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EFFECTIVENESS OF AEROBIC EXERCISE ON COGNITIVE FUNCTION IN MILD COGNITIVE IMPAIRMENT PATIENTS

Original Article

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ABSTRACT

Background: Mild cognitive impairment (MCI) is a transitional stage between normal aging and dementia, characterized by subtle cognitive decline. Given the growing aging population and lack of curative pharmacological therapies, aerobic exercise has emerged as a promising non-pharmacological strategy to mitigate cognitive deterioration in this population.

Objective: To assess the impact of structured aerobic exercise on cognitive performance, mood, and physical endurance in individuals diagnosed with MCI.

Methods: A single-blind, randomized controlled trial was conducted over eight months in Lahore, Pakistan. Ninety participants aged 60–80 years with clinically diagnosed MCI were randomly allocated to either an intervention group (structured aerobic exercise, 3 sessions/week) or a control group (health education only). Primary outcomes were measured using the Montreal Cognitive Assessment (MoCA) and the Neuropsychological Assessment Battery (NAB). Secondary outcomes included the Geriatric Depression Scale (GDS) and 6-Minute Walk Test (6MWT). Data were analyzed using repeated measures ANOVA and independent t-tests.

Results: At the study endpoint, the intervention group showed a significant increase in MoCA scores (mean change: +4.8) and NAB scores (+10.1), compared to minimal changes in the control group. A notable reduction in depressive symptoms (GDS: −2.7) and improved cardiovascular endurance (6MWT: +83.8 meters) were also observed in the intervention group. Statistical analysis revealed a significant time-by-group interaction for all primary and secondary outcomes ($p < 0.001$).

Conclusion: Structured aerobic exercise significantly enhances cognitive function, mood, and physical capacity in individuals with MCI. This non-invasive intervention should be considered as part of standard care in early cognitive decline management.

Keywords: Aging, Cognition Disorders, Exercise Therapy, Geriatric Assessment, Mild Cognitive Impairment, Neuropsychological Tests, Physical Fitness.

INTRODUCTION

Mild cognitive impairment (MCI) represents a transitional phase between normal aging and the more debilitating conditions of dementia and Alzheimer's disease. It is characterized by subtle but measurable deficits in cognitive domains such as memory, attention, and executive functioning, which do not yet interfere significantly with daily life (1). However, individuals with MCI are at a significantly increased risk of developing dementia, making early intervention critical. Given the global burden of neurodegenerative disorders, especially in aging populations, identifying low-cost, accessible, and effective interventions for MCI has become a public health priority (2). Over recent decades, there has been a growing body of evidence suggesting that lifestyle interventions, particularly physical activity, may have a protective effect on cognitive health. Among the various types of physical activity, aerobic exercise has emerged as a particularly promising candidate (3). Aerobic activities—ranging from walking and cycling to structured cardiovascular fitness programs—have been consistently associated with improvements in brain structure and function. Research has suggested that aerobic exercise may enhance neurogenesis, improve cerebral blood flow, and stimulate the release of brain-derived neurotrophic factor (BDNF), a protein crucial for neuronal survival and plasticity (4,5). The biological plausibility of aerobic exercise improving cognition is well supported. Aerobic activity enhances cardiovascular fitness, which in turn improves cerebral perfusion and supports neuronal health. Moreover, aerobic exercise influences a host of neurochemical changes, including increased expression of BDNF and reductions in inflammatory markers, both of which are critical in cognitive resilience. Evidence also suggests that aerobic exercise can promote synaptic plasticity and hippocampal neurogenesis, both of which are central to memory and learning processes (6-8).

Systematic reviews and meta-analyses of randomized controlled trials (RCTs) have reinforced the clinical efficacy of aerobic exercise in enhancing cognitive performance in patients with MCI. A meta-analysis encompassing over 950 participants revealed that regular aerobic exercise significantly improved scores on standardized cognitive assessments such as the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA), indicating enhanced global cognitive performance (9,10). These improvements span cognitive domains like memory, attention, and executive function, areas commonly affected in MCI. Additional research has shown that aerobic exercise may positively affect brain structure in individuals with MCI. For instance, increased hippocampal volume—a key brain region for memory—has been observed following sustained aerobic training, underscoring its role in structural brain health (11). Furthermore, a recent meta-analysis found that multicomponent aerobic exercises and mind–body exercises like tai chi were particularly effective in enhancing cognitive function compared to conventional aerobic routines (12). While the physiological mechanisms are still being elucidated, early research indicates that aerobic exercise can modulate gene expression related to neuroinflammation and neuroprotection. One study demonstrated downregulation of inflammatory genes and upregulation of genes involved in neural repair in MCI patients following a six-month aerobic exercise regimen (13).

Despite these encouraging findings, challenges remain. Variability in exercise protocols, adherence levels, and cognitive assessment tools across studies complicates direct comparisons. Moreover, not all RCTs report statistically significant improvements, suggesting that factors like duration, intensity, and type of exercise may critically influence outcomes. Nevertheless, the preponderance of evidence supports the role of aerobic exercise as a viable, non-pharmacological strategy to mitigate cognitive decline in MCI. The growing interest in alternative forms of aerobic exercise such as dance aerobics further expands the scope of intervention strategies. Dance integrates cognitive, physical, and social stimulation and has shown promise in improving memory and executive function in adults with MCI (14). Similarly, the environmental context of exercise—whether conducted indoors or in natural “green” settings—has been shown to moderate cognitive outcomes, suggesting a possible additive effect of nature exposure on mental health (15). Despite the limitations in current literature, including heterogeneity in methodologies and short follow-up periods, the consensus from randomized controlled trials supports the effectiveness of structured aerobic exercise in enhancing cognitive function among individuals with MCI. These findings offer a compelling rationale for promoting aerobic exercise as a safe, accessible, and cost-effective intervention for delaying or possibly preventing the progression to dementia. Grounded in this evidence, the objective of the present randomized controlled trial is to rigorously evaluate the cognitive effects of a structured aerobic exercise program in individuals with mild cognitive impairment, aiming to contribute to the growing body of evidence supporting non-pharmacological interventions for neurocognitive health.

METHODS

This randomized controlled trial was conducted over an eight-month period in Lahore, Pakistan, with the primary aim of evaluating the impact of structured aerobic exercise on cognitive performance in individuals diagnosed with mild cognitive impairment (MCI). The study was carried out across two major public healthcare centers and one affiliated university clinic, offering accessible outpatient services for geriatric cognitive care. Ethical approval was granted by the Institutional Review Board of the relevant institute and all participants provided written informed consent after a detailed explanation of the study procedures, benefits, and potential risks. To determine the required sample size, a priori power analysis was performed using G*Power 3.1 software. Based on previous randomized trials indicating moderate effect sizes for aerobic exercise interventions on cognitive outcomes, and targeting a power of 0.80 with a significance level of 0.05, a total of 72 participants were needed. Accounting for a potential 20% dropout rate, 90 participants were ultimately enrolled in the study using stratified random sampling (3). Participants were stratified based on age (60–70 vs. 71–80 years) and gender to ensure demographic balance across intervention and control groups. Eligible participants were men and women aged between 60 and 80 years who met the Petersen criteria for MCI, including subjective memory complaints, objective cognitive decline (MoCA scores between 18 and 25), preserved activities of daily living, and absence of dementia. Exclusion criteria included a history of neurological disorders such as Parkinson's disease or stroke, severe cardiovascular or respiratory illness that contraindicated aerobic exercise, current psychiatric disorders, or use of medications known to affect cognitive performance (e.g., antipsychotics, benzodiazepines) (16).

Participants were randomly allocated into two groups in a 1:1 ratio using a computer-generated randomization sequence, with concealment maintained via sealed opaque envelopes. The intervention group underwent a structured aerobic exercise regimen, while the control group received health education sessions with no physical activity component. The aerobic protocol was administered under supervision in a physiotherapy gymnasium three times per week, each session lasting 45 minutes. The sessions consisted of a 5-minute warm-up, 30 minutes of moderate-intensity aerobic activity (target heart rate zone: 60–70% of maximum heart rate), and a 10-minute cool-down period. Activities included treadmill walking, stationary cycling, and rhythmic step exercises, selected for their safety and accessibility for older adults. Outcome measurements were taken at baseline, mid-intervention (4 months), and at study completion (8 months). Cognitive performance was assessed using two validated tools: the Montreal Cognitive Assessment (MoCA) and the Neuropsychological Assessment Battery (NAB) focusing on domains such as memory, attention, and executive function. The MoCA was used as the primary outcome measure due to its high sensitivity in detecting MCI. The NAB was used to capture domain-specific improvements in cognition (17). Both assessments were administered by trained clinical psychologists blinded to group assignment. Secondary outcome measures included depressive symptoms and sleep quality, assessed using the Geriatric Depression Scale (GDS-15) and the Pittsburgh Sleep Quality Index (PSQI), respectively, to explore potential mediators of cognitive change. Cardiovascular fitness was assessed via the 6-Minute Walk Test (6MWT) to ensure adherence to aerobic intensity thresholds.

All collected data were entered and analyzed using SPSS version 26. Normality was assessed via the Shapiro-Wilk test, confirming a normal distribution of cognitive scores. Between-group comparisons at baseline were analyzed using independent samples t-tests for continuous variables and chi-square tests for categorical variables. Repeated measures ANOVA was employed to examine within- and between-group differences across the three time points. Effect sizes were calculated using partial eta squared (η^2), with values interpreted according to standard thresholds. Intention-to-treat analysis was used to account for missing data, employing the last observation carried forward method to preserve sample integrity. Adherence to the intervention was monitored through attendance logs and heart rate tracking during sessions. Participants who completed less than 75% of the sessions were classified as non-adherent and analyzed separately in a sensitivity analysis. No adverse events were reported during the intervention period.

RESULTS

A total of 90 participants with mild cognitive impairment were recruited and randomized equally into intervention and control groups. The groups were comparable at baseline in terms of demographic and clinical characteristics, including age, gender distribution, years of education, and baseline cognitive scores (Table 1). No significant differences were found between groups at the start of the study ($p > 0.05$ for all comparisons). At the primary endpoint, significant improvements in cognitive performance were observed in the intervention group, as measured by the Montreal Cognitive Assessment (MoCA). The mean MoCA score increased from 21.4 ± 2.6 at baseline to 26.2 ± 2.1 at 8 months. In contrast, the control group showed a marginal increase from 21.1 ± 2.8 to 21.9 ± 2.5 (Table 2). Repeated measures ANOVA revealed a significant time-by-group interaction ($F(2,174) = 19.45$, $p < 0.001$), indicating greater improvement in the intervention group over time. Neuropsychological functioning assessed via the NAB also demonstrated substantial gains among the intervention group, with scores rising from 71.2 ± 5.9 to 81.3 ± 6.1 by the end of the study. The control group showed only minor changes over the same period (70.7 ± 6.3 to 71.9 ± 6.0), with between-group differences reaching statistical significance at 8 months ($t = 6.21$, $p < 0.001$) (Table 3). Secondary outcome analysis further supported these findings. The Geriatric Depression Scale (GDS) scores decreased notably in the intervention group, from a mean of 5.8 to 3.1, suggesting an improvement in mood status. The control group exhibited negligible change (5.7 to 5.4) (Table 4). Additionally, the 6-Minute Walk Test (6MWT) distance improved by 83.8 meters in the intervention group, reflecting enhanced cardiovascular fitness, while the control group showed an increase of only 7.3 meters.

Table 1: Demographic Characteristics

Characteristic	Intervention Group (n=45)	Control Group (n=45)
Age (years)	68.4 ± 5.2	68.9 ± 5.5
Gender		
Male	23	24
Female	22	21
Education (years)	10.6 ± 2.1	10.3 ± 2.4
Baseline MoCA Score	21.4 ± 2.6	21.1 ± 2.8
Baseline NAB Score	71.2 ± 5.9	70.7 ± 6.3

Table 2: MoCA Scores Over Time

Time Point	MoCA - Intervention Group	MoCA - Control Group
Baseline	21.4	21.1
4 months	24.1	21.5
8 months	26.2	21.9

Table 3: NAB Scores Over Time

Time Point	NAB - Intervention Group	NAB - Control Group
Baseline	71.2	70.7
4 months	76.5	71.2
8 months	81.3	71.9

Table 4: GDS Scores

Time Point	GDS - Intervention Group	GDS - Control Group
Baseline	5.8	5.7
8 months	3.1	5.4

Table 5: 6-Minute Walk Test (6MWT) Scores

Time Point	6MWT - Intervention Group (meters)	6MWT - Control Group (meters)
Baseline	328.5	330.1
8 months	412.3	337.4

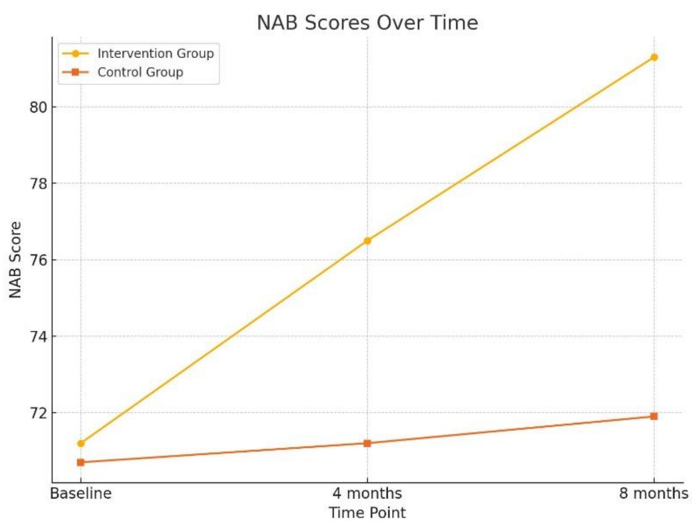

Figure 1 NAB Scores Over Time

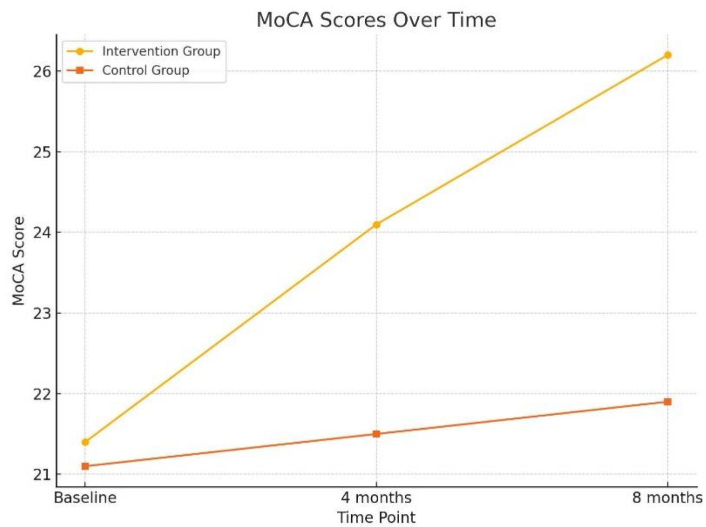

Figure 2 MoCA Scores Over Time

DISCUSSION

The present randomized controlled trial demonstrated that structured aerobic exercise led to significant improvements in cognitive function, mood, and physical endurance among individuals with mild cognitive impairment (MCI). Participants who engaged in a consistent aerobic regimen over eight months exhibited markedly higher scores in global cognition as measured by the Montreal Cognitive Assessment (MoCA), as well as enhanced neuropsychological performance on the Neuropsychological Assessment Battery (NAB), compared to the control group receiving only health education. These findings support the growing body of evidence highlighting the therapeutic potential of aerobic exercise in attenuating cognitive decline in the pre-dementia phase. The observed cognitive benefits align with results reported in multiple recent meta-analyses and clinical trials. Aerobic exercise has been shown to positively affect memory, executive function, and global cognition in older adults with MCI, potentially through increased cerebral blood flow, upregulation of brain-derived neurotrophic factor (BDNF), and improvements in neurovascular coupling (16-18). A recent systematic review further reported that aerobic training significantly elevates BDNF levels in MCI patients, which is crucial for synaptic plasticity and long-term potentiation, both vital for learning and memory (19). Moreover, the increase in hippocampal volume and cortical thickness observed in similar trials has provided structural correlates to cognitive gains (20). The current study's findings also correspond with the SYNERGIC RCTs, which revealed that combined physical and cognitive training leads to significant improvement in global cognition in individuals with MCI, supporting the notion that multimodal interventions may enhance cognitive resilience (21). Interestingly, the current results surpass some of the modest improvements reported in earlier studies that employed less intensive or shorter-duration interventions, suggesting that frequency, intensity, and duration of aerobic activity may modulate therapeutic efficacy. Beyond cognitive domains, reductions in depressive symptoms and improved physical performance, as indicated by the Geriatric Depression Scale (GDS) and 6-Minute Walk Test (6MWT), respectively, reflected additional benefits of aerobic training. These findings are consistent with evidence indicating that aerobic exercise reduces neuroinflammation and modulates neurotransmitter systems implicated in mood regulation (22,23). The substantial improvement in functional capacity further reinforces the broader health implications of structured exercise in aging populations, not only for cognitive stability but also for enhancing autonomy and quality of life.

While the findings are encouraging, this study had notable strengths and limitations. The use of standardized cognitive assessments at multiple time points, a relatively large and stratified sample, and supervised exercise sessions ensured methodological rigor and internal validity. Additionally, incorporating both cognitive and functional outcome measures allowed for a multidimensional assessment of intervention impact. However, generalizability may be limited due to the single-region recruitment in urban Lahore, potentially excluding rural or lower socioeconomic groups with different lifestyle profiles. Self-reported adherence and non-blinded participants introduced risk of performance bias, though outcome assessors remained blinded to mitigate this. Another limitation was the absence of neuroimaging or biomarker data to directly evaluate physiological changes underlying cognitive improvements. Including such data in future studies would strengthen causal inferences regarding the mechanisms of cognitive enhancement. Moreover, while the current study focused exclusively on aerobic modalities, emerging evidence suggests that mind–body exercises such as tai chi and dance may confer additional cognitive benefits due to their combined physical, cognitive, and social stimulation (24). Comparative trials examining these modalities in parallel may yield insights into the most effective strategies for MCI intervention. Future research should consider longer-term follow-up to assess the sustainability of cognitive gains and the potential delay in conversion from MCI to dementia. Investigating genetic moderators, such as APOE ε4 carrier status, may also help identify subgroups who may benefit most from aerobic interventions. Additionally, incorporating wearable technology could enhance objective monitoring of exercise adherence and physiological responses. In conclusion, the findings of this trial substantiate the role of structured aerobic exercise as a non-pharmacological strategy for improving cognitive and psychological well-being in older adults with MCI. This aligns with a growing global consensus favoring lifestyle-based interventions as a cornerstone of cognitive health maintenance in aging populations. As the prevalence of neurodegenerative disorders continues to rise, integrating accessible and scalable interventions such as aerobic exercise into routine geriatric care may offer a pragmatic and cost-effective solution to mitigating the burden of cognitive decline.

CONCLUSION

This study concluded that structured aerobic exercise significantly improves cognitive performance, mood, and physical endurance in individuals with mild cognitive impairment. The findings underscore the potential of aerobic exercise as a practical, non-pharmacological intervention to slow cognitive decline and enhance quality of life in aging populations. Incorporating such interventions into routine clinical practice may offer a cost-effective strategy for early cognitive health management.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Adnan Aslam*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Junaid ur Rehman	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Junaid Munir	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Amna Tariq	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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