Changes in Cognitive Function and in the Levels of Glycosylated Haemoglobin (HbA1c) in Older Women with Type 2 Diabetes Mellitus Subjected to a Cardiorespiratory Exercise Programme

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Abstract: Ageing and diabetes are recognised as important risk factors for the development of cognitive deterioration. The aim was to analyse the effects of a walking-based training programme on cognitive deterioration and glycosylated haemoglobin (HbA1c) in older women with type 2 diabetes. This was a six-month experimental and longitudinal study with an experimental group (EG) (n = 57) and a control group (CG) (n = 52). All participants were diabetic with hypoglycaemic treatment. EG carried out a walking-based training program. After the training, we evaluated the diabetic state (HbA1c), cognitive functioning with the Mini-Mental State Examination (MMSE), cardiorespiratory fitness (VO2max) and body mass index (BMI). Results: EG obtained better results than CG in all the analysed variables. EG showed a significant improvement in the levels of HbA1c (−4.5%; p < 0.001), VO2max (+5.9%; p < 0.001) and BMI (−5.4%; p < 0.001); it also obtained increases in the scores of cognitive functioning, which were statistically significant in all dimensions, except for calculation (p = 0.384) and language (p = 0.168). Conclusion: The aerobic treatment produced significant improvements in the diabetic state and cognitive functioning in older women with type 2 diabetes.

Keywords: physical activity; walking; training; health; cognitive impairment; ageing

1. Introduction

Type 2 diabetes mellitus (DM2) represents an important disease burden in terms of morbidity, mortality and disability [1,2], which is associated with states of fragility [3]. More evident states of prefragility-fragility are shown in patients with DM2 than in non-diabetic people of the same age and sex [4], with both states increasing the risk of mortality and cardiovascular events [5]. Therefore, aging and diabetes are recognised as important risk factors for the development of functional deterioration and disability [6]. However, changes in lifestyle, nutrition, physical activity and cognitive training decrease the fragility index [7], since it has been reported that cognitive deterioration and/or physical fragility are powerful factors that identify diabetic people with high mortality risk [8].

DM2 has been shown to increase the risk of cognitive impairment [9] and depression [10]; it has also been proven to reduce pharmacological adherence and increase metabolic decompensation [11]. Likewise, DM2 patients present greater cognitive impairment, with prevalence of psychiatric...
disorders [12]. This cognitive fragility, in addition to physical fragility, is more frequent in younger individuals with DM2 than in those without diabetes [13], with the cognitive decrease being more evident in older women with DM2, who generally have a lower education level [14]. Cognitive decline in older individuals with DM2 has been attributed to a decrease in cerebral blood flow, affecting the medial temporal lobe and lower parietal regions [15], to brain network atrophy [16] and to the action of the adipocytokine protein nicotinamide phosphoribosyltransferase, which favours early cognitive damage [17].

Several studies associate diabetes with cognitive deterioration, since a linear correlation has been found between the latter and the blood levels of HbA1c, regardless of the diabetic state [18], suggesting that people with DM2 can reduce the risk of cognitive deterioration by maintaining good long-term glycaemic control [19]. High HbA1c concentration is associated with greater risk of dementia [20], since the former has been correlated with poorer executive functioning among people with cognitive deterioration [21], thus the presence of high levels of glycosylated peptides can be associated with greater cognitive deterioration, especially affecting the executive functions [22]. Furthermore, it has been concluded in animal models that aerobic exercise could partially reverse the cognitive deterioration associated with diabetes, as it reduces oxidative stress and brain inflammation [23]. Physical activity from early childhood to old age has been reported to have cognitive benefits, with potential long-lasting effects on brain health [24]. It has been asserted that physical training can potentially contribute to improving cognitive performance in patients with DM2 [25]. Moreover, slow walking has been previously identified as a predictor of both cognitive deterioration and dementia [14]. Likewise, the increase in walking speed has shown benefits in the cognitive functioning of older and sedentary people with diabetes [26].

However, it is globally estimated that 27% of cases of DM2 are caused by physical inactivity [27]. Furthermore, the literature does not provide complete evidence to assert that physical activity or exercise interventions contribute to improving the cognitive functioning of patients with DM2 or glucose intolerance [28]. The studies published to date on this topic do not seem to be sufficient to conduct a complete evaluation of the effects of non-pharmacological interventions to improve the cognition of DM2 patients [29].

The aim of the present study was to analyse the effects of a progressive walking training intervention on plasma concentrations of HbA1c and cognitive function in older women with type 2 diabetes mellitus and mild cognitive impairment (MCI).

2. Materials and Methods

2.1. Participants

This was a 6-month, experimental, longitudinal, and non-probabilistic study. Figure 1 shows the flowchart for the sample recruitment from a potential population of older individuals (n = 1150), who were registered patients of a healthcare centre of the Metropolitan Region of Santiago de Chile. Older women (n = 232) diagnosed with type 2 diabetes mellitus (DM2) were selected, all of whom had been under treatment with Metformin (850 mg/day) for 3 or 5 months. All the women were pensioners and they claimed to have a sedentary lifestyle, therefore, they just carried out basic domestic activities for self-help. Of this group of 232 women, 114 participated in the study and 107 completed the entire intervention period.

The sample size was calculated with an α of 5%, 95% confidence interval, and 0.5 minimal detectable difference. Two groups were randomised as experimental group (EG, n = 55) and control group (CG, n = 52). Both groups maintained the pharmacological treatment throughout the entire study. EG followed an aerobic physical training regime, which consisted of a structured programme of progressive walking. CG did not carry out any planned physical activity and performed their activities of daily living (ADLs). The women of both groups had an academic level that allowed them to read and write correctly without assistance. Table 1 shows the characteristics of the participants.
The following inclusion criteria were considered: (1) women over 65 years of age registered in the participating healthcare centre and with updated clinical examinations; (2) medical authorization compatible with the requirements of the cardiorespiratory physical training; (3) patients diagnosed with DM2 and under treatment with Metformin (850 mg/day) (4); pharmacological treatment of 3–5 months since diagnosis; (5) Mini-Mental State Examination (MMSE) score ≤ 24 points; (6) serum HbA1c ≥ 7.5%; (7) patients with reading and writing skills; and (8) signed voluntary consent. The following exclusion criteria were applied: (1) suffering from depressive episodes with medication; (2) pathological conditions incompatible with physical exercise; (3) missing over 20% of the training sessions; (4) showing some severe pathology during the study period. The process followed the indications of the Declaration of Helsinki approved by the World Medical Association [30] and by the Ethical Committee of the Pablo de Olavide University (Seville, Spain).

2.2. Procedure

For the blood analysis, the healthcare personnel of the healthcare centre took vein blood samples from the participants in the morning. The puncture was performed in the forearm vein, extracting
10 mL of blood into vacuum collection tubes for conservation and later analysis. The stable fraction of HbA1c was determined in the laboratory of the healthcare centre by ion exchange chromatography (IEC). The results were recorded for later treatment, assigning them a number associated with the name of each patient.

Cognitive deterioration was evaluated using the Mini-Mental State Examination (MMSE) [31] in its Spanish version, which had been previously validated in a sample of older Chilean adults [32]. We considered the recommendations on the clinical use of the Spanish versions of the MMSE [33] and we used a total valuation of 30 points and a cutoff score of ≤24 for the diagnosis of pathological suspicion of mild cognitive impairment (MCI) [34]. The test was administered individually and with no time limit. Prior to its administration, the test instructions were read, assigning an identification number to each individual with the aim of protecting their identity.

The 6-min walk test (6MWT) allowed determining the cardiorespiratory fitness of the participants (VO2max). This test can accurately estimate VO2max in a healthy adult population [35] with excellent test-retest reliability and moderate construct validity for the evaluation of patients with good functional capacity to perform exercises [36]. It can also be used to predict cardiorespiratory fitness in asymptomatic individuals [37] and it has been used in studies with patients who had different symptoms [38–40]. Moreover, it has been reported that the 6MWT is easy to perform and reliable for the evaluation of cardiorespiratory fitness in patients with DM2 [41]. Likewise, a significant correlation has been observed between the results of this test and the values of HbA1c [42]; it has even provided reliable and valid results to evaluate the walking capacity in fragile older individuals with dementia [43]. The 6MWT was carried out in homogenous groups of 10 participants in a 400-metre flat track, marked every 50 metres. The participants were encouraged to walk the longest possible distance in 6 min. The test was administered twice at the beginning of the intervention (test-retest), obtaining a correlation coefficient of \( r = 0.97 \) between the two measurements. VO2max was estimated using the following equation [44]:

\[
\text{VO2max} = 17.59 + 0.028 \times (6\text{MWT [m]}) - 0.256 \times (\text{BMI [kg/m}^2]) - 2.567 \times \text{gender: 0 male, 1 female) ± 3.25 mL/kg}^1 \times \text{min}^{-1}
\]

Table 2 shows the 6-month physical cardiorespiratory training, which was composed of 72 training sessions of 60 minutes each, with 3 sessions per week. The training sessions consisted in low to moderate progressive walks between 2.2 MET and 3.6 MET in a horizontal plane, with a fluctuation of the maximum cardiovascular demand between 40% and 65% of VO2max, and with a maximum energy expenditure of 4.6 Kcal/min.

2.3. Statistical Analysis

The statistical analysis was carried out using IBM-SPSS v.23. Means and standard deviations were obtained with descriptive statistics of central tendency and dispersion, respectively. We also obtained the confidence interval of the means at 95% as an indicator of reliability. Regarding the inferential statistics, the normality of the results was evaluated using the Kolmogorov-Smirnov test. The Levene statistic was obtained to determine the homoscedasticity between the groups. For the intragroup contrasts, the Student’s \( t \)-test or Wilcoxon’s test was carried out for related data, depending on the normality test. For the intergroup comparisons, the Student’s \( t \)-test or Mann-Whitney \( u \)-test was conducted, depending on the normality and homoscedasticity test. The effect size was calculated using Cohen’s \( d \). It was considered that values below 0.2 indicated a small effect size, 0.5 represented a medium magnitude and 0.8 indicated a large effect size.
Table 2. Cardiorespiratory training programme (walking).

| Week | Mesocycle 1 | Mesocycle 2 | Mesocycle 3 | Mesocycle 4 | Mesocycle 5 | Mesocycle 6 |
|------|-------------|-------------|-------------|-------------|-------------|-------------|
|      | %VO₂max    | Speed (m/min) | Speed (km/h) | METs        | Kcal/min    |
| 1    | 40          | 56.2        | 3.3         | 2.2         | 2.8         |
| 2    | 45          | 67.6        | 4.0         | 2.5         | 3.2         |
| 3    | 45          | 67.6        | 4.0         | 2.5         | 3.2         |
| 4    | 50          | 67.6        | 4.0         | 2.7         | 3.6         |
| 5    | 50          | 67.6        | 4.7         | 3.0         | 3.9         |
| 6    | 55          | 79.0        | 5.4         | 2.7         | 3.6         |
| 7    | 55          | 79.0        | 5.4         | 3.0         | 3.9         |
| 8    | 55          | 79.0        | 5.4         | 3.0         | 3.9         |
| 9    | 55          | 79.0        | 5.4         | 3.0         | 3.9         |
| 10   | 60          | 90.4        | 6.1         | 3.3         | 4.3         |
| 11   | 60          | 90.4        | 6.1         | 3.3         | 4.3         |
| 12   | 65          | 102         | 6.3         | 3.6         | 4.6         |
| 13   | 65          | 102         | 6.3         | 3.6         | 4.6         |
| 14   | 60          | 112         | 6.3         | 3.6         | 4.6         |
| 15   | 60          | 112         | 6.3         | 3.6         | 4.6         |
| 16   | 65          | 127         | 6.3         | 3.6         | 4.6         |
| 17   | 65          | 127         | 6.3         | 3.6         | 4.6         |
| 18   | 60          | 132         | 6.3         | 3.6         | 4.6         |
| 19   | 60          | 132         | 6.3         | 3.6         | 4.6         |
| 20   | 65          | 137         | 6.3         | 3.6         | 4.6         |
| 21   | 65          | 137         | 6.3         | 3.6         | 4.6         |
| 22   | 60          | 142         | 6.3         | 3.6         | 4.6         |
| 23   | 60          | 142         | 6.3         | 3.6         | 4.6         |
| 24   | 65          | 147         | 6.3         | 3.6         | 4.6         |
3. Results

Table 3 shows the pre-post comparisons in EG for all the analysed variables. As can be observed, there was a statistically significant improvement in all physiological variables. Thus, while VO2max increased (Pre-test: 19.2; Post-test: 20.3; \( p < 0.001 \)) there was a significant decrease in plasma HbA1c concentration (Pre-test: 8.1; Post-test: 7.7; \( p < 0.001 \)) and a considerable decrease of BMI. The EG improved the cardiorespiratory fitness and the diabetic state. Regarding the cognitive state variables, the MMSE recorded a statistically significant increase (Pre-test: 23.0; Post-test: 23.9; \( p < 0.001 \)), with a large effect size. Lastly, all dimensions increased significantly, except calculation and language.

Table 3. Intragroup comparisons before (pre-test) and after (post-test) the intervention (mean, standard deviation and confidence interval).

| Variable          | Pre          | Post         | Mean ± SD      | 95% (CI)  | Mean ± SD      | 95% (CI)  | p-Value          | Effect Size | Magnitude |
|-------------------|--------------|--------------|----------------|-----------|----------------|-----------|------------------|-------------|-----------|
| HbA1c (a)         | 8.10 ± 0.47  | (7.97 to 8.2) | 7.72 ± 0.55    | (7.6 to 7.9) | <0.001         | 0.66      | Medium           |
| BMI (b)           | 25.54 ± 2.17 | (24.9 to 26.1) | 24.13 ± 2.18  | (23.5 to 24.7) | <0.001         | 0.64      | Medium           |
| VO2max (a)        | 19.24 ± 1.64 | (18.8 to 19.7) | 20.35 ± 1.82  | (19.8 to 20.8) | <0.001         | 0.61      | Medium           |
| MMSE (b)          | 23.04 ± 0.69 | (22.8 to 23.2) | 23.96 ± 0.98  | (23.7 to 24.2) | <0.001         | 0.95      | Large            |
| Time Or. (b)      | 3.71 ± 0.63  | (3.54 to 3.98) | 4.38 ± 0.59   | (4.22 to 4.54) | <0.001         | 1.10      | Large            |
| Spatial Or. (b)   | 3.76 ± 0.58  | (3.61 to 3.92) | 4.20 ± 0.59   | (4.04 to 4.36) | 0.001          | 0.75      | Medium           |
| Registration (b)  | 2.02 ± 0.62  | (1.85 to 2.19) | 2.36 ± 0.59   | (2.20 to 2.52) | 0.001          | 0.57      | Medium           |
| Calculation (b)   | 5.44 ± 0.66  | (3.26 to 3.61) | 3.53 ± 0.72   | (3.33 to 3.72) | 0.984          | 0.13      | Trivial           |
| Recall (b)        | 2.35 ± 0.67  | (2.16 to 2.53) | 2.62 ± 0.49   | (2.49 to 2.75) | 0.009          | 0.46      | Medium           |
| Language (b)      | 1.29 ± 0.17  | (1.24 to 1.34) | 1.32 ± 0.13   | (1.28 to 1.35) | 0.168          | 0.18      | Trivial           |

Note: *p*-value: T test or Wilcoxon according to Normality. (a) Physiological variables and (b) Cognitive state variables; HbA1c: Glycosylated haemoglobin (%); BMI: Body Mass Index (kg/m²); VO2max: Maximum Oxygen intake (ml/kg/min); MMSE: Mini-Mental State Examination (maximum score 30); MMSE dimensions: Time Orientation, Spatial Orientation, Registration, Calculation, Recall, Language (maximum score 5).

Table 4 shows the pre-post comparisons in CG. Unlike in EG, all variables obtained lower values at the end of the study. Thus, VO2max presented a significant decrease (Pre-test: 19.3; Post-test: 18.6; \( p < 0.001 \)). However, BMI (Pre-test: 25.7; Post-test: 18.6) and HbA1c (Pre-test: 8.1; Post-test: 8.4) registered an increase at the end of the intervention period, both statistically significant (\( p < 0.001 \)). It is noted that the effect size was small or medium in physiological variables, while in MMSE total score (Pre-test: 23.3; Post-test: 22.5) the effect size was Large. All dimensions of cognitive status decreased significantly.

Table 4. Intragroup comparisons before (pre-test) and after (post-test) the intervention (mean, standard deviation and confidence interval).

| Variable          | Pre          | Post         | Mean ± SD      | 95% (CI)  | Mean ± SD      | 95% (CI)  | p-Value          | Effect Size | Magnitude |
|-------------------|--------------|--------------|----------------|-----------|----------------|-----------|------------------|-------------|-----------|
| HbA1c (a)         | 8.14 ± 0.51  | (8.03 to 8.3) | 8.45 ± 0.56   | (8.3 to 8.6) | <0.001         | 0.56      | Medium           |
| BMI (b)           | 25.71 ± 2.29 | (25.1 to 26.3) | 26.6 ± 2.44  | (25.9 to 27.3) | <0.001         | 0.36      | Small            |
| VO2max (a)        | 19.35 ± 1.53 | (18.9 to 19.8) | 18.6 ± 1.27  | (18.3 to 19)  | <0.001         | 0.86      | Large            |
| MMSE (b)          | 23.33 ± 0.65 | (23.1 to 23.5) | 22.5 ± 0.98  | (22.2 to 22.7) | <0.001         | 0.86      | Large            |
| Time Or. (b)      | 3.65 ± 0.68  | (3.46 to 3.84) | 3.31 ± 0.64  | (3.13 to 3.49) | 0.002          | 0.52      | Medium           |
| Spatial Or. (b)   | 3.81 ± 0.56  | (3.65 to 3.96) | 3.44 ± 0.75  | (3.23 to 3.65) | 0.002          | 0.55      | Medium           |
| Calculation (b)   | 3.35 ± 0.76  | (3.13 to 3.56) | 2.67 ± 0.78  | (2.45 to 2.89) | <0.001         | 0.87      | Large            |
| Recall (b)        | 2.42 ± 0.67  | (2.24 to 2.61) | 2.04 ± 0.74  | (1.83 to 2.24) | <0.001         | 0.55      | Medium           |
| Language (b)      | 1.31 ± 0.16  | (1.27 to 1.35) | 1.20 ± 0.18  | (1.15 to 1.25) | <0.001         | 0.67      | Medium           |

Note: *p*-value: T test or Wilcoxon according to Normality. (a) Physiological variables and (b) Cognitive state variables; HbA1c: Glycosylated haemoglobin (%); BMI: Body Mass Index (kg/m²); VO2max: Maximum Oxygen intake (ml/kg/min); MMSE: Mini-Mental State Examination (maximum score 30); MMSE dimensions: Time Orientation, Spatial Orientation, Registration, Calculation, Recall, Language (maximum score 5).

Table 5 presents the changes after the intervention (Post-test–Pre-test), and the comparisons between the two groups studied. The results clearly show that there was a totally different response in the group of women who carried out the exercise programme (EG) with respect to the group of
women who only did their activities of daily living (CG). All the analysed variables showed statistically significant differences (P < 0.001) with a magnitude effect size of large. The largest differences between groups were found in HbA1c and BMI with an effect size value of 2.2 and 1.8, respectively.

Table 5. Changes after the intervention. Between-group comparisons (mean, standard deviation and confidence interval).

| Change Exp. Group (n = 55) | Change Control Group (n = 52) | p-Value | Effect Size | Magnitude |
|----------------------------|-------------------------------|---------|-------------|-----------|
| Mean ± SD | 95% (CI) | Mean ± SD | 95% (CI) |
| HbA1c (a) | −0.36 ± 0.31 (-0.45 to 0.28) | 0.31 ± 0.30 (0.23 to 0.39) | <0.001 | 2.20 Large |
| BMI (a) | −1.41 ± 1.63 (-1.85 to −0.96) | 0.88 ± 0.64 (0.70 to 1.06) | <0.001 | 1.82 Large |
| VO2max (a) | 1.11 ± 1.20 (0.79 to 1.43) | −0.69 ± 1.31 (-1.06 to −0.33) | <0.001 | −1.44 Large |
| MMSE (b) | 0.93 ± 1.1 (0.63 to 1.23) | −0.85 ± 1.04 (-1.13 to −0.56) | <0.001 | −1.66 Large |
| Time O (b) | 0.67 ± 0.79 (0.46 to 0.89) | −0.35 ± 0.74 (-0.55 to −0.14) | <0.001 | −1.33 Large |
| Spatial O (b) | 0.44 ± 0.83 (0.21 to 0.66) | −0.37 ± 0.77 (-0.58 to −0.15) | <0.001 | −1.00 Large |
| Registrat. (b) | 0.35 ± 0.70 (0.16 to 0.53) | −0.48 ± 0.61 (-0.65 to −0.31) | <0.001 | −1.26 Large |
| Calculat. (b) | 0.09 ± 0.78 (-0.12 to 0.30) | −0.67 ± 0.55 (-0.83 to −0.52) | <0.001 | −1.13 Large |
| Recall (b) | 0.27 ± 0.73 (0.07 to 0.47) | −0.38 ± 0.66 (-0.57 to −0.20) | <0.001 | −0.94 Large |
| Language (b) | 0.03 ± 0.15 (-0.01 to 0.07) | −0.11 ± 0.16 (-0.15 to −0.06) | <0.001 | −0.88 Large |

*p-value: T test or U Mann-Whitney according to Normality and Homoscedasticity; (a) Physiological variables and (b) Cognitive State variables; HbA1c: Glycosylated haemoglobin (%); BMI: Body Mass Index (kg/m²); VO2max: Maximum Oxygen intake (ml/kg/min); MMSE: Mini-Mental State Examination (maximum score 30); MMSE dimensions: Time Orientation, Spatial Orientation, Registration, Calculation, Recall, Language (maximum score 5).

Figure 2 shows the percentage change of the Post-test with respect to the Pre-test in the physiological variables and in the results of the MMSE, comparing the analysed groups. As can be observed, the response of the groups is totally different in all variables. Thereby, HbA1c and BMI decreased in the EG (−4.5% and −5.4% respectively), while in the CG both increased (3.8% and 3.4% respectively). Regarding cardiorespiratory fitness (VO2max), the response was better in the EG (5.9% increase), than the CG (−3.3%). As for MMSE, the EG improved the score after the intervention program (4.1%), while the CG declined (−3.6%). All comparisons between groups showed statistically significant differences.
Figure 3 compares the percentage change of the cognitive state variables. The results are similar to those in Figure 2, that is, they are largely better in the EG than in the CG. While the EG improved all scores on all dimensions, the GC showed worse results on all dimensions at the end of the 6 months of intervention. The most important differences were recorded in registration (EG: 27% vs. CG: −26%) and recall (EG: 24% vs. CG: −15%). The smallest differences were found in language (EG: 3% vs. CG: −8%). All dimensions showed statistically significant differences in between-group comparisons.

![Figure 3. Between-group percentage change comparisons (MMSE dimensions); MMSE Dimensions: Time Orientation, Spatial Orientation, Registration, Calculation, Recall, Language (maximum score 5); (*) Significant differences T Student test or U Mann-Whitney Test.](image)

4. Discussion

The aim of this study was to verify whether aerobic physical exercise improves the levels of glycosylated haemoglobin and cognitive functioning in older women diagnosed with type 2 diabetes mellitus. To this end, the maximal aerobic power and BMI were evaluated as indicators of the degree of response to aerobic stimuli. Two groups of women diagnosed with type 2 diabetes were compared, with one of these groups conducting a 24-week cardiorespiratory training programme based on walking, whereas the other group maintained their usual activities of daily living.

4.1. Cardiorespiratory Fitness

The first consequence that can be attributed to the practice of physical activity is the significant improvement of VO2max in the experimental group (Table 3), whereas the control group showed a decrease in cardiorespiratory fitness (Table 4). These results are in line with those of numerous studies that demonstrate the importance of physical exercise in older adults [45–47], for instance in the improvement of aerobic power [48]; some studies even report that walking-based training programs improve the physical state in these populations [49]. On the contrary, a sedentary lifestyle in older adults with risk factors such as DM2 can have negative consequences on cardiovascular risk factors [50,51]. Corroborating the above mentioned in Table 5 and Figure 2, it is demonstrated that physical exercise is a determining factor of the different responses observed. These responses increased in the experimental group and decreased in the control group, and these differences were statistically significant between the two groups (p < 0.001), with a large effect size.
4.2. Body Mass Index

Regarding BMI, there was a response practically identical to that observed in VO2max in the two groups. As is shown in Table 3, the experimental group showed a significant decrease in BMI ($p < 0.001$) after completing the walk training, whereas the control group showed a statistically significant increase in this parameter after the 24-week period ($p < 0.001$). Most of the findings reported in the literature are in line with those obtained in this study, that is, the regular and systematic practice of exercise improves the BMI values in older populations [52]. Figure 2 presents the response obtained in the two groups, showing that a sedentary lifestyle has a negative impact on BMI [53].

4.3. Glycosylated Haemoglobin

The significant decrease observed in the experimental group after the 24-week walk training programme ($p < 0.001$ and a medium effect size) is in line with the results of numerous recent studies that reported changes in HbA1c in older adults with DM2. For example, a recent study carried out with only 22 women with DM2 obtained a decrease of almost 1% of the levels of HbA1c in the group subjected to the training programme [54], although the authors applied a Pilates program. However, exercise programs based on aerobic training in older women with DM2 have shown improvements in HbA1c levels [55]. A different study did not find a correlation between low-intensity physical exercise and improvements in HbA1c levels [56], although it was not an intervention study, as it evaluated physical activity via a telephone survey. Numerous studies demonstrate that the regular and systematic practice of physical exercise improves insulin resistance and HbA1c levels, even with low-intensity training programs [57–60], showing further efficiency with hypoglycaemic treatments [61]. These findings are in agree with the substantial difference in the response between the experimental group and the control group in HbA1c levels obtained in the present study (Figure 2). The lack of physical activity and a sedentary lifestyle lead to harmful responses related to insulin resistance and prediabetes indicators [62].

4.4. Cognitive State

Tables 3 and 4 show that the two groups began with mild cognitive deterioration. However, after the intervention period, the EG improved its MMSE score significantly ($p < 0.001$), almost reaching 24 points, with a large effect size. It has recently been reported that a multi-component physical exercise program did not improve cognitive function in participants with type 2 diabetes, perhaps because of the characteristics of the exercises program and the methodology design [63]. However, our results agree with several recent studies that reported improvements in cognitive deterioration in older women who carried out an aerobic exercise programme [64–67]. On the other hand, the CG showed a worse cognitive state after the 24-week study period, with a significant decrease in MMSE score ($p < 0.001$). This totally different behaviour between groups observed in cognitive deterioration (Figures 2 and 3) is corroborated with the statistically significant differences between the two groups shown by the data presented in Table 5.

It has been demonstrated that DM is a pathology that enhances cognitive deterioration in older people [18,20]. The results obtained in the control group, who did not carry out any physical activity other than their usual activities of daily living (Figure 3 and Table 3), confirm this increase of cognitive deterioration in all the dimensions evaluated in the MMSE. This cognitive deterioration has been described in older adults with DM and mild cognitive impairment (MCI) [17], also affecting executive functions [21]. On the other hand, the experimental group showed a statistically significant improvement in all the dimensions of the MMSE, except in calculation and language (Table 3); however, when compared to the control group, significant differences were found between the two groups in the five dimensions and the opposite behaviour of these variables in the two groups (Table 5 and Figure 3). Although some authors have reported that the effect of exercise does not improve the cognitive level in all dimensions [63,68], the scientific literature shows a large amount of recent evidence
on the improvement of the cognitive state in older adults after carrying out different types of physical exercise programs [69–71]. Thus, specifically older adults with type 2 diabetes, undergoing structured physical training, have shown improvements in aspects of cognitive function such as concentration and attention [72]. In any case, robust, long-term, large-scale randomized controlled trials are required to determine whether exercise improves cognition in this group of population (elderly people with type 2 diabetes) [28,73].

5. Conclusions

The results obtained in this study demonstrate that a low-moderate intensity aerobic exercise programme reduces the plasma levels HbA1c in older women with type 2 diabetes mellitus. Similarly, the group of diabetic women who carried out the aerobic training programme significantly improved their cognitive functioning valued through the MMSE. Moreover, the active group showed an important improvement of their cardiorespiratory fitness and body mass index.

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