ORGINAL ARTICLE

Effect of Aerobic Exercise on HbA1c and Cognitive Function in Prediabetes Patients with Mild Cognitive Impairment

Fatemeh Khodaee[1], Hojjatollah Nikbakht[2*], Mandana Gholami[3], Mohammad Ali Babaee-Beigi[4], Khosrow Ebrahim[5]

1. PhD student of department of Physical Education and Sport Science, Science and Research Branch, Islamic Azad University, Tehran, Iran.
2. Department of Physical Education and Sport Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran.
3. Department of Physical Education and Sport Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran.
4. Department of Cardiology, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran.
5. Department of Sport and Exercise Physiology, University of Shahid Beheshti, Tehran, Iran

***Correspondence:**
Hojjatollah Nikbakht. Department of Physical Education and Sport Science, Science and Research Branch, Islamic Azad University. Daneshgah Blvd, Simon Bulivar Blvd, Tehran, Iran.
Tel: (98) 912 106 7749
Email: Hojnik1937@yahoo.com

Received: 13 September 2019

Accepted: 09 January 2020

Published in April 2020

Abstract

Objective: This study aimed to investigate the effects of moderate to high-intensity aerobic exercise on HbA1c (Glycated hemoglobin), FBS (fasting blood sugar) and cognitive function in mild cognitive impairment prediabetes patients.

Materials and Methods: Seventeen elderly mild cognitive impairment (age 55-70) men and women were selected and were randomly divided into 2 groups as aerobic (n=10) and control (n=10). Six subjects were excluded during the study. Finally, 14 subjects were continued the exercise program. Assessments were done at baseline and 12 weeks after intervention. The 12-weeks aerobic exercise program consisted of 90 min sessions in length 3 days per week under the supervision of the exercise specialist. Cognitive function, HbA1c, and FBS were evaluated. The differences in all variables (one way ANOVA), correlation (Pearson single correlation) and relative changes between baseline and 12 weeks (paired T-tests) were investigated.

Results: HbA1c, FBS decreased significantly in the aerobic group whereas cognitive function increased significantly after 12 weeks aerobic (*P*-value< 0.05 for all). Also, the change of cognitive function was significantly associated with a change of FBS (r= -0.84) after a 12-week aerobic exercise (*P*-value: 0.011). Differences between groups in HbA1c, FBS and cognitive function (Mini-Mental State Examination) were not significant.

Conclusion: Aerobic exercise may improve HbA1c, FBS and subsequently cognitive function in prediabetes elderly subjects. Therefore, a decrease in glycemic indicators could lead to improve cognitive function.

Keywords: Glycated hemoglobin A1c, Fasting blood sugar, Aerobic exercise, Mild cognitive impairment

Introduction

A lot of studies have been performed to determine the association between diabetes and dementia (1,2). However, The dependency on diabetes and cognitive decline are not well studied (1).

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

Diabetes is an identified risk factor for cognitive impairment and dementia (3,4). Although, the pathophysiologic mechanisms sustaining these associations are not well clear (3), but recognizing the risk factors of the cognitive impairment could help screening who may benefit from early intervention. (1,5).

Glycosylated hemoglobin is an important glycemic control indicator that illustrates an average of three months of blood glucose prediction (6). It is noticeable that increasing the level of HbA1c is highly associated with cognitive performance in middle-aged and older individuals (7). Moreover, In comparing to fasting plasma glucose, it is not clear whether HbA1c can provide more information about the cognitive function (8).

Due to the well-known effects of adiposity on insulin sensitivity and resistance, losing weight is key to prevent and control diabetes (9). Also, exercise training is a proven part of type 2 diabetes treatment. On the other hand, numerous clinical trials in type 2 diabetes patients, illustrated that structured exercise training improves coronary vessel disease (CVD) risk factors and glycemic control (10, 11) According to WHO, not enough physical activity may be considered as one of the foremost causes of mortality and disability throughout the world. However, exercise has an essential effect on blood glucose levels and therefore plays a significant role in the treatment of diabetic patients. On the other hand, various earlier investigations revealed that regular exercise training significantly reduces the values of HbA1c (12).

It has been well documented that regular exercise plays an important role in preventing and management of dementia by reducing the risk of T2DM (13). Aerobic exercise training has been recommended as the most appropriate form of exercise form which has a lot of positive metabolic effects, including reduced fasting blood sugar (FBS) levels (14) and also brain atrophy in older adults (7). On the other hand, it has been proved that exercise can improve cognitive function. However, most of the studies conclude to this, have been on healthy older adults, and therefore the applicability of these findings to older adults who are at high risk of cognitive decline and diabetes are not well documented. Also, there are few studies that have investigated the effects of exercise on cognitive function, HbA1c, and FBS (and whether exercise has a beneficial effect on the improvement of these three items) in prediabetes patients with mild cognitive impairment (15). The available guidelines for this matter are remarkably general and do not contain necessary information about duration, intensity, or most beneficial type of exercise for mentioned subpopulations to maximize the benefit while preserving minimal risk (16). To the best knowledge of present authors, not many studies directly investigated the effects of aerobic exercise on cognitive function, FBS and HbA1c (16). Therefore, this study aims to investigate the effects of 12 weeks of moderate to high aerobic exercise program on cognitive function, HbA1c, and FBS in prediabetes patients with mild cognitive impairment.

Materials and Methods

This research is a pilot study and was performed at the Shiraz university sports center and Imam Reza Cardiovascular Clinic, Shiraz, South Iran between October 2018 and January 2019. We selected 20 male and female patients with mild cognitive impairment (age 55-70) and were randomly divided into two groups as aerobic (n=10) and control (n=10). Three subjects were excluded during the study due to chest pain (n=1), job reason (n=2) and not have regular participation (n=3). Inclusion criteria in this study were as follows: subjects should have type 2 diabetes or prediabetes, they should not have regular physical activity from six months before the beginning of the research, they should not have the respiratory disease and heart failure and also do not have surgery for at least 6 months. The subjects selecting and their characteristics have been considered in Figure1 and Table1

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

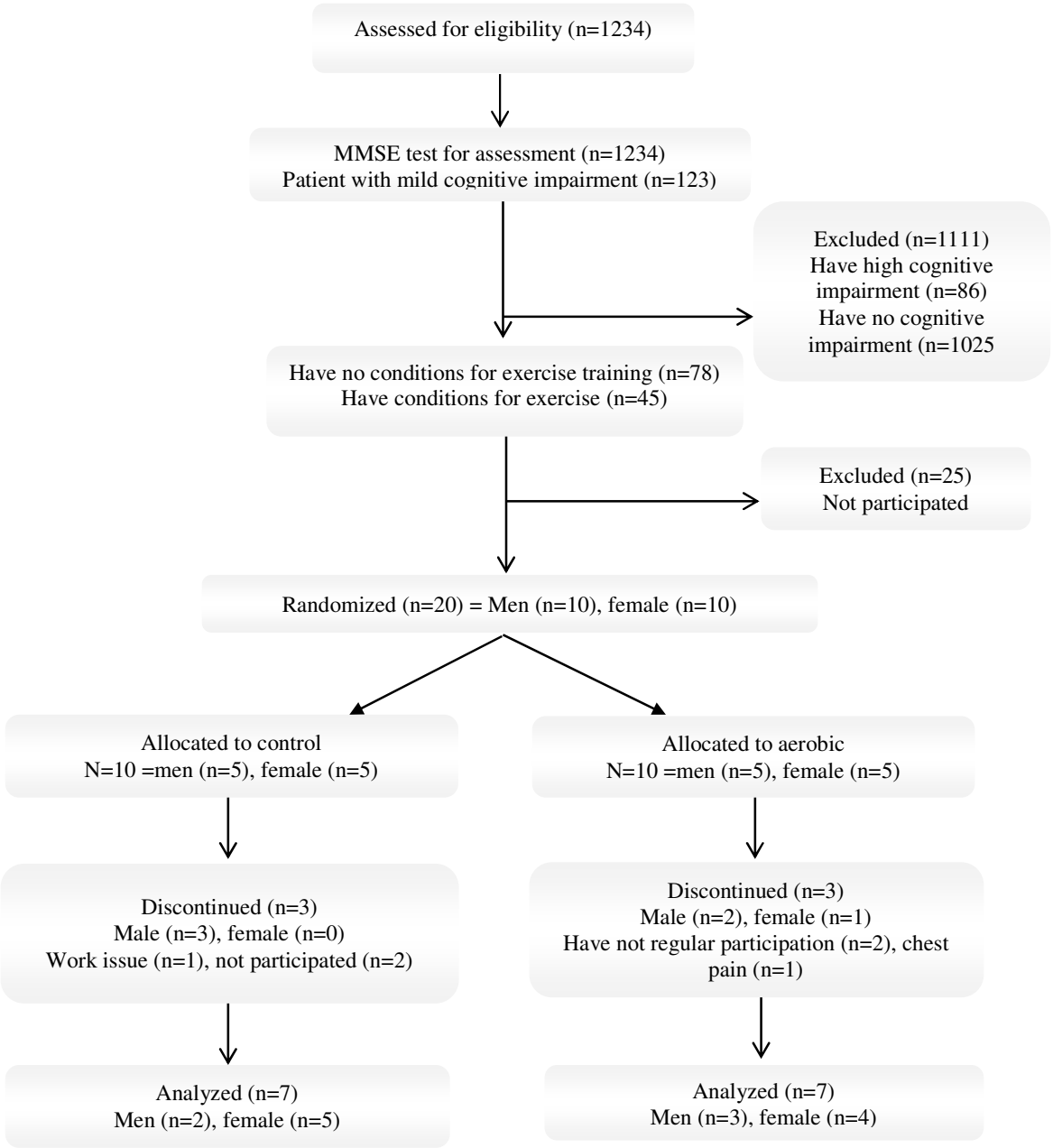


Figure 1. Selecting the subject flow diagram.

Table 1. The studied patients characteristics at baseline (n= 14)

Variable	Control (n=7)	Aerobic (n=7)
Male/female (n)	2/5	3/4
Age (y)	66.79 (±2.50)	65.4 (±2.93)
Height (cm)	157.41 (±4.45)	156.85 (±2.71)
BMI (kg/m^2)	28.61 (±1.83)	26.2 (±1.09)
HR (beats/min)	82.33 (±2.81)	73.57 (±2.37)
Systolic BP (mmHg)	132.5 (±3.00)	116.8 (±3.50)
Diastolic BP (mmHg)	83.3 (±3.30)	81.5 (±2.50)

Note. Data are mean ± SD, BMI = body mass index; HR=heart rate,

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

Aerobic exercise

The 12 weeks aerobic exercise program consisted of 90 min sessions in length 3 days per week. The first two weeks were considered for compatibility with exercise. Each session included a 10 minutes warm-up before and the same period cool-down after the exercise program, 10 minutes of aerobic games with mental challenges (Design by author), various walking methods for 15 min, 15 min walking on a treadmill,10 min cycling on cycle ergometer, 5 min stopper, 5 min kayak and 10 min for rest undertook progressive (moderate to high) intensity (60–85% of VO2 PEAK) 3 days per week (weeks 3-5; 60% of vo2 peak, weeks 6-8; 70% of vo2 peak, weeks 9-12; 85% vo2peak) (17).

Cognitive assessment

The cognitive function was assessed with the Mini-Mental State Examination (MMSE). The MMSE is a neuropsychological test (18). This examination has been widely used and according to this test, we can recognize cognitive impairment if the MMSE score, was 24 or less (9). The MMSE includes 11 questions and the test time is 5-10 minutes. The maximum score in MMSE is 30 and the questions are asked to the subjects and then scored. For any score, less than 25, suspect some degree of cognitive impairment (18). The MMSE is formed into two segments. The first part that has a maximum score of 21 consists of memory, addresses orientation and attention. The second part that has a maximum score of 9 includes, assessment of the ability of the participant to name, verbal commands and follow written, copy a complex polygon, and write a sentence. Most of the studies have used the MMSE as an instrument to evaluate cognitive impairment, and evidence has shown that the MMSE is a multidimensional instrument to recognize the cognitive function that includes attention, memory, concentration, language, and orientation (19). Seyedian et al by using the ROC curve showed that a cut-off point of 22 illustrated a sensitivity of 90 and specificity of 93.5 percent (20).

Biochemical parameters

Blood samples were collected between at baseline and 12 weeks after a 12 h overnight fasting for testing levels of FBS and HbA1c and sent to the biochemistry department at the Shiraz Hafez hospital, Iran for laboratory analysis. The glucose oxidase method, using Eco-Pak glucose reagent was implemented to measure the blood glucose. Moreover, HbA1c was determined by utilizing the immunoturbidimetric method which measured the absorbance of the HbA1c fraction and total hemoglobin fraction at 415 nm.

Statistical analysis

To examine group differences, data presented as mean ± SD were analyzed using a one-way analysis of variance (ANOVA). Relationships of cognitive function, FBS and HbA1c were evaluated by Pearson's single correlation test (10). To detect differences between pre and post time points, the paired T-tests were performed. For statistical analysis, Statistical Package for the Social Sciences (SPSS) ver. 22 (SPSS Inc, Chicago, IL, USA) was utilized. Statistical significance was set at P-value<0.05 (21).

Ethical considerations

Ethical approval was obtained from the ethics review board of the Institute of Physical Education and Sport Sciences (Code: IR.SSRC.REC.1397.019) and IRCT code: IRCT20181001041198N1.

Results

Subject characteristics at baseline are shown in Table 1.

Effects of aerobic exercise on cognitive function, HbA1c, body weight, and FBS:

After 12 weeks of aerobic exercise, cognitive function improved significantly (P-value: 0.007). Also, we observed that body weight, FBS and HbA1C decreased at 12th week compared with baseline and this reduction was significant in FBS (P-value: 0.01), body

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

weight (p-value: 0.03) and HbA1C (*P*-value: 0.01). (Table2)

FBS, HbA1C and cognitive function differences between groups:
There was no significant observed difference between control and aerobic groups in cognitive function (MMSE), FBS and HbA1C.

Associations of FBS, HbA1C and cognitive function (MMSE) at baseline:
At baseline, there were no meaningful correlations observed between FBS, HbA1C and cognitive function (MMSE). (Table3)

Relationships between changes in FBS, HbA1C and cognitive function (MMSE):
After 12 weeks aerobic exercise, decreased in FBS was associated with increased in cognitive function (*P*-value: 0.01, r= 0.84). Also decreased in body weight was associated with increased in cognitive function (*P*-value: 0.01, r= 0.84). There were no meaningful correlations between HbA1C and cognitive function (MMSE). (Table4)

Discussion

This research investigated the effects of a 12 weeks aerobic exercise training on cognitive function, FBS, HbA1c and body weight in elderly prediabetes with mild cognitive impairment. The main finding of this research

Table 2. The absolute changes in cognitive function, HbA1c, body weight, and FBS after 12 weeks

Variable	Baseline	12 weeks	Difference	*P*-value
HbA1c %				
Aerobic (n=7)	5.81 (±0.08)	5.06 (±0.20)	0.75 (±0.21)	0.013*
Control (n=7)	5.79 (±1.56)	5.76 (±1.45)	0.03 (± 0.11)	0.625
FBS (mg/dL)				
Aerobic (n=7)	101.28(±6.31)	77.14 (±1.56)	24.14 (±6.46)	0.011*
Control (n=7)	99.00 (±10.80)	98.50 (±10.08)	0.50 (±0.25)	0.660
MMSE				
Aerobic (n=7)	25.7 (±0.80)	28.1 (±0.50)	-2.42 (±0.61)	0.007*
Control (n=7)	23.60 (±3.55)	23.42 (±2.60)	0.18 (±0.95)	0.585
Body Weight (kg)				
Aerobic (n=7)	66.40 (±1.68)	65.51 (±1.90)	0.88 (±0.31)	0.032*
Control (n=7)	72.20 (±6.20)	71.80 (±6.98)	0.40 (±0.78)	0.574

Abbreviations: HbA1C: Glycated hemoglobin; FBS: Fasting Blood Sugar, MMSE: Mini-Mental State Examination Statistically significant difference within the group from baseline is indicated by *P*-value< 0.05 and *. Values are the mean and standard deviation of the mean (aerobic= 7, control: n= 7). The paired t-tests were performed to detect differences between time points (pre and post).

Table 3. Partial Correlations of FBS, HbA1c and cognitive function (MMSE) at baseline

Variable	Body weight		MMSE	
	r	*P*-value	r	*P*-value
Aerobic group:				
FBS (mg/dL)	-0.43	0.33	0.44	0.31
HbA1c %	0.25	0.58	-0.09	0.84
MMSE	-0.66	0.10	-	-

Note: MMSE= Mini-Mental State Examination, FBS= Fasting blood sugar, HbA1C= Glycated hemoglobin, * = significant. Evaluated by Pearson's single correlation test.

Table 4. Relationships between changes FBS, body weight, HbA1c and cognitive function (MMSE). N=7

Variable	Body weight		MMSE	
	r	*P*-value	r	*P*-value
Aerobic group:				
FBS (mg/dL)	-0.16	0.72	0.84	0.01*
HbA1c %	-0.11	0.65	0.004	0.99
MMSE	0.84	0.01*	-	-

Note: MMSE= Mini-Mental State Examination, FBS= Fasting blood sugar, HbA1C= Glycated hemoglobin, * = significant. Evaluated by Pearson's single correlation test.

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

was that the 12 weeks aerobic exercise training increased cognitive function simultaneously with decreasing FBS, HbA1C and body weight in elderly prediabetes women and men with mild cognitive impairment.

Relationship between HbA1c, FBS, cognitive function and body weight after 12 weeks' exercise:

To our knowledge, the studies about the effect of exercise training on the association of cognitive function and glycemic indicators are rare.

In this study, we demonstrated that decrease in HbA1c (nonsignificant) and FBS (r= 0.84 and *P*-value: 0.01) after 12 weeks of aerobic exercise was simultaneous with an increase in cognitive function. According to this, we can conclude that it seems a decrease in HbA1C and FBS was an independent risk factor for the future mild cognitive impairment in prediabetes elderlies. So according to these results, we can conclude that a further decrease in HbA1c and FBS leads to a greater increase in cognitive function. In the early stages of diabetes, cerebral neuropathological changes begin, which is with decreasing cognitive performance (24). According to some studies in literature, in comparison with healthy adults, abnormal blood glucose which is a characteristic of both prediabetes and type 2 diabetes is directly associated with increased risk of cognitive impairment (25). Hence, regular exercise has the ability of therapeutic effects on the cognitive function which is jeopardized by cognitive decline (such as Alzheimer's Disease) and type 2 diabetes (26). On the other hand, several other studies which in those who performed aerobic training or aerobic training plus diet control were not reported such a relationship between cognitive function and glucose changes (25). However, some previous studies which evaluated groups without diabetes were mainly focused on aerobic exercise and linked it to enhanced executive function (27). It is noticeable that adults with abnormal fasting blood glucose could show very early cognitive impairment (26). In comparison with non-diabetic individuals, mental speed and flexibility reduced in patients with type 2 diabetes (28). The mechanisms that lead diabetic patients to cognitive impairment are not fully understood. At the cellular level, fluctuations in glycemia have been shown more adversely affect endothelial function and in comparison to sustained hyperglycemia, cause oxidative stress (29), which potentially leads to more cerebrovascular damage and cognitive decline. Different researches reported that nominally by increasing the level of HbA1c cognitive function would be improved (30). Some studies demonstrated a noteworthy faster cognitive decline in diabetic than whom with normoglycemia (31). However, studies show inconsistency in the relationship between prediabetes and cognitive decline. As an example, Tuligenga et al stated no significant acceleration in cognitive decline in prediabetes people than those with normal HbA1C levels (5). Against that, Rawlings et al stated cognitive decline significantly accelerated in people with prediabetes than those with normoglycaemia (31). Therefore the second type of results confirms our opinion that HbA1C and FBS levels are critical to prevent cognitive decline within both direct and indirect mechanisms (32). So according to the identification of the results of pre-diabetic individuals is necessary to prevent cognitive impairment.

This study is one of the rare studies in elderly men and women that examine the influence of aerobic exercise on the association between cognitive function, HbA1c, FBS and body weight. It is noticeable that the present study was non-invasive research for examining the effectiveness of exercise preventing cognitive impairment concerning HbA1c, FBS and bodyweight reduction. However, it had several limitations. It is difficult to find patients who simultaneously have mild cognitive impairment and prediabetes, so we could not find more patients with such characteristics. Moreover, due to the small sample size, it was not possible to examine the influence of gender on the effect of regular exercise on this

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

mentioned. Furthermore, the limitations include the short duration of the study and also sample size (mentioned above); any mentioned factor could have changed the results of the investigation. Therefore, to realize the influence of exercise on HbA1c, FBS, cognitive function and body weight, a larger sample size over a longer period of training is required. Also, we could not measure the postprandial blood glucose. Finally, the patients' diet was out of control due to their physical condition.

Conclusions

In conclusion, aerobic exercise training may improve cognitive function after improving HbA1c, FBS in mild cognitive function patients. According to this, HbA1c and FBS levels are important factors for the prevention of cognitive impairment and hence we can conclude that the HbA1c and FBS reduction are independent risk factors for the future cognitive impairment in the elderly and the aerobic exercise is suitable for prediabetes elderlies with mild cognitive impairment.

Funding

This study was not funding supported.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

1. Zheng F, Yan L, Yang Z, Zhong B, Xie W. HbA 1c, diabetes and cognitive decline: the english longitudinal study of ageing. Diabetologia. 2018;61(4):839-48.
2. Crane PK, Walker R, Hubbard RA, Li G, Nathan DM, Zheng H,et al. Glucose levels and risk of dementia. New England Journal of Medicine. 2013;369(6):540-8.
3. Rawlings AM, Sharrett AR, Mosley TH, Ballew SH, Deal JA, Selvin E. Glucose peaks and the risk of dementia and 20-year cognitive decline. Diabetes Care. 2017;40(7):879-86.
4. Ryan JP, Fine DF, Rosano C. Type 2 diabetes and cognitive impairment: contributions from neuroimaging. Journal of geriatric psychiatry and neurology. 2014;27(1):47-55.
5. Tuligenga RH, Dugravot A, Tabák AG, Elbaz A, Brunner EJ, Kivimäki M, et al. Midlife type 2 diabetes and poor glycaemic control as risk factors for cognitive decline in early old age: a post-hoc analysis of the Whitehall II cohort study. The lancet Diabetes & endocrinology. 2014;2(3):228-35.
6. Olt S, Şirik M, Baykan AH, Çeliker M. The relationship between HbA1c and carotid intima-media thickness in type 2 diabetic patients. Pan African Medical Journal. 2016;23(1).
7. Zhao RR, O'Sullivan AJ, Singh MA. Exercise or physical activity and cognitive function in adults with type 2 diabetes, insulin resistance or impaired glucose tolerance: a systematic review. European Review of Aging and Physical Activity. 2018;15(1):1.
8. Huang Y, Bi Y, Wang W, Xu M, Xu Y, Li M, et al. Glycated hemoglobin A1c, fasting plasma glucose, and two-hour postchallenge plasma glucose levels in relation to carotid intima-media thickness in chinese with normal glucose tolerance. The Journal of Clinical Endocrinology & Metabolism. 2011;96(9):E1461-5.
9. Bower JK, Meadows RJ, Foster MC, Foraker RE, Shoben AB. The association of percent body fat and lean mass with HbA1c in US adults. Journal of the Endocrine Society. 2017;1(6):600-8.
10. Byrkjeland R, Njerve IU, Anderssen S, Arnesen H, Seljeflot I, Solheim S. Effects of exercise training on HbA1c and VO2peak in patients with type 2 diabetes and coronary artery disease: a randomised clinical trial. Diabetes and Vascular Disease Research. 2015;12(5):325-33.
11. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes care. 2010;33(12):e147-67.
12. Najafipour F, Mobasseri M, Yavari A, Nadrian H, Aliasgarzadeh A, Abbasi NM, et al. Effect of regular exercise training on changes in HbA1c, BMI and VO2max among patients with type 2 diabetes mellitus: an 8-year trial. BMJ Open Diabetes Research and Care. 2017;5(1):e000414.(in persian)
13. Callisaya M, Nosaka K. Effects of exercise on type 2 diabetes mellitus-related cognitive impairment and dementia. Journal of Alzheimer's Disease. 2017;59(2):503-13.
14. Siavoshy H, Heidarianpour A. Effects of Three Type Exercise Training Programs on FBS and HbA1C of Elderly Men with Type 2 Diabetes.

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]

Iranian Journal of Diabetes and Obesity. 2017;9(1):14-9.(in persian)
15. Byrkjeland R, Stensæth KH, Anderssen S, Njerve IU, Arnesen H, Seljeflot I, et al. Effects of exercise training on carotid intima-media thickness in patients with type 2 diabetes and coronary artery disease. Influence of carotid plaques. Cardiovascular diabetology. 2016;15(1):13.
16. Bweir S, Al-Jarrah M, Almalty AM, Maayah M, Smirnova IV, Novikova L,et al. Resistance exercise training lowers HbA1c more than aerobic training in adults with type 2 diabetes. Diabetology & metabolic syndrome. 2009;1(1):27.
17. Elsawy B, Higgins KE. Physical activity guidelines for older adults. American family physician. 2010;81(1):55-9.
18. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. Journal of psychiatric research. 1975;12(3):189-98.
19. Jones RN, Gallo JJ. Dimensions of the Mini-Mental State Examination among community dwelling older adults. Psychological medicine. 2000;30(3):605-18.
20. Seyedian M, Falah M, Nourouzian M, Nejat S, Delavar A, Ghasemzadeh H. Validity of the Farsi version of mini-mental state examination. Journal Of Medical Council Of I.R.I. 2008;25.(in persian)
21. Park J. Effects of 24-week resistance exercise training on carotid peak systolic and end diastolic flow velocity in healthy older adults. Journal of physical therapy science. 2016;28(10):2793-7.
22. Musenge EM, Manankov A, Mudenda B, Michelo C. Glycaemic control in diabetic patients in Zambia. The Pan African medical journal. 2014;19.
23. Cukierman-Yaffe T, Gerstein HC, Williamson JD, Lazar RM, Lovato L, Miller ME,et al. Relationship between baseline glycemic control and cognitive function in individuals with type 2 diabetes and other cardiovascular risk factors: the action to control cardiovascular risk in diabetes-memory in diabetes (ACCORD-MIND) trial. Diabetes care. 2009;32(2):221-6.
24. Luchsinger JA. Adiposity, hyperinsulinemia, diabetes and Alzheimer's disease: an epidemiological perspective. European journal of pharmacology. 2008;585(1):119-29.
25. Yuan XY, Wang XG. Mild cognitive impairment in type 2 diabetes mellitus and related risk factors: a review. Reviews in the Neurosciences. 2017;28(7):715-23.
26. Yaffe K, Blackwell T, Kanaya AM, Davidowitz N, Barrett-Connor E, Krueger K. Diabetes, impaired fasting glucose, and development of cognitive impairment in older women. Neurology. 2004;63(4):658-63.
27. Smith PJ, Blumenthal JA, Hoffman BM, Cooper H, Strauman TA, Welsh-Bohmer K, et al. Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. Psychosomatic medicine. 2010;72(3):239.
28. Brands AM, Biessels GJ, De Haan EH, Kappelle LJ, Kessels RP. The effects of type 1 diabetes on cognitive performance: a meta-analysis. Diabetes care. 2005;28(3):726-35.
29. Ceriello A, Esposito K, Piconi L, Ihnat MA, Thorpe JE, Testa R, et al. Oscillating glucose is more deleterious to endothelial function and oxidative stress than mean glucose in normal and type 2 diabetic patients. Diabetes. 2008;57(5):1349-54.
30. Beeri MS, Schmeidler J, Haroutunian V, West R, Ostad D, Grossman HT, et al. Better cognitive performance associated with worse cardiac functioning suggests antagonistic pleiotropy in very elderly subjects. The American journal of geriatric psychiatry: official journal of the American Association for Geriatric Psychiatry. 2009;17(10):911.
31. Rawlings AM, Sharrett AR, Schneider AL, Coresh J, Albert M, Couper D, et al. Diabetes in midlife and cognitive change over 20 years: a cohort study. Annals of internal medicine. 2014;161(11):785-93.
32. Luchsinger JA, Reitz C, Patel B, Tang MX, Manly JJ, Mayeux R. Relation of diabetes to mild cognitive impairment. Archives of neurology. 2007;64(4):570-5.

[Downloaded from ijdo.ssu.ac.ir on 2026-11-23]

[DOI: 10.18502/ijdo.v11i4.2877]