10.93)	23.57 (4.86)	22.71 (4.75)
Response time (ms)	643.57 (158.27)	767.71 (148.38)	747.23 (57.36)	695.86 (46.00)
Total score	25.00 (2.70)	38.14 (3.97)	26.57 (1.81)	25.42 (3.15)
Wechsler working memory				
Auditory memory	11.14 (1.34)	17.00 (1.82)	12.43 (1.27)	11.86 (1.06)
Visual memory	13.86 (2.54)	21.14 (2.34)	14.14 (1.86)	13.57 (2.44)
Brain fog				
Brain fog	61.14 (4.25)	13.14 (6.25)	62.85 (4.70)	57.85 (3.80)
Severity of brain fog	78.57 (6.90)	22.86 (8.09)	77.71 (6.70)	80.71 (8.76)

Values are mean (SD). Tower of London total, delay, and execution times are in seconds (s). N-back response time is the mean for correct responses, in milliseconds (ms).

Table 2. Univariate ANCOVAs of postintervention outcomes for problem-solving, working memory, and brain fog

Outcome	MS	*F*	*P* value	Holm-adjusted *P* value	η_p^2	Adjusted mean difference (95% CI)
Tower of London						
Total time (s)	986 863.50	24.98	.001	.010	0.67	-390.350 (-547.128, -233.571)
Delay time (s)	237 641.14	11.88	.005	.02	0.49	-181.831 (-333.432, -30.230)
Execution time (s)	257 314.57	25.46	.001	.010	0.68	-219.761 (-285.466, -154.055)
Number of errors	2040.07	27.97	.001	.010	0.70	-18.283 (-26.768, -9.799)
Total score	445.78	37.29	.001	.010	0.75	9.316 (6.494, 12.139)
N-back test						
Incorrect answer	5168.64	39.05	.001	.010	0.76	-36.698 (-48.984, -24.412)
No answer	833.14	5.16	.04	.08	0.30	-14.326 (-21.298, -7.353)
Correct percentage	7042.57	99.05	.001	.010	0.89	47.289 (37.254, 57.325)
Response time (ms)	18 072.07	1.49	.24	.24	0.11	-16.633 (-115.721, 82.456)
Wechsler Memory Scale III (WMS-III)						
Total score	565.78	43.92	.001	.010	0.78	13.979 (9.956, 18.003)
Auditory memory	92.57	41.36	.001	.010	0.77	5.732 (3.826, 7.638)
Visual memory	200.64	35.11	.001	.010	0.74	7.742 (5.294, 10.189)
Brain fog						
Total score	6997.76	261.01	.001	.010	0.95	-48.226 (-54.841, -41.610)
Severity of brain fog	11 716.07	183.95	.001	.010	0.93	-58.135 (-67.582, -48.689)

Abbreviations: ANCOVA, analysis of covariance; CI, confidence interval; MS, mean square; η_p^2, partial eta squared.
df = 1 for all outcomes. Unrounded Holm-adjusted *P* values were .014 for outcomes displayed as .010 and .015 for delay time (displayed as .02).
Note. Adjusted mean differences were calculated as intervention minus control. Adjusted mean differences and 95% confidence intervals are based on estimated marginal means from the ANCOVA models and are unadjusted for multiple comparisons. The Holm–Bonferroni procedure was applied only to the *P* values. Adjusted mean differences and their 95% confidence intervals are in seconds (s) for Tower of London total time, delay time, and execution time, and in milliseconds (ms) for mean N-back response time for correct responses. Mean squares (MS) are in the squared units of their corresponding outcomes.

DISCUSSION

The present study provides preliminary evidence that executive function-based CR may improve working memory, problem-solving performance, and subjective brain fog symptoms in women with breast cancer undergoing chemotherapy. These findings are consistent with previous studies showing that CR can reduce cancer-related cognitive impairment.[12,21] However, the present study extends previous evidence by focusing on executive functions as the primary rehabilitation target rather than training isolated cognitive skills. The intervention simultaneously addressed working memory, problem-solving, and everyday executive strategies, which may have contributed to the concurrent improvements observed across objective cognitive performance and subjective

cognitive complaints.

The observed improvements in working memory and problem-solving are consistent with the central role of executive functions in regulating complex cognitive activities. Chemotherapy-related cognitive impairment has previously been associated with deficits in executive control, working memory, and information processing.[13,15] Improving executive functioning may therefore enhance the ability to organize, monitor, and manipulate information while supporting goal-directed behavior. Because effective problem-solving depends on maintaining relevant information and selecting appropriate responses, strengthening executive functioning may contribute to improvements in working memory and problem-solving performance.

Although significant improvements were observed across almost all working memory measures, no significant difference was found for N-Back response time, suggesting that the intervention may have affected accuracy more than speed. Participants made fewer errors and gave more correct responses after treatment, which may reflect more effective strategies for managing increasing task demands.

The intervention was also associated with a substantial reduction in subjective brain fog symptoms. This finding is consistent with previous reports indicating that CR may reduce cognitive complaints experienced by patients with cancer.[16,35] Brain fog is increasingly recognized as a multidimensional cognitive experience characterized by difficulties with memory, concentration, mental clarity, fatigue, and cognitive efficiency rather than as an isolated cognitive deficit.[17] Previous studies have suggested that multiple biological and psychological mechanisms contribute to these symptoms.[36] It should be noted, however, that subjective brain fog during chemotherapy may also be influenced by factors including anxiety, depressive symptoms, and psychological distress.[37,38] Because this was a pilot study, the potential contribution of these factors to changes in Brain Fog Scale scores was not specifically examined; therefore, their influence on the observed reduction in subjective brain fog cannot be determined. Nevertheless, the present findings provide preliminary evidence that executive function-based cognitive rehabilitation is associated with meaningful reductions in subjective brain fog symptoms in women undergoing chemotherapy for breast cancer.

A key finding was the concurrent improvement in objective neuropsychological performance and subjective cognitive complaints. This pattern is consistent with the multidimensional nature of cancer-related cognitive impairment, in which executive functioning, memory, attention, and subjective cognitive experience are closely interconnected.[27] Rather than improving a single cognitive ability, the intervention appeared to influence several related cognitive domains simultaneously. A possible explanation is the multidimensional design of the rehabilitation program. Unlike interventions based mainly on repetitive cognitive exercises, the present intervention combined cognitive training with executive strategy instruction, structured problem-solving, compensatory techniques, homework assignments, and practice of these strategies in everyday situations. Because the rehabilitation program directly targeted the same executive processes that were evaluated in the outcome measures, improvements were observed consistently across different measures of working memory, problem-solving, and subjective cognitive functioning. Given the overlap between the intervention exercises and the neuropsychological outcome measures, some of the observed improvements in neuropsychological performance may have been influenced by practice or task-specific learning. Nevertheless, the intervention extended beyond repetitive practice of the outcome tasks and incorporated executive strategy instruction, structured problem-solving, compensatory strategies, and application of these strategies to everyday situations. The concurrent improvements across multiple measures of working memory, problem-solving, and subjective cognitive complaints are therefore also compatible with the broader effects of engaging multiple cognitive and executive processes through the rehabilitation.

Although the intervention included the application of cognitive strategies in everyday situations, the transfer of these strategies to everyday functioning should be considered a possible clinical benefit rather than a demonstrated outcome.

From a clinical perspective, executive function-based CR represents a practical, nonpharmacological intervention that can be integrated into supportive cancer care and provides patients with cognitive strategies that may support the management of cognitive difficulties in everyday situations.

The limitations of the present study include several considerations. First, the sample size was relatively small because this was a pilot study. Second, time since diagnosis differed descriptively between the intervention and control groups. Because time since diagnosis was not specifically controlled for in the analysis, this imbalance represents a potential source of confounding and should be considered when interpreting the between-group differences. Future studies with larger samples should ensure greater balance in clinical characteristics between groups and examine whether time since diagnosis influences the observed intervention effects. Third, the study did not include longer-term follow-up or functional and quality-of-life outcomes; therefore, the persistence of the observed benefits and their potential impact on broader functioning remain to be established. Fourth, detailed information on cancer stage and specific ongoing systemic treatments was limited in the available study records, limiting the extent to which these clinical factors could be considered when interpreting the findings. Additionally, because the intervention was evaluated only in women with breast cancer aged 20 to 50 years, the findings may have limited generalizability to older patients and to patients with other types of cancer. Future studies should examine the applicability of this intervention in larger

and more diverse cancer populations, including older adults.

CONCLUSION

This pilot randomized controlled trial provides preliminary evidence that executive function-based cognitive rehabilitation can improve working memory, problem-solving, and subjective brain fog symptoms in women with breast cancer undergoing chemotherapy. This multidimensional approach may offer a promising nonpharmacological option alongside routine oncological care. Larger trials with more diverse samples are needed to confirm these findings and determine whether benefits are maintained over time.

ETHICAL CONSIDERATIONS

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of the University of Isfahan (Approval No. IR.UI.REC.1401.046). All participants provided written informed consent before enrollment and were informed that participation was voluntary and that they could withdraw at any time without affecting their routine oncological care. All participant data were coded to ensure confidentiality and were used exclusively for research purposes. Following completion of the postintervention assessment, participants in the waitlist control group were offered the executive function-based CR.

DATA AVAILABILITY

The data are available from the corresponding author upon request. Data confidentiality was ensured throughout all stages of the study.

CONFLICT OF INTERESTS

The authors declare no conflicts of interest.

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AI DISCLOSURE

Artificial intelligence tools were used solely for linguistic correction. The authors assume full responsibility for the content of the manuscript.

AUTHOR CONTRIBUTIONS

AM: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. MT: Conceptualization, Formal analysis, Supervision, Writing – review & editing.

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