BMC Geriatrics

RESEARCH

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Enhancing cognitive performance and mitigating dyslipidemia: the impact of moderate aerobic training on sedentary older adults

Ahmad H. Alghadir[1], Sami A. Gabr[1] and Amir Iqbal[1*]

Abstract

Background The present study aimed to evaluate the effects of 24 weeks of moderate aerobic exercise on lipids and lipoprotein levels; Lipo (a) markers, and their association with cognitive performance in healthy older adults.

Methods A total of 150 healthy subjects (100 males and 50 females; age range: 65–95 years) were recruited for this study. Based on the LOTCA test score, subjects were classified into two groups: the control group ($n=50$) and the cognitive impairment group ($n=100$). Cognitive functioning, leisure-time physical activity (LTPA), lipid profile, total cholesterol, TG, HDL-c, LDL-C, and lipo(a) were assessed at baseline and post-24-week aerobic exercise interventions using LOTCA battery, pre-validated Global Physical Activity Questionnaire (GPAQ) version II, colorimetric, and immunoassay techniques, respectively.

Results Significant improvements in cognitive function and modulation in lipid profile and lipoprotein (a) markers were reported in all older subjects following 24 weeks of moderate exercise. LOTCA-7-sets scores significantly correlated with physical activity status and the regulation of lipids and Lipo (a) markers. Physically active persons showed higher cognitive performance along with a reduction in the levels of T-Cholest., TG, LDL-C, Lipo (a), and an increase in the levels of HDL-C and aerobic fitness VO2max compared with sedentary participants. Cognitive performance correlated positively with increased aerobic fitness, HDL-C, and negatively with T-Cholest., TG, LDL-C, and Lipo (a). However, a significant increase in the improvement of motor praxis, vasomotor organization, thinking operations, attention, and concentration were reported among older adults.

Conclusions The study findings revealed that supervised moderate aerobic training for 24 weeks significantly enhances cognitive functions via mitigating older adults' lipid profiles and lipoprotein (a). Cognitive performance is positively correlated with aerobic fitness and HDL-C level and negatively with T-Cholest., TH, LDL-C, and Lipo (a).

Keywords LOTCA, Lipid profile, Moderate aerobic exercise, Cognitive abilities, Lipoprotein (a)

*Correspondence:
Amir Iqbal
physioamir@gmail.com; ajamaluddin@ksu.edu.sa
[1]Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, P.O. Box 10219, Riyadh 11433, Saudi Arabia

Introduction

Cognitive abilities refer to all essential mental skills that the various processes and capacities of the mind that enable us to acquire, process, store, and apply knowledge. These abilities play a crucial role in how we perceive and interact with the world, solve problems, make decisions, and engage in complex thinking task that control the behavioral lifestyle of humans, including day routine work [1]. It's important to note that these changes in cognitive abilities can vary widely among individuals, and not everyone will experience the same degree or pattern of decline with aging [2, 3].

Declines in cognitive abilities were shown to produce more drastic problems for older adults in performing their daily life activities [2]. However, more studies tried to maintain or enhance cognitive abilities in older adults by enhancing or delaying functional disabilities [3]. The results of these trials are not precise; this may be because most of these trials concentrated on treatment schedules rather than prevention in older subjects with cognitive deficits or functional disabilities. Previously it was reported that prevention or improvement of cognitive deficits among normal older adults is accessible, but the treatment parameters did not include the outcome measures, which may relate to the limited and lack of sample randomization [4, 5]. Thus, there are more pathological and physiological parameters or factors were involved in the progression of cognitive decline among both young and older ages [4–7]. The impairment in brain function in older age is performed via many pathological mechanisms [6, 7]. The most important is tissue damage and neural cell death, which occur via the interaction of complex path physiological processes [8]. In addition to that, decline in cognitive abilities among older adults were significantly associated with many severe age-related diseases, such as inflammation which is related to chronic pathological processes. Moreover, the incidence of inflammation and poor in immunosenescence resulted in a decline of multiple physiological systems and functional dependence in brain among the elderly [9–11]. Besides, abnormal in the cellular levels of lipid profiles is another physiological factor reported to be associated with cognitive decline among older adults [11, 12]. Many research studies reported that cognitive impairment and increased risk for CVD among older subjects are associated with abnormal lipid profiles [12–14], higher levels of low-density lipoprotein (LDL) cholesterol, total cholesterol levels, and lower high-density lipoprotein (HDL) cholesterol were significantly linked with lower scores of cognitive impairment older subjects with dementia [15, 16]. However, lower LDL, HDL, and higher HDL were associated with reduced or improved cognitive impairment [17, 18]. Similarly, lipoprotein (a) was reported as a possible risk factor for vascular dementia and cognitive impairments in older subjects [19, 20]. Lipoprotein (a) in many studies was reported as one of the cholesterol derivatives that exist in human plasma and structurally similar to low-density lipoprotein (LDL), but with a glycoprotein called [21, 22]. Thus, collectively both cellular physiological changes in lipid profiles are in connection in such away with the status of cognitive abilities and essential mental skills which are interconnected and contribute to overall cognitive functioning and performance in various domains of life, including academics, work, and daily activities [19–22]. These essential physiological and behavioral factors can be developed and improved through practice, learning, and engaging in activities that challenge and stimulate the mind.

Previous studies have shown that appropriate physical exercise and physical activity are effective means for cardiopulmonary function and brain cognition, which can enhance the cognitive ability of stroke patients, reduce pain, relieve cardiovascular pressure, and improve walking ability [23–26].

Physical activity of all kinds with a variety of intensities, ranging between light, moderate, and vigorous (or high) intensity are beneficial for human health. Light-intensity activities require the least amount of effort (<3METS) compared to moderate (3–6 METS) and vigorous activities (>6 METS). Many researchers showed that the therapeutic effect of aerobic exercise with different intensities, like light, moderate, and sternness is the most significant for improving cardiopulmonary function and brain cognition [27–29].

In this regard, many studies focused on the importance of body physical activity and its positive effects on cognitive abilities, especially in older ages. Physical exercise was shown to play a protective role against hippocampal cell injury, which produces brain memory loss [30]. Whereas physical facilitate recovery from injury and improves cognitive function via an increase in the expression of many neurotrophic and physiological factors involved in neural survival, differentiation, and improvement of memory function [31].

Recent studies reported the potential action of exercise as an anti-apoptotic parameter against many brain diseases such as brain inflammatory conditions [32], mice Parkinson's disease [33], in the improvement of depressive symptoms [34], traumatic brain injury [35, 36], and alleviation of memory impairment [37].

It was reported that physical exercise performs sound effects on cognitive abilities in different ways, which argues its importance as non-drug and non-invasive essential targets for long-term health programs for all ages [38, 39]. The marked improvement was manifested in both function and biomarker integrity, as shown in recent studies [40, 41]. This indicates the non-drug efficiency of exercise, especially of moderate type, to change lifestyle and improve lipoprotein and lipid levels in adults [42]. A significant positive change in the levels of lipids and lipoproteins was reported among both men and women following aerobic exercise [43, 44].

Most research topics studied the combined effects of exercise and diet on lipids and lipoproteins furthermore, few studies concentrated on the effects of physical exercise alone [45, 46]. Thus, the benefits of regular physical exercise as a health-ensuring necessity over age, gender, occupation, and affective status cannot be overestimated [47, 48]. In this study, it was hypothesized that moderate aerobic exercise as non-drug remedy for 24 weeks might have a potential role in the improvement of cognitive abilities among older adults via reducing the levels of lipid profiles.

Therefore, the present study was designed to evaluate the effects of 24 weeks of moderate aerobic exercise on the levels of lipids and lipoprotein (a) markers and their association with cognitive performance in healthy older adults.

Materials and methods

Subjects

A total of 200 subjects were invited to participate in this study. Only, one-hundred-fifty healthy subjects (100 males, 50 females; mean age between 65 and 95 years) who matched inclusion criteria were recruited for this study. Subjects with physical disability and endocrine, immune, psychiatric illness, eating disorders, and taking glucocorticoid medication that could interfere with lipid profile and cognitive ability measurements were excluded from this study. In addition, subjects who are the overweight and obese (body mass index [BMI] ≥ 25 and ≥ 30 kg/m2 were also excluded. Also, subjects who participated in other exercise programs were excluded from this study. Based on the LOTCA test scores, subjects were classified into two groups, the control group (n = 50) and the cognitive impairment group (n = 100). To record any drop out, the diet or lifestyle of all participants were observed and subjected under follow up for any change during the period of the exercise program (24 weeks). Demographic and anthropometric data of participants were included in Table (1).

Table 1 General characteristics of subjects

Parameters	Control group (n = 50)	Cognitive group (n = 100)
Male/Female	30/20	70/30
Age (years)	67.3 ± 2.8	67.2 ± 3.2
BMI (kg/m2)	22.3 ± 2.7	23.4 ± 1.7 *
Waist (cm)	75.3 ± 10.2	86.3 ± 11.7
Hips (cm)	88.5 ± 5.2	87.5 ± 18.3
WHR	0.82 ± 0.07	0.98 ± 0.10 *
Systolic BP (mmHg)	122.2 ± 6.5	118.5 ± 10.8
Diastolic BP (mmHg)	78.5 ± 11.9	82.5 ± 10.3
Fasting Blood sugar (mg/dl)	98.5 ± 6.3	105 ± 3.5
HbA1c (%)	6.2 ± 1.5	6.4 ± 1.9
VO2 max (ml/kg*min)	34.6 ± 3.7	31.4 ± 2.9
Mean LOTCA score (SD)	97.8 ± 7.91	76.2 ± 8.24**
LTPA (MET-H /week)	156.9 ± 15.6	96 ± 9.7**

Values are expressed as mean ± SD; *P < 0.05, **P < 0.01, ***P < 0.001. Significance at p < 0.05

Training procedure

Participants were involved in an exercise program designed according to Karvonen's formula [49] thrice weekly for 24 weeks. Whereas the training intensity of each intervention was prepared according to each participant's maximum and resting heart rate. During warming, the subject performed stretching exercises and walking for 5 to 10 min. During the active phase, the subject could reach his pre-calculated training heart rate (THR max; 60 to 70% for 45–60 min) in bouts form using a treadmill, bicycle, and stair master [50, 51]. Each participant's exact calculated heart rate was monitored via a wearable automatic portable heart rate meter (Polar Electro, Kempele, Finland). The exercise test gave the participants physical activities corresponding to 30–45% of VO2 max uptake [52].

Assessment of leisure-time physical activity (LTPA)

A pre-validated global physical activity questionnaire version II (GPAQ v. II) calculates a leisure-time physical activity (LTPA). The energy expenditure rates were calculated weekly in metabolic equivalents per hour/week (T-LPTA-MET/H/W), as previously reported [53].

Assessment of cognitive abilities

Instrument

Trained research assistants assessed the cognitive abilities of older adults at pre and post-supervised aerobic exercise using the Loewenstein Occupational Therapy Cognitive Assessment (LOTCA) battery. Assessments are required between 45 and 90 min. The LOTCA consists of seven main domains divided into 26 subtests, with each subtest scored on a four- or five-point Likert scale. The assessment of the LOTCA test was performed according to instruction manuals as reported in the literature [54]. In this study, the applied LOTCA test was valid for older adults with different ages as has been evaluated in recent studies [55–59]. Results are presented as a profile along with all subtests. A composite score for each domain was calculated by summing the scores of the relevant subtests. The LOTCA score was calculated by summing the score of all subtests. The maximum score on the test is 123, and the minimum score is 27. A higher score indicates better cognitive performance.

LOTCA test Validity

The test has excellent intra-rater reliability (100%) and good inter-rater reliability (86%), as well as criterion validity (78%) [60]. This LOTCA test was chosen because of its psychometric properties and primarily non-verbal nature, making it more suitable for evaluating the cognitive abilities of individuals from non-Western and non-English-speaking cultures. Several studies have used this instrument on Western and Arab populations [1, 60].

Assessment of dyslipidemia

All serum samples were taken from all participants in the morning following an overnight fast at pre and post-exercise training program for estimation of the following parameters;

Analysis of lipoprotein A and lipid profile

The Immunoassay ELISA technique was performed to measure lipoprotein A levels in the serum of participants pre- and post-exercise interventions using the DRG ELISA kit of Total Human Lipoprotein (A) (DRG International Inc., USA). The serum was analyzed for total cholesterol by the enzymatic (CHOD-PAP) colorimetric method and triglycerides by the enzymatic (GPO-PAP) method [49, 50]. HDL-Cholesterol estimated by precipitant method and LDL-Cholesterol by Friede wald formula (1972) [LDL-C=TC - HDL-C – (TG/5)] [61, 62].

Sample size calculation

In this study, the power of the sample size was estimated by using the G ∗ Power program for Windows (version 3.1.9.7). A sample comprising 150 of subjects was included in this study. Using the T-test and Wilcoxan signed-rank test with a significance level of 0.05, the total sample of 150 achieves a power of 95% with effective size d of 0.276, Df=142.23, critical t=1.655, and noncentrality -α=3.305.

Table 2 LOTCA scores in studied subjects following 24 weeks supervised aerobic training program (means ± SD)

Parameters	Control Group (*n* = 50)		Cognitive Group (*n* = 100)	
	Pre	Post	Pre	Post
Orientation	12.8 ± 1.8	16.7 ± 2.5 *	9.0 ± 2.3	21.8 ± 0.5 **
Visual Perception	18.2 ± 2.9	21 ± 0.98*	11.3 ± 2.5	18.1 ± 1.9 **
Spatial Perception	10.5 ± 0.4	13.5 ± 0.4 *	9.5 ± 2.1	21.13 ± 0.91 **
Motor Praxis	8.8 ± 0.68	11.9 ± 0.52 *	9.4 ± 3.8	25.7 ± 2.3 **
Vasomotor organization	21.3 ± 2.6	25.1 ± 2.86 *	11.9 ± 3.7	38.1 ± 2.9 **
Thinking Operations	23.7 ± 3.7	26.8 ± 2.95 *	9.6 ± 2.65	315 ± 2.6 **
Attention and Concentration	3.7 ± 0.51	3.9 ± 0.18 *	2.1 ± 0.31	5.3 ± 0.45 **
Total LOTCA score	97.8 ± 7.91	98.9 ± 7.5 *	76.2 ± 8.24	110.8 ± 5.6 **

Values are expressed as mean ± SD; $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$. Significance at $p<0.05$

Statistical analysis

Statistical analysis was performed using SPSS version 17. The data were expressed as mean ± SD. The comparison and correlation of the studied parameters were investigated using both student's t-test and Pearson's correlation coefficient, respectively. Paired t-test was used for within-group comparison. The data was deemed to be significant at P-values < 0.05.

Results

A total of 150 healthy subjects were involved in this study. 67% of the sample was male (*n*=100), and 70% of subjects were highly educated (*n*=105). They are classified according to LOTCA test scores into a control group (*n*=50) and a cognitive impairment group (*n*=100). There was a significant difference in WHR (*P*=0.05), LPTA (*P*=0.001), and average LOTCA scores (*P*=0.01) of exercise participants compared to the control group (Table 1).

This study showed a significant (*P*=0.01) improvement in all LOTCA 7 -subsets variables among subjects following 24 weeks of moderate aerobic training compared to the pre-test, and the control group showed a slight improvement in LOTCA scores, as shown in Table (2). However, significant (*P*=0.001) improvements in motor praxis, vasomotor organization, thinking operations, attention, and concentration were reported among older adults following 24 weeks of aerobic exercise. The data revealed positive significant correlations between the LOTCA scores of older subjects and their performance of cognitive abilities. Moreover, significant correlations were obtained between the older subjects in the motor praxis, vasomotor organization, thinking operations, attention and concentration domains of the LOTCA – scores, and their performance of a functional physical activity, as shown in Table (3).

Lipid profile and lipoprotein (a) makers, cholesterol, TG, HDL-C, LDL-C, and Lipo (a) were estimated in this study. Paired t-test and independent t-test analysis showed that participants with cognitive impairments had abnormal basal levels of lipids and lipoprotein (a) makers compared with (*p*=0.001) control groups (Table 4). Paired t-test analysis within groups showed a significant reduction in the levels of TG, LDL-C, and Lipo (a), along with an increase in the level of HDL-C in participants with cognitive impairment (*p*=0.001) and control (*p*=0.01) compared with baseline values following 24 weeks of moderate aerobic training as shown in Table (4). The data were significantly correlated with the physical

Table 3 Post training correlation analysis of lipid and lipoprotein (a) markers, and cognitive abilities (LOTCA scores) variables according to the level of leisure-time physical activity (LPTA-MET-H /week) after 24-week of exercise

Parameters	Cognitive group ($n = 100$); (R)	
	(low LTPA) (baseline)	(High LTPA) (Pos-training)
Total LOTCA score	0.21*	0.26 **
Orientation	0.16 *	0.35**
Visual Perception	0.25*	0.28**
Spatial Perception	0.21*	0.33**
Motor Praxis	0.21*	0.16**
Vasomotor organization	0. 27*	0.32**
Thinking Operations	0.41*	0.27**
Attention and Concentration	0.51*	0.25**
T-Cholesterol (mg/dl)	0.42*	0.35**
TG (mg/dl)	−0.35*	−0.61**
HDL-C (mg/dl)	0.30*	0. 41**
LDL-C (mg/dl)	- 0.38*	−0.52**
Lipo(a) (mg/dl)	- 0.38*	−0.53**

Data presented as coefficient (R); * denotes significance at <0.01; ** denotes significance at <0.001

Table 4 Changes in the levels of lipid and lipoprotein (a) markers, and leisure-time physical activity (LTPA) score of participants pre- and Post- 24 weeks supervised aerobic training program (paired t-test analysis)

Parameters	Control group ($n = 50$)		Cognitive group ($n = 100$)	
	Pre	Post	Pre	Post
T-Cholesterol (mg/dl)	185 ± 3.7	181.5 ± 4.2 *	231 ± 38.7	198 ± 21.3 * *
TG (mg/dl)	125.2 ± 5.7	124.9 ± 6.2 *	157.6 ± 52.4	134 ± 25.1 * *
HDL-C (mg/dl)	48.5 ± 2.7	49.9 ± 2.5 *	43.7 ± 11.3	76.3 ± 9.7 * *
LDL-C (mg/dl)	102.5 ± 3.4	98.7 ± 2.5 *	128 ± 31.5	98.7 ± 12.3 * *
Lipo(a) (mg/dl)	23.8 ± 2.5	22.9 ± 3.4 *	35.4 ± 6.7	27.2 ± 3.8 * *
LTPA (MET-H /week)	157 ± 15.6	165 ± 12.8 *	96 ± 9.7	350 ± 21.6 * *
VO2 max (ml/kg*min)	34.6 ± 3.7	38.3 ±1.9 *	31.4 ± 2.9	48.7 ± 5.3 * *

Values are expressed as mean ± SD; $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$. Significance at $p<0.05$

fitness of the participants. Physical fitness scores were correlated negatively with the reduction in the levels of TG, LDL-C, and Lipo (a), and positively with the increase in the level of HDL-C (Table 3).

Regarding LOTCA scores, the improvements in cognitive abilities among physically active participants were significantly correlated with the change in the levels of lipids and lipo(a) markers. Cognitive parameters were correlated negatively with TG, LDL-C, and lipo (a) and positively with increased HDL-C and aerobic fitness as measured by VO2 max (Table 5).

Discussions

Physical activity as non-drug modulates consider one of the most promising strategies to prevent or improve cognitive disabilities among elderly populations [63]. It was reported that physically active people throughout their lives minimize the incidence rates of dementia and cognitive difficulties [64–66]. Whereas many studies reported a lower rate of cognitive disorders among subjects who participated in higher levels of physical activity interventions than persons with lower scores of physical activity [67, 68].

Recently, many research works revealed that moderate-intensity physical exercise produces remarkably higher levels of improvement in skills, mobility, and mood in both younger [69] and older adults [70]. However, little is known about whether the positive effect of moderate exercise on cognitive abilities occurs via modulating lipid profiles and lipoprotein (a).

Therefore, the current research aimed to investigate the probable correlation between anti-dyslipidemic mechanisms of exercise on cognitive abilities among one-hundred-fifty older adults who participated in a supervised aerobic training program for 24 weeks.

In the present study, the cognitive abilities of 150 older adults of the control and exercise groups were measured using LOTCA scores, a cognitive evaluation test of 7-subsets variables. In older subjects who participated in moderate aerobic exercise for 24 weeks, there was a significant improvement in cognitive performance via an increase in all LOTCA 7-subsets variables compared to the control group. The data revealed positive significant

Table 5 Post training correlation coefficients among factors involved in Dyslipidemia and cognitive parameters ($n = 100$)

Parameters	VO2 max	T-Cholesterol (mg/dl)	TG (mg/dl)	HDL-C (mg/dl)	LDL-C (mg/dl)	Lipo(a) (mg/dl)
Orientation	0.33**	−0.33**	−0.45**	0.22 **	−0.65**	−0.58**
Visual Perception	0.24**	-0.24**	−0.33**	0.29 **	−0.32**	−0.51**
Spatial Perception	0.24**	-0.24**	−0.29**	0.37**	−0.58 **	−0.52**
Motor Praxis	0.34**	-0.34 **	−0.35**	0.46 **	−0.67 **	−0.69**
Vasomotor organization	0.25**	-0.25 **	−0.41**	0.55 **	−0.75 **	−0.78**
Thinking Operations	0.48 **	-0.48 **	−0.39**	0.57 **	−0.78 **	−0.56**
Attention and Concentration	0.36**	-0.36 **	−0.47**	0.62 **	−0.59 **	−0.43**

Data presented as coefficient (R); * denotes significance at < 0.01; ** denotes significance at < 0.001

correlations between the total LOTCA scores of older subjects and their performance of cognitive abilities. Thus, the accuracy and evaluation of the LOTCA test support its use as a diagnostic tool for cognitive function, as previously reported [1].

Moreover, a significant positive correlation was obtained between the older subjects in the motor praxis, vasomotor organization, thinking operations, attention and concentration domains of the LOTCA –scores, and their performance of the functional physical activity. The data matched with others who suggested the strongest indication of physical exercise benefits cognition function via enhancing academic performance and psychological well-being [71, 72].

Similarly, our study was in accordance with recent studies that reported improvement in cognitive performance on a working memory task among younger and older adults following moderate-intensity cycling [73]. In addition, our study supported that the positive effects of physical exercise intervention rely on enhancing psychological well-being, cognitive functioning, and quality-of-life, especially in older subjects with mild cognitive impairment, as reported recently in literature [74–76].

The present study showed a slightly insignificant change in cognitive ability scores and lipid profile-related markers among the control group. This change may be due to low-intensity physical activity, such as routine daytime life, which accounts for most activity energy expenditure (AEE) in people who do not regularly exercise [77]. These activities may be useful in health outcomes such as cognitive impairment. This is indicated by other research work, which reported that older women identified a positive association between cognitive performance and total daytime movement, which suggests that total activity may be necessary for cognitive outcomes [78]. Cognitive impairment and other metabolic disorders like CVD and stroke are significantly interrelated in older subjects with dyslipidemia [16, 79, 80]. However, lipid-lowering therapies have demonstrated benefits in stroke prevention and prognosis [18, 57, 81, 82].

Lipid profile and lipoprotein (a) makers, cholesterol, TG, HDL-C, LDL-C, and Lipo (a) were estimated in this study. Paired t-test and student t-test analysis showed that participants with cognitive impairments had abnormal basal levels of lipids and lipoprotein (a) makers. The data matched many studies that reported a significant relationship between abnormal lipid profiles and a negative impact on cognition in old age [83–87].

Also, this study had a significant association between physical activity and cognitive impairment as measured by LOTCA scores. In physically active participants, there was a significant reduction in the levels of TG, LDL-C, and Lipo (a), along with an increase in the level of HDL-C and LOTCA scores with overall cognitive improvement status following 24 weeks of moderate aerobic training. The data aligned with many studies that performed the positive effects of physical exercise as anti-dyslipidemia modulates via a significant reduction in the levels of circulating lipids and apolipoproteins (apos) induced by regular physical exercise [88–90]. Thus, incorporating exercise as a non-drug modulator in subjects with abnormal lipid profiles has priority among many clinical trials [91, 92]. The association between biological and cognitive aging among older ages is greatly supported by the dynamic link between physical activity and cognitive functioning via changes in biological fluids related to cognitive domains [86, 93, 94].

In the present study, cognitive parameters correlated negatively with the reduction in TG, LDL-C, and lipo (a) and positively with the increase in HDL-C and aerobic fitness levels as measured by VO2 max. The data were consistence with other studies that reported the potential positive link of many physiological mediators, including lipid profiles and aerobic fitness as potential mediators in physical activity-cognition relationships [95], and that the improved cognition significantly correlated with the increase in aerobic fitness and reduction in the levels of lipid profile [94–96].

Finally, the data obtained showed that physical activity status, aerobic fitness, and lipid profile played a pivotal role in the cognitive performance of healthy older adults.

Conclusions

In conclusion, the study's results indicate that engaging in moderate exercise for a duration of 24 weeks can lead to significant improvements in cognitive function among older individuals. These improvements were accompanied by positive changes in lipid profile and lipoprotein (a) markers. The findings revealed a strong correlation between cognitive performance and physical activity status and the regulation of lipids and lipo(a) markers. Specifically, physically active individuals demonstrated higher cognitive performance, reduced levels of total cholesterol, triglycerides, LDL cholesterol, and lipoprotein (a), as well as increased levels of HDL cholesterol and aerobic fitness (VO2 max) compared to sedentary participants. Cognitive performance was positively associated with increased aerobic fitness and HDL cholesterol while displaying negative associations with total cholesterol, triglycerides, LDL cholesterol, and lipoprotein (a). Notably, among older adults, significant improvements were observed in various aspects of cognitive function, including motor praxis, vasomotor organization, thinking operations, attention, and concentration. These findings highlight the importance of regular exercise for promoting cognitive health and lipid regulation in the aging population. Further research in this field can provide additional insights into the mechanisms underlying the relationship between exercise, cognitive function, and lipid metabolism, leading to the development of targeted interventions for optimizing brain health in aging populations.

Acknowledgements
The authors are grateful to the Researchers Supporting Project number (RSP2024R382), King Saud University, Riyadh, Saudi Arabia for funding this research.

Author contributions
Conceptualization, A.H.A. S.A.G and A.I; Data curation, S.A.G and A.H.A; Formal analysis and interpretation, S.A.G and A.I; Methodology, S.A.G; Project administration, A.H.A.; Supervision, A.H.A.; Writing – original draft, A.H.A. S.A.G and A.I; Writing – review & editing, S.A.G and A.I. All authors read, understood, and approved the final manuscript version to be published.

Funding
Researchers Supporting Project number (RSP2024R382), King Saud University, Riyadh, Saudi Arabia.

Data availability
All the data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
The study was performed according to the ethical guidelines of the 2013 Declaration of Helsinki, the study protocol was reviewed and approved by the Ethics Sub-Committee, King Saud University, Kingdom of Saudi Arabia, under file number ID: RRC-2014-011. Before data collection, written informed consent was obtained from all participating patients.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 9 January 2024 / Accepted: 2 August 2024
Published online: 13 August 2024

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