International Journal of Environmental Health Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cije20

Effect of aquatic exercise on mental health, functional autonomy, and oxidative damages in diabetes elderly individuals

Luciano Acordi da Silva, Lorhan da Silva Menguer, Ramiro Doyenart, Daniel Boeira, Yuri Pinheiro Milhomens, Beatriz Dieke, Ana Maria Volpato, Anand Thirupathi & Paulo Cesar Silveira

INTERNATIONAL JOURNAL OF ENVIRONMENTAL HEALTH RESEARCH
https://doi.org/10.1080/09603123.2021.1943324

Taylor & Francis
Taylor & Francis Group

Effect of aquatic exercise on mental health, functional autonomy, and oxidative damages in diabetes elderly individuals

Luciano Acordi da Silva[a,b], Lorhan da Silva Menguer[a], Ramiro Doyenart[a], Daniel Boeira[a], Yuri Pinheiro Milhomens[a], Beatriz Dieke[a], Ana Maria Volpato[a], Anand Thirupathi[c] and Paulo Cesar Silveira[a]

[a]Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, Universidade do Extremo Sul Catarinense, Criciúma, Brazil; [b]Faculdade de Educação Física, Centro Universitário Barriga Verde, Orleans, brazil; [c]Faculty of Sports Science, Ningbo University, Ningbo, China

ABSTRACT

This study investigated the effect of aquatic exercise on mental health, functional autonomy, and oxidative dysfunction in elderly with DM2. A total of 104 elderly were included in the longitudinal clinical study and were attributed to the diabetes group (n = 30) and the non-diabetic group (n = 29). Both groups were involved in the aquatic exercise (nine exercises; 3 sets x 1-minute duration each; linear intensity and frequency measured twice a week) for 12 weeks. The assessments of mental health, functional autonomy, and oxidative dysfunction were done. All results were evaluated at baseline and 12 weeks later. The values of the following variable scores decreased in the DM2 group after participation in the aquatic exercise: depression (−56 ± 2 scores; 57%), anxiety (−8.2 ± 2 scores; 41%), stress (−3.1 ± 0.3 scores; 32%), and sleep (−3. 7 ± 1.3 points; 51%); an improvement in Berg scores was observed (+53.1 ± 2 points; 8%), Tug tests (−6.1 ± 0.7 points; 25%), carbonyl groups (−0.048 ± 0.01 nnmol/mg/protein; 49%), and total thiol (+0.33 ± 0.08 nnmol/mg/protein; 83%). We have concluded that a linear intensity aquatic exercise program improves mental health, functional autonomy, and oxidative dysfunction in elderly with DM2.

ARTICLE HISTORY
Received 5 March 2021
Accepted 10 June 2021

KEYWORDS
Anxiety; depression; exercise aquatic; functional mobility

Introduction

Type 2 diabetes mellitus (DM2) is a chronic metabolic disorder with tremendous socioeconomic impact. It affects around 347 million individuals per year worldwide and consequently causes more than 3.5 million deaths (Artilheiro et al. 2014; Delevatti et al. 2018). In 90% of the cases, these individuals are affected by the loss of peripheral insulin sensitivity, which leads to the development of hyperglycemic condition (Osama and Shehab 2015). Furthermore, this condition originates from multiple factors, including metabolic, genetic, and environmental factors (Osama and Shehab 2015; Cugusi et al. 2015) and can consequently compromise the mental health, functional autonomy, and oxidative dysfunction of diabetic subjects (Leedom et al. 1991; Chakraborty et al. 2011; Andersen et al. 2014; Delevatti et al. 2018; ShadiSadat et al. 2018).

Research has shown an increasingly noticeable relationship between DM2 diagnosis and a variety of mental health issues (Robinson et al. 2018). The prevalence of clinically relevant depressive symptoms among people with DM2 is approximately 30% (Barnard et al. 2006; Ali

CONTACT Luciano Acordi da Silva luciano_acordi@yahoo.com.br Laboratory of Exercise Psychophysiology, Advanced Aquatic Exercise Research Group, Universidade do Extremo Sul Catarinense, Criciúma, Brazil

et al. 2006). Stress disorder is associated with a 40% increased risk of developing DM2 (Kelly and Ismail 2015). Likewise, people with sleep apnea develop diabetes at higher rates than those without the condition (Ramos et al. 2015). One study even estimated that 14% of individuals with diabetes suffered from generalized anxiety disorder, with 28% experiencing a subclinical anxiety disorder and 52% having at least some anxiety symptoms (Grigsby et al. 2002). However, signs and symptoms of depression, anxiety, and stress in DM2 subjects can be correlated with problems that arise from the disease itself, which increase the severity of the mental health concerns (Naicker et al. 2017). DM2 subjects have feelings of inferiority due to the constant attention required to control the disease; at its most severe point, these feelings can trigger psychosis (Grigsby et al. 2002; Jernigan et al. 2012; Naicker et al. 2017).

Moreover, the deterioration of functional autonomy in DM2 individuals initiates sedentarism, which causes a deleterious, vicious cycle that further deteriorates the physical and mental health of elderly with DM2 (Morrison et al. 2012; Van der Heijden et al. 2013). In this sense, a decrease in functional autonomy has been associated with advanced DM2. In fact, DM2 is associated with a 50 to 100% excess risk of disability in men and women; nearly one in five cases of disability among older women is due to the disabling effects of diabetes (Volpato et al. 2010). In addition, older people with DM2, specifically those 60 years and older, are two to three times more likely to report an inability to walk a quarter mile, climb stairs or do housework compared to their non-diabetic peers (Kataoka et al. 2016).

Recently, research in this area has been focused on biochemical markers reflecting common pathophysiological processes of insulin resistance and oxidative dysfunction assumed to be intertwined in DM2 elderly (Lovrenčić et al. 2015; Rochette et al. 2014). This oxidation dysfunction has been the result of oxidant–antioxidant unbalance in favor of oxidants, resulting in oxidative damage. It is well known that the intensity of oxidative damage in diabetes is positively associated with the severity of disease (Lovrenčić et al. 2015; ShadiSadat et al. 2018). DM2 patients are particularly vulnerable to these detrimental effects, since hyperglycemia per se promotes excessive production of ROS resulting in oxidative damage (Chakraborty et al. 2011; Rochette et al. 2011)·

On the other hand, regular exercise has been associated with systemic adaptations that reduce clinical risk factors (decrease in fat mass, increase in lean mass, improvement in aerobic capacity, and regulation of dyslipidemia) that are associated with improvement in mental and muscular health in pathological subjects (Lovrenčić et al. 2015; Kataoka et al. 2016). Physical training in water is an alternative exercise regimen, and we have recently observed positive effects of aquatic exercise in pathological elderly (Silva et al. 2017, 2019). In diabetic individuals, aquatic exercises have improved the muscular resistance of the lower and upper limbs (Asa et al. 2012). Specific adaptations in skeletal muscle after exercise seem to benefit patients with 2DM since the active muscle tissue reveals a higher metabolic rate in glucose metabolism (Delavantti et al. 2018; Asa et al. 2012; Albright et al. 2000). Aquatic exercise enables a combination of aerobic and resistance exercises and is especially suitable for patients with advanced age, orthopaedic problems, or other comorbidities that hamper exercises on land (Delavantti et al. 2015). Due to the fluctuation effect in the water, the weight-bearing activities are much easier and the risk of falling in the elderly is less (Silva et al. 2019; Rochelle et al. 2014; Asa et al. 2012).

****Furthermore, the general outcome from research indicates that exercise with continuous intensity improves mental health (by reducing depression, anxiety, and stress) and autonomy functioning (by improving static and dynamic balance) and reduces oxidative damage (Van der Heijden et al. 2013; Volpato et al. 2010; Kataoka et al. 2016; Lovrenčić et al. 2015; Rochette et al. 2014). However, the specific effects of a linear intensity aquatic exercise program on the mental health, functional autonomy, and oxidative dysfunction in elderly diabetics remain unexplored. Thus, the objective of the study is to verify the effects of an aquatic exercise program with linear characteristics on mental health parameters, functional autonomy, and oxidative dysfunction in

DM2 elderly individuals. We hypothesized that exercise aquatic program improves mental health, functional autonomy, and reduced oxidative dysfunction of elderly with DM2.

Materials and methods

Ethical considerations

This study was carried out according to Resolution 466/12 of the National Health Council and was approved by the local ethics committee (CAE 63,101,316.3.0000.0119), obeying the basic criteria of Consort (Boutron et al. 2017). All participants provided informed written consent prior participation.

Randomized clinical trial

This longitudinal clinical study was conducted for 12 weeks, in which randomized groups consisting of subjects with and without DM2 participated in the same aquatic exercise program. The scores of mental health, functional autonomy, and oxidative damage parameters were analyzed 48 hours before staring and after completing the exercise program.

Randomization

There were 223 individuals recruited primarily from the list provided by the clinic sector of the local university. A researcher not involved in the study carried out this procedure to maintain the confidentiality of allocation and the blinding of investigators, by using simple randomization model with a computer-generated random binary list. The processes of randomization and allocation were performed after the completion of the initial assessment. From this list, 78 patients were clinically diagnosed with type II diabetes mellitus. Of these, on the day of the visit, 55 patients appeared for the screening process. Of the 55 patients, 20 were excluded based on the exclusion criteria, while an additional 5 refused to participate. Thus, 30 adult patients (5 men and 25 women) with ages ranging from 61 to 71 years were included and assigned to the DM2 group (66 ± 5 years). In the other group, 49 randomized non-diabetes subjects were selected, of which 14 were excluded based on the exclusion criteria, while an additional 6 refused to participate. Thus, 29 elderly subjects without diabetes (9 men and 20 women) aged between 60 and 68 years formed the non-diabetes group (64 ± 4 years) and were included in the study. Both groups participated in the same physical training program at the same place, time, and day of the week (Figure 1 – Randomization).

Subjects

Recruited subjects were elderly DM2 volunteers who received treatment for diabetes for a significant time span (7.3 ± 3.3 years), used diabetes medication, had a BMI of ≥25 kg/m2, and did not have any limitations on their physical activity, or changes to their drug therapy during the 6 months that preceded the study period. All the subjects signed the informed consent form, as well as the physical activity readiness questionnaire (Almeida and Ribeiro 2014 attesting that they were sedentary). Exclusion criteria were coronary artery disease; chronic pulmonary disease; heart failure; renal, pulmonary, and musculoskeletal disorders that impede the practice of aerobic exercise or psychological disorders; status after stroke; or other disabling diseases that might interfere with their participation in the aquatic exercise program. The process of patient recruitment is described in Figure 1. The patients were instructed not to change their medications as prescribed by the endocrinologist throughout the study (Table 1). In addition, participants from both groups who failed to complete more than 90% of the stipulated physical activity program were excluded from the analysis.

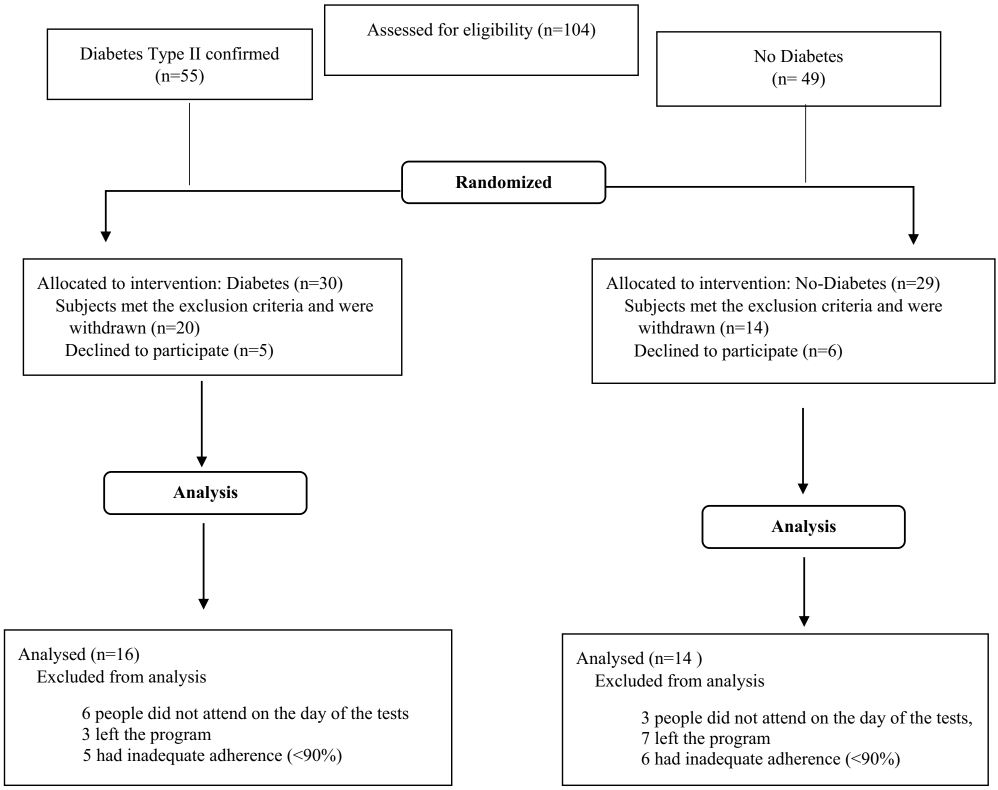

Figure 1. The CONSORT-Flow chart depicts the study-flow from screening until the analysis.

Table 1. Characterization of study subjects.

	No-Diabetes	Diabetes	P (value)
Age	64 ± 4	66 ± 5	0.091
Boy mass (Kg)	71 ± 14	78 ± 12	0.086
Height (m)	1.56 ± 10	1.58 ± 8	0.089
BMI (Kg^2)	29 ± 3	31 ± 4	0.977
Gender (M/W)	9/20	5/25	0.435
Medical Treatment	0	0	
Alprazolam	0	6	
Enalapril	0	2	
Fluoxetine	0	4	
Glibenclamide	0	1	
Glifage	0	1	
Glimepiride	0	8	
Losartana	0	5	
Meritor	0	9	
Rivotril	0	1	

Obs: Both groups had a 90% attendance rate. All middle-aged adults were new to the exercise model.

Intervention

Patients underwent a 12-week aquatic training program with biweekly sessions, each lasting 41 minutes. The intensity was similar in both groups. Heart rate was monitored using the Polar Heart (PolarM200) watch, and the Borg score for the rate of perceived exertion was measured in the final 20 s of each stage. The classes were conducted in the afternoon, in a pool with a depth of 1.40 m, and an area of 25 m x 12.5 m, filled with water at 26–28°C.

Exercise program

Each 41-minute session consisted of three phases: The first phase was a warm-up, with 5 minutes of shifting exercises that required subjects to move their arms and legs. After stretching the limbs, the static method was used. In the second phase, denominated as principal, specific hydro-gymnastics exercises were conducted according to the guidelines of the Association of Aquatic Exercises (Netto and Alevatto 2014). Methodologically, this part consisted of 31 minutes and 30 seconds, containing nine exercises of linear characteristics. The first three exercises were performed with light intensity (slow movements), the next three exercises with moderate intensity (moderate movements), and the last three with high intensity (fast movements). Each exercise consisted of three 1-minute series, with no interval. Between each exercise, 30 seconds of active interval was performed. Finally, the third phase, called relaxation, consists of slow walks for 4 minutes and 30 seconds. Both groups were observed by the same instructor, on the same day of the week and period, and the methodology of the session was identical.

Control in exercise intensity

Control of the exercise intensity was assessed by the maximum heart rate (HR) (Kanitz et al. 2019) and Borg scale (Borg 2000). The estimated maximum heart rate (HR) was achieved (220 minus the age of the participant, in beats per minute [BPM]), and the evaluation scale of Borg range from 6 to 20 was evaluated. HR intensity range was from 50 to 90% and the Borg between 11 to 16 points. One week prior the initiation of the experiment, all subjects were familiarized with the Borg scale at the pool edge and the heart rate monitors. During the exercise sessions, three students stood at the edge of the pool to collect data by asking senior practitioners questions about scale and HR at 10 min, 20 min, 31 min, and 41 min time points of the classes.

Clinical tests

Forty-eight hours prior to the first session and after the last training session, patients were clinically evaluated for their mental health, functional autonomy, and oxidative damage parameters. Dietary control was also undertaken with a 3-day diet record that was filled before and after the interventions (data not shown).

Mental health

The Beck's Depression Inventory (BDI) (Gomes-Oliveira et al. 2012) is a standardized self-administered questionnaire, described by the researchers at the Center for Cognitive Therapy (CCT) as a widely used measure for the self-assessment of depression, both in research and in clinical settings (Castelino et al. 2013). The BDI is a participant-administered questionnaire with 21 items. The total score ranged from 0 to 63 points, referring to sadness, pessimism, feeling of failure, lack of satisfaction, feeling of guilt, among others. Beck's Anxiety Inventory (BAI) (Gorenstein and Andrade 1996) is a scale presented with 21 items related to anxiety symptoms, each composed of four affirmations that evolve in the degree of intensity from 0 to 3. More than one affirmation can be chosen; however, the computed score is always one of greater intensity. Both inventories were translated into Portuguese and validated for the Brazilian population according to Gorenstein and Andrade (1996). Stress was measured using the Stress Inventory for Adults (ISSL) (Lipp 2000), which provides an objective measure of stress, consisting of three phases (alertness, endurance, and exhaustion). The Pittsburgh Scale (PSQI) was used to measure sleep quality (check the month), and the Epworth Sleepiness Scale (ESS-BR) (Bertolazi et al. 2009) was used to assess the level of sleepiness of people while performing daily tasks. The quantification of results is accounted for using the Likert scale ranging from 0 to 24 points. Cronbach's alpha ranged between 0.73 and 0.96.

Functional autonomy

To evaluate the risk of falls, we used the test 'Timed Up and Go' (TUG) in its classical version, developed by Podsiadlo and Richardson in (Podsiadlo and Richardson 1991). The test consists of raising of a standardized chair (seat height 43 cm; arm height 61 cm; seatback height 43 cm; depth 42 cm; width 40 cm), walking 3 meters in a straight line, turning around, returning to the place of departure, and sitting down again. To start the test, the test administrator gives the verbal command 'go.' The timer is triggered by the first movement of the old person's trunk and stops when the same leans on the chair. The lower the score, the better the result. The Berg balance scale (BBS) assesses functional balance performance based on 14 items common to daily life (Berg et al. 1992). The maximum score that can be reached is 56, and each item possesses an ordinal scale of five alternatives ranging from 0 to 4 points. The test is simple, easy to administer, and safe for the evaluation of elderly patients. It only requires a watch and a ruler as equipment and takes approximately 15 min to perform. The higher the score, the better.

Oxidative dysfunction

The oxidative dysfunction was measured by the determination of carbonyl groups (Levine et al. 1990) and total thiol content (Silva et al. 2017). Carbonyl groups are determined based on a reaction with dinitrophenylhydrazine (DNPH) (Levine et al. 1990). Proteins were precipitated by adding 20% trichloroacetic acid and reacted with DNPH. The samples were then redissolved in 6 M guanidine hydrochloride, and the carbonyl contents were determined by measuring absorbance at 370 nm using a molar absorption coefficient of 22,000 M − 1. The total thiol content was determined using the 5,5′-dithiobis (2-nitrobenzoic acid) method (DTNB) (Sigma) (Aksenov and Markesbery 2001). The reaction was started by adding 30 μL of 10 mM DTNB stock solution to phosphate-buffered saline (PBS). Control samples did not include DTNB. After 30 min of incubation at room temperature, the absorbance at 412 nm was measured, and the amounts of TNB (2-nitro-5-mercapto-benzoic acid) formed were calculated (equivalent to the amount of sulfhydryl proteins groups) according to the Aksenov and Markesbery technique.

Blood collection

Eight-milliliter samples of blood were obtained from the antecubital vein. Blood was collected in vacutainers without additives and centrifuged at 1500 rpm for 10 min at 4°C. Aliquots of red blood cells and serum were stored at −70°C until used in the biochemical assays.

Statistical analysis

Data points are expressed as means ± standard errors of the mean (SEM). The Kolmogorov–Smirnov test was used to confirm normality. The Chi-square test for nonparametric analyses was also used and followed by the Bonferroni post hoc test. A priori sample size was calculated based on a predicted difference of 0.5% for the score of TUG = 0.05 and a power of 0.90, performed with IBM Statistical Package for the Social Sciences (SPSS) software (Armonk, New York; version 18), that was based on the study of Silva et al. (2019). This calculation indicates that 14 patients in each group were sufficient to detect significant changes in functional autonomy. The level of significance established for the test was $p < 0.05$.

Results

Figure 1-Randomized: Group DM2: Of the 55 eligible patients, 20 patients were excluded according to the exclusion criteria and five refused to participate. Therefore, 30 elderly (5 males and 25 females)

were included in this study. During the exercise program, 6 people did not attend on the day of the tests, 3 left the program, and 5 had inadequate adherence (<90%), which resulted in a final sample of 16 elderly. Non-Diabetic group: Of the 49 patients assessed for eligibility, 14 did not meet the inclusion criteria, and 6 refused to participate. Therefore, 29 elderly (9 males and 20 females) were included in the study. During the exercise program, 3 people did not attend on the day of the tests, 7 left the program, and 6 had inadequate adherence (<90%), which resulted in a final sample of 14 elderly.

Table 1: Baseline characteristics of the subjects, including age, body mass, BMI, gender, and medical treatment, are shown in Table 1, and we observed that there were no significant differences between groups in these parameters ($p > 0.05$). The values are presented as means ± SEM.

Table 2: Next, we studied the exercise intensity of the non-diabetic and DM2 elderly (Table 2). We observed that there was a significant linear increase in HR and BORG scores of bouts ($p < 0.05$) at 10 min (84 ± 7 HR; 99 ± 10 HR; 11 ± 1ponts 12 ± 2ponts), 20 min (110 ± 7 HR; 114 ± 9 HR; 12 ± 2ponts; 13 ± 1ponts), and 31 min (139 ± 5 HR; 142 ± 8 HR; 15 ± 1ponts; 16 ± 1ponts) during the exercise as compared to before the exercise (74 ± 5 HR; 82 ± 6 HR; 0ponts; 0ponts) and during the times of 10 min and 20 min.

Table 2. Intensity control of the exercise sessions.

	Before	10 mim	20mim	31mim	41mim
No-diabetes (HR)	74 ± 5	84 ± 7*	110 ± 7**	139 ± 5***	85 ± 9
Diabetes	82 ± 6	99 ± 10*	114 ± 9*	142 ± 8***	92 ± 7
No- diabetes (Borg)	0	11 ± 1*	12 ± 2*	15 ± 1**	0
Diabetes	0	12 ± 2*	13 ± 1*	16 ± 1***	0

Note: Values were obtained during the 1st, 6th and 12th week of the exercise program. The statistical differences ($p < 0.05$) are marked with (*) signaling in relation to the values before, (**) signaling in relation to the values in 10mim; (***) signaling in relation to the values in 20mim. Heart rate (HR); Borg Scale of Perceived Exertion (BORG);

Table 3. Mental health.

	Non-diabetes	P (value)	Diabetes	P (value)
Depression (scores)				
Before	4.69 ± 4.13		13.3 ± 6.07	
After	5.50 ± 5.66	0.85	5.66 ± 3.12*	0.01
Percent	19%		-57%	
Anxiety (score)				
Before	4.8 ± 2		14 ± 1.6	
After	4.2 ± 4	0.06	8.2 ± 2.1*	0.05
Percent	−12%		-41%	
Stress (score)				
Phase 1				
Before	2.3 ± 0.7		3.2 ± 0.4	
After	2.5 ± 0.6	0.73	2.4 ± 0.2*	0.05
Percent	8%		-25%	
Phase 2				
Before	3.1 ± 0.4		4.3 ± 0.8	
After	3.0 ± 0.2		4 ± 0.5	0.08
Phase 3				
Before	2.8 ± 0.4		4.6 ± 0.4	
After	3.3 ± 0.5	0.06	3.1 ± 0.3*	0.04
Percent	17%		-32%	
Sleep (score)				
Before	3.5 ± 1		7.7 ± 2	
After	3.3 ± 2	0.81	3.7 ± 1.3*	0.03
Percent	−5%		-51%	
Somnolence (score)				
Before	5.8 ± 3		4.6 ± 2	
After	4.7 ± 3		6.4 ± 2	0.077

Note: The symbol (*) indicates intra group statistical differences.

Table 3: Then, we evaluated the mental health of DM2 and non-diabetic elderly before and after exercise. Our results observed a significant reduction ($p < 0.01$) in the levels of depression of DM2 elderly after exercise (5.66 ± 3.12 scores) when compared to before exercise (13.3 ± 6.07 scores). In relation to the non-diabetic elderly, there was no significant difference after the program (5.50 ± 5.66 scores) when compared to before the program (4.69 ± 4.13 scores). Also, depression levels decreased (57%) in DM2 elderly after exercise when compared to before exercise. Anxiety levels were also significantly reduced for DM2 elderly after the program (8.2 ± 2.1 scores), when compared to before (14 ± 1.6 scores), whereas non-diabetic subjects had a significant difference after exercise (4.2 ± 4 scores), when compared to before (4.8 ± 2 scores). Clinically, the anxiety level (41%) of DM2 and non-diabetic elderly decreased after performing exercise when compared to before exercise.

In relation to stress levels, our findings demonstrate that DM2 elderly after the aquatic exercise program had significantly reduced ($p < 0.05$) stress parameters in phase 1 (2.4 ± 0.2 scores) and 3 (3.1 ± 0.3 scores) when compared to before the aquatic exercise program (3.2 ± 0.4 scores, 4.6 ± 0.4 scores, respectively). In relation to the non-diabetic elderly, there was no significant ($p > 0.05$) difference in phase 1 (2.5 ± 0.6 scores), 2 (3.0 ± 0.2 scores), and 3 (3.3 ± 0.5 scores), when compared to before the aquatic exercise program (2.3 ± 0.7 scores, 3.1 ± 0.4 scores, 2.8 ± 0.4 score, respectively.) Clinically, there was a decreased stress level in phase 1 by 25% and in phase 3 by 32%.

Regarding sleep quality, we observed a significant difference in sleep disturbances ($p < 0.05$) in the DM2 elderly after the aquatic exercise program (3.7 ± 1.3 scores), when compared to before the exercise program (7.7 ± 2 scores). In relation to non-diabetic elderly, there was no significant difference ($p > 0.05$) after the program (3.3 ± 2 scores) compared to before (3.5 ± 1.5 scores). We observed that clinically there was an improvement (51%) in sleeping quality. In relation to sleepiness, our results showed that there was no significant difference ($p > 0.05$) in both groups, after the program (4.7 ± 3 scores; 6.4 ± 2 scores), compared to before the program (5.8 ± 3 scores; 4.6± scores).

Table 4: Next, we analyzed the task-oriented balance of the DM2 and non-diabetic groups using the BERG test. There was a significant increase ($p < 0.05$) in the BERG scale for both the DM2 (53.1 ± 2.1 scores) and non-diabetic (53.2 ± 2.3 scores) groups after completing the training program compared to before completing it (46 ± 2.1 sec; 49 ± 1.9 scores) (Table 4). Clinically, there was an 8% increment observed in the static mobility of the elderly. Then, we used the TUG test to assess static and dynamic balance of DM2 and non-diabetic elderly (Table 4). We observed a significant decrease in the TUG scores for DM2 elderly after the training program (6.1 ± 0.7 sec), compared to before (8.2 ± 0.9 sec). Meanwhile, there was no significant alteration ($p = 0.089$) in the TUG test of the non-diabetic elderly after the training program (6.4 ± 0.6 sec), compared to before (7.2 ± 1.1 sec) (Table 4). Clinically, there was a 25% improvement in the dynamic mobility in elderly.

Table 5: Next, we analyzed the oxidative dysfunction of the DM2 and non-diabetic groups using the protein carbonylation and total thiol content techniques. There was a significant reduction ($p < 0.05$) in after aquatic exercise program the carbonyl group (0.048 ± 0.01 nnmol/mg/protein)

Table 4. Functional autonomy.

	No-diabetes	Diabetes	Percent
Berg Balance Scale (scores)			
Before	49 ± 1.9	46 ± 2.1	
After	53.2 ± 2.3*	53.1 ± 2.1*	8%
Timed Up & Go (seconds)			
Before	7.2 ± 1.1	8.2 ± 0.9	
After	6.4 ± 0.6	6.1 ± 0.7*	25%

Note: Values were obtained before and after the aquatic training program. The symbol (*) indicates intra group statistical differences ($p < 0.05$). Berg Balance Scale and Timed Up & Go.

Table 5. Analyzed the oxidative dysfunction.

Marcadores	No-diabetes	Diabetes	Percent
Protein carbonylation (nnmol/mg/ proteín)			
Before	0.076 ± 0.02	0.097 ± 0.02	
After	0.061 ± 0.01	0.048 ± 0.01*	49%
Total thiol content (nnmol/mg/ proteín)			
Before	0.27 ± 0.05	0.18 ± 0.05	
After	0.36 ± 0.07	0.33 ± 0.08*	83%

Note: Values were obtained before and after the aquatic training program. The symbol (*) indicates intra group statistical differences ($p < 0.05$). Protein oxidation and total thiol content.

and an increase in the total thiol (0.33 ± 0.08 nnmol/mg/protein) in the DM2 group compared to the pre-program (0.097 ± 0.02 nnmol/mg/protein; 0.18 ± 0.05 nnmol/mg/protein), respectively.

However, there were no significant changes ($p > 0.05$), in the non-diabetic group when compared post-program (0.061 ± 0.01 nnmol/mg/protein; 0.36 ± 0.07 nnmol/mg/protein) and pre-program (0.076 ± 0.02 nnmol/mg/protein; 0.27 ± 0.05 nnmol/mg/protein) (Table 5). Clinically, there was a reduction of 49% in protein carbonylation and an increase in thiol content of 83% of the elderly.

Discussion

Several studies have pointed out that exercise programs with continuous characteristics have improved mental health and functional autonomy for patients with chronic diseases (Van der Heijden et al. 2013; Chang et al. 2017; Ebrahimi et al. 2017). The present study demonstrated that 12 weeks of an aquatic exercise program with linear characteristics may contribute to improved mental health scores, functional parameters, and reduced oxidative dysfunction in elderly with DM2. We emphasize that non-diabetic subjects respond in the same way in relation to the effects of exercise in the evaluated parameters. The comorbidities of the disease limit the diabetic subject's active lifestyle. Aquatic physical exercise is a smart strategy to overcome complications, as it has high adherence rates and low risk. In our study, 90% of diabetics who started the aquatic exercise program finished it.

Clinically, heart rate and Borg scale have been used in previous studies to control the intensity, due to the operational difficulty of using gas analyzers to measure VO2max. Our study pointed out that the heart rate and Borg scale (Table 2) increased linearly during the exercise sessions, characterizing the program as linear. Several studies indicate that exercise programs with continuous characteristics have been used on individuals with DM2, positively affecting mental health (Colberg et al. 2010; Cugusi et al. 2015; Gilani and Feizabad 2019). We suggest that the linear model used in the present study presents similar results to the continuous exercise models regarding mental health and autonomy aspects (Colberg et al. 2010; Gilani and Feizabad 2019).

Specifically, various mental health scores were evaluated in the present study. The first parameter investigated was the levels of depression (Table 3) of DM2 elderly. Several studies have pointed out that subjects with DM2 have altered levels of depression (Leedom et al. 1991; Van der Heijden et al. 2013; Moraes et al. 2017). According to our findings, the proposed intervention model was able to reduce depressive parameters of the DM2 in elderly (Antunes et al. 2005) demonstrating that aerobic exercise (3 times a week for 6 months) with constant intensity reduced depression scores in the elderly. Another study with another model of physical exercise shows similar results (Van der Heijden et al. 2013; Osama and Shehab 2015). As per the current literature, that diabetes mellitus has neurochemical impacts on noradrenergic, serotonergic, and dopaminergic central systems, leading to a decrease in monoaminergic function, similar to the physiological experience of being in a depressive state (Van der Heijden et al. 2013; Moraes et al. 2017). Despite these neural underpinnings associated with diabetes, several studies have shown that the benefits of exercise are psychophysiological and, thus, allow improved mood, decreased sadness, and increased oxygenation of the cerebral cortex and monoamines, all which consequently help reduce depression (Antunes et al. 2005; Hofmann et al. 2016).

Next, we investigated the effect on anxiety levels. Studies have reported that people with DM2 have developed clinical signs of generalized anxiety (Araújo et al. 2007; Colberg et al. 2010; Naicker et al. 2017). Our results demonstrate significant reductions in anxiety levels after 12 weeks of the intervention, which may be because aerobic exercises of moderate intensity do not accumulate blood lactate. According to (Araújo et al. 2007), accumulation of blood lactate is directly related to psychological disorders. Psychological complications occur because the brain depends on the main energy source (glucose) for the excessive energy demand that the brain requires to function (Osama and Shehab 2015; Cugusi et al. 2015). Gilani and Feizabad (2019) used a steady-state aerobic exercise program to improve the anxiety scores of diabetic patients. Thus, our findings suggest that the linear characteristics of the aquatic exercises adopted in this study may modulate biochemical substances, which may explain anxiety reduction. Overall, this possible modulation should be noted for future studies.

We analyzed the stress levels of DM2 elderly. Stress has been shown as an automatic and natural response of the body to situations that are challenging or threatening. Diabetes and aging can increase susceptibility to the effects of stress (Hofmann et al. 2016). Our results observed that an aquatic aerobic program undertaken by DM2 elderly reduced their stress levels significantly. A different study with another model of physical exercise shows similar results (Van der Heijden et al. 2013; Fiocco et al. 2013). The explanation for this finding is that physical exercise releases endorphins captured in specific regions of the central nervous system producing an analgesic and tranquilizing effect by adjacent mechanisms. It is proven that models of aquatic exercises have stimulated the increased production of the neurotransmitter's dopamine, serotonin, and norepinephrine, which helped in this process (Van der Heijden et al. 2013; Fiocco et al. 2013).

The fourth measure investigated in our study was the behavior of sleep. When the individual abstains from sleep, hypersecretion of insulin occurs, necessitating a greater intake of food, especially carbohydrates, which can in excess trigger obesity, aggravating the clinical picture of diabetes (Driver and Taylor 2000; Durstine et al. 2013). Our results demonstrate a significant improvement in sleep of DM2 elderly. Delevatti et al. (2018) found improvements in sleep quality of diabetic subjects due to a linear intensity aquatic aerobic exercise program. The explanation for this finding has been supported by studies that suggest that body temperature rises when exercising, which then helps 'the firing' of the onset of sleep by activating the heat dissipation processes regulated by the hypothalamus, which is also the region responsible for sleep (Driver and Taylor 2000). Furthermore, in regard to a psychophysiological state, exercise has been associated with a melatonin-releasing mechanism that contributes to this outcome (Levine et al. 1990). It is important to note, however, that there were no significant differences in the levels of sleepiness in our results. A possible cause for this lack of significance is that the general classification system of the scale resulted in our subjects falling within normality, a finding that corroborates with those of other studies (Driver and Taylor 2000; Ebrahimi et al. 2017).

We evaluated the functional autonomy through the BERG test (Table 4). Impaired balance is one of the top three risk factors for falling and, therefore, associated with fear of falling and reduced quality of life in people with DM2 (Morrison et al. 2012; Durstine et al. 2013). Our results evidenced a significant improvement of this aspect in DM2 elderly following the aquatic exercise program, corroborating with other findings (Oliveira et al. 2015; Ebrahimi et al. 2017). Pernambuco et al. (2013) conducted a hydro gymnastic program with constant intensity, which improved functional autonomy in older women. It is important to emphasize that the physical properties of the water (density and viscosity) alter the gait pattern and therefore reduce vertical overload (gravitational force) and increase horizontal overload (water resistance force), which may help to elucidate these results given the increase in force and horizontal instability provided by the liquid medium.

Another parameter of functional autonomy was evaluated using the TUG test (Table 4). The test has been widely used in clinical practice as an outcome measure to evaluate functional mobility, fall risk, or dynamic balance of the population (Steffen et al. 2002; Shumway-Cook et al. 2002). The study by Morrison et al. (2012) pointed out that the loss of functional capacity increases the risk of falls, which is thus aggravated by the onset of diabetes mellitus. Our results observed that there was an improvement in how elderly with DM2 performed on this test following the program of aquatic physical exercises. This functional improvement is interconnected with the neuromuscular effect that aquatic training produces in the practitioners. Ruzene and Navega (2014) demonstrated that aquatic training improves the responses demanded by the TUG test in diabetic men. This result shows that exercise performed in a liquid environment improves the muscular activity of the elderly, supporting their basic strength and agility in performing vital daily activities, such as sitting and lifting.

Finally, we evaluate the oxidative dysfunction (Table 5). This is a result of the executive production of EROs and the inefficiency of an antioxidant defense system, in favor of pro-oxidants result oxidative damage (Chakraborty et al. 2011; Silva et al. 2017; ShadiSadat et al. 2018). There is evidence that people with DM2 have higher concentrations of oxidative damage (Roberts and Sindhu 2009; Ávila-Escalante et al. 2020). Our results show that elderly diabetics submitted to an aquatic exercise program with a linear characteristic have reduced oxidized proteins (carbonyl) and increased non-oxidized proteins (thiol). This response is an excellent indicator of reduced oxidative disfunction (Chakraborty et al. 2011; Silva et al. 2017; Seyyedebrahimi et al. 2018). The reduction in oxidative dysfunction can be explained by the oxidative adaptations (enzymatic and non-antioxidants, shock proteins, and tissue resistance to attack by EROS), which are caused by aquatic training in normal and pathological individuals (Ji 2002; Silva et al. 2017, 2019). We suggest that elderly diabetics respond in a similar way.

As a limitation, we pointed out the lack of a balanced nutritional diet and the absence of medication to control diabetes during the entire study. This limitation occurs frequently for ethical reasons in studies involving humans.

Conclusion

The present study concludes that 12 weeks of linear aquatic exercise program can reduce depression, anxiety, and stress by improving sleep quality, functional autonomy, and oxidative dysfunction in DM2 elderly individuals. We also point out that DM2 elderly respond in the same way as non-diabetic individuals in relation to the effects of a linear aquatic exercise program. We believe that the use of drugs associated with the exercise program helped in the treatment by improving the results of this study.

Acknowledgments

The authors thank especially all the participants who made this project possible.

Disclosure statement

The authors report no conflict of interest.

Funding

This study was funded by a scholarship from the Universidade do Extremo Sul Catarinense. This study would not have been possible without the dedication of students of scientific initiation of the undergraduate course of physical education and psychology of the local University and the students and elderly residents of Criciúma/SC.

ORCID

Anand Thirupathi http://orcid.org/0000-0002-0924-2538

Paulo Cesar Silveira http://orcid.org/0000-0003-4908-2257

References

Aksenov MY, Markesbery WR. 2001 Apr. Changes in thiol content and expression of glutathione redox system genes in the hippocampus and cerebellum in Alzheimer's disease. Neurosci Lett. 302:141–145. doi:10.1016/S0304-3940(01)01636-6.

Albright A, Franz M, Hornsby G, Kriska A, Marrero D, Ullrich I, Verity LS. 2000 Jun. American College of Sports Medicine position stand. Exercise and type 2 diabetes.Medicine and Science in Sports and Exercise. 2000:32:1345-1360. doi:10.1097/00005768-200007000-00024

Ali S, Stone MA, Peters JL, Davies MJ, Khunti K. 2006 Nov. The prevalence of co-morbid depression in adults with type 2 diabetes: a systematic review and meta-analysis. Diabet Med. 23:1165–1173. DOI:10.1111/j.1464-5491.2006.01943.

Almeida MCB, Ribeiro JL. 2014 Jun. Adaptation of the modified habitual physical activity questionnaire (Baecke) to the Portuguese. Rev Enferm Ref. IV/3:27–36. DOI:10.12707/RIII1303.

Ávila-Escalante ML, Coop-Gamas F, Cervantes-Rodríguez M, Méndez-Iturbide D, Aranda-González II. 2020. May The effect of diet on oxidative stress and metabolic diseases-Clinically controlled trials. J Food Biochem. 44:13–191. doi:10.1111/jfbc.13191.

Andersen TR, Schmidt JF, Thomassen M, Hornstrup T, Frandsen U, Randers MB, Hansen PR, Krustrup P, Bangsbo J. 2014 Aug. A preliminary study: effects of football training on glucose control, body composition, and performance in men with type 2 diabetes. Scand J Med Sci Sports. 24:43–56. DOI:10.1111/sms.12259.

Antunes HK, Stella SG, Santos RF, Bueno OFA, Mello MTD. 2005 Dec. Depression, anxiety and quality of life scores in seniors after an endurance exercise program. Braz J Psych. 27:266–271. DOI:10.1590/s1516-44462005000400003.

Araújo SRC, Mello MT, Leite JR. 2007 Jun. Transtorno de ansiedade e exercício físico. Braz J Psych. 29:164–171. DOI:10.1590/S1516-44462006005000027.

Artilheiro MV, Franco SC, Schulz VB, Coelho CC. 2014 Apr. Quem são e como são tratados os pacientes que internam por diabetes mellitus no SUS? Rev. Saúde Deb. 38:210–224. doi:10.5935/0103-1104.20140019.

Asa C, Maria S, Sunnerhagen KS, Bert A. 2012 Apr. Aquatic Exercise Is Effective in Improving Exercise Performance in Patients with Heart Failure and Type 2 Diabetes Mellitus. *Evid Based Complement Alternat Med*. 2012; 2012: 349209. doi:10.1155/2012/349209

Barnard KD, Skinner TC, Peveler R. 2006 Apr. The prevalence of co-morbid depression in adults with type diabetes: systematic literature review. Diabet Med. 23:445–448. DOI:10.1111/j.1464-5491.2006.01814.

Berg KO, Maki BE, Williams JI, Holliday PJ, Wood-Dauphinee SL. 1992 Nov. Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil. 73:1073–1078.

Bertolazi AN, Fagondes SC, Hoff LS, Pedro VD, Menna Barreto SS, Johns MW. 2009 Sep. Portuguese-language version of the Epworth sleepiness scale: validation for use in Brazil. J Bra Pneumol. 35:877–883. DOI:10.1590/s1806-37132009000900009.

Borg G. 2000. Escalas de Borg para a Dor e o Esforço Percebido. São Paulo: Manole.

Boutron I, Altman DG, Moher D, Schulz KF, Ravaud P. 2017 Jul. CONSORT statement for randomized trials of nonpharmacologic treatments: a 2017 update and a CONSORT extension for nonpharmacologic trial abstracts. *Annals of internal medicine*. Am Col Phys. 4-167:40. PMID: 28630973.

Castelino A, Fisher M, Hoskyns S, Zeng I, Waite A. 2013 Oct. The effect of group music therapy on anxiety, depression and quality of life in older adults with psychiatric disorders. Australas Psychiatry. 21:506–507. DOI:10.1177/1039856213492355.

Chakraborty A, Chowdhury S, Bhattacharyya M. 2011 Jul. Efect of metformin on oxidative stress, nitrosative stress and infammatory biomarkers in type 2 diabetes patients. Diabetes Res Clin Pract. 93:56–62. doi:10.1016/j.diabres.2010.11.030.

Chang YC, Lu MC, Hu IH, Wu WCI, Hu S. 2017 May. Effects of different amounts of exercise on preventing depressive symptoms in community-dwelling older adults: a prospective cohort study in Taiwan. BMJ. 7:14256. doi:10.1136/bmjopen-2016-014256.

Colberg SR, Albright AL, Blissmer BJ,Braun B, Chasan-Taber L, Fernhall B, Regensteiner JG, Rubin RR, Sigal RJ. 2010 Dec. Exercise and type 2 diabetes: American college of sports medicine and the American diabetes association: joint position statement. exercise and type 2diabetes. American college of sports medicine; American diabetes association. Med Sci Sports Exerc. 42:2282–2303. doi:10.1249/MSS.0b013e3181eeb61c.

Cugusi L, Cadeddu C, Nocco S, Orrù F, Bandino S, Deidda M, Caria A, Bassareo PP, Piras A, Cabras S, Mercuro G. 2015 Feb. Effects of an aquatic-based exercise program to improve cardiometabolic profile, quality of life, and physical activity levels in men with type 2 diabetes mellitus. Phys Med Rehabil. 7:141–148. doi:10.1016/j.pmrj.2014.09.004.

Delevatti RS, Schuch FB, Kanitz AC, Alberton CL, Marson EC, Lisboa SC, Pinho CDF, Bregagnol LP, Becker MT, Kruel LFM. 2018 May. Quality of life and sleep quality are similarly improved after aquatic or dry-land aerobic training in patients with type 2 diabetes: a randomized clinical trial. J Sci Med Sport. 21:483–488. DOI:10.1016/j.jsams.2017.08.024.

Driver HS, Taylor SR. 2000 Aug. Exercise and sleep. Sleep Med Rev. 4:387–402. DOI:10.1053/smrv.2000.0110.

Durstine JL, Gordon B, Wang Z, Luo X. 2013 Mar. Chronic disease and the link to physical activity. J Sport Health Sci. 2:3–11. DOI:10.1016/j.jshs.2012.07.009.

Ebrahimi M, Guilan-Nejad TN, Pordanjani AF. 2017 Apr. Effect of yoga and aerobics exercise on sleep quality in women with Type 2 diabetes: a randomized controlled trial. Sleep Sci. 10:68–72. DOI:10.5935/1984-0063.20170012.

Fiocco AJ, Scarcello S, Marzolini S, Chan A, Oh P, Proulx G, Greenwood C. 2013 Aug. The effects of an exercise and lifestyle intervention program on cardiovascular, metabolic factors and cognitive performance in middle-aged adults with type II diabetes: a pilot study. Can J Diabetes. 37:214–219. DOI:10.1016/j.jcjd.2013.03.369.

Gilani SRM, Feizabad AK. 2019 Mar. The effects of aerobic exercise training on mental health and self-esteem of type 2 diabetes mellitus patients. Health Psychol Res. 11:6576. DOI:10.4081/hpr.2019.6576.

Gomes-Oliveira MH, Gorenstein C, Lotufo Neto F, Andrade LH, Wang YP. 2012 Dec. Validation of the Brazilian Portuguese version of the beck depression inventory-II in a community sample. Rev Bras Psiquiat. 34:384–394. DOI:10.1016/j.rbp.2012.03.005.

Gorenstein C, Andrade L. 1996 Apr. Validation of a Portuguese version of beck depression inventory and the state-trait anxiety inventory in Brazilian subjects. Braz J Med Biol Res. 29:453–457. DOI:10.1590/S0100-879X2005000300011.

Grigsby AB, Anderson RJ, Freedland KE, Clouse RE, Lustman PJ. 2002 Dec. Prevalence of anxiety in adults with diabetes: a systematic review. J Psychosom Res. 53:1053–1060. DOI:10.1016/s0022-3999(02)00417-8.

Hofmann M, Dack C, Barker C, Murray E. 2016 Nov. The impact of an internet-based self-management intervention (help-diabetes) on the psychological well-being of adults with type 2 diabetes: a mixed-method cohort study. J Diabetes Res. 2016:1–13. DOI:10.1155/2016/1476384.

Jernigan SD, Pohl PS, Mahnken JD, Kluding PM. 2012 Nov. Diagnostic accuracy of fall risk assessment tools in people with diabetic peripheral neuropathy. Phy Ther. 92:1461–1470. DOI:10.2522/ptj.20120070.

Ji LL. 2002. Exercise-induced modulation of antioxidant defense. Ann N Y Acad Sci. 959:82–92. doi:10.1111/j.1749-6632.2002.tb02085.x.

Kanitz AC, Barroso BM, Barbosa, Barbosa GZ, Mello AI, Bagatini NC, Reichert T, Lucas EP, Costa RR, Delevatti RS, et al.. 2019 Nov. Aquatic and land aerobic training for patients with chronic low back pain: a randomized study. Hum Mov. 20:1–8. DOI:10.5114/hm.2019.77468.

Kataoka H, Miyatake N, Kitayama N, Murao S, Kohi F, Tanaka S. 2016 Jul. Relationship of toe pinch force to other muscle strength parameters in men with type 2 diabetes. Environ Health Prev Med. 21:179–185. DOI:10.1007/s12199-016-0512-8.

Kelly SJ, Ismail M. 2015 Mar. Stress and type 2 diabetes: a review of how stress contributes to the development of type 2 diabetes. Annu Rev Public Health. 36:441–462. DOI:10.1146/annurev-publhealth-031914-122921.

Leedom L, Meehan WP, Procci W, Zeidler A. 1991 Aug. Symptoms of depression in patients with type II diabetes mellitus. Psychosomatics. 32:280–286. DOI:10.1016/S0033-3182(91)72066-5.

Levine RL, Garland D, Oliver CN, Amici A, Climent I, Lenz AG, Ahn BW, Shaltiel S, Stadtman RE. 1990. Determination of carbonyl content in oxidatively modified proteins. Methods Enzymol. 186:464–478.

Lipp ME. 2000. Inventário de Sintomas de Stress para Adultos. São Paulo: Casa do Psicólogo.

Lovrenčić MV, Okanović MP, Šekerija M, Piljac A, Jurisic Erzen D, Novak B, Kastelan S, Lovrencic MV, Brkljacic N. 2015 Aug. Improvement in Depressive Symptoms Is Associated with Reduced Oxidative Damage and Inflammatory Response in Type 2 Diabetic Patients with Subsyndromal Depression: the Results of a Randomized Controlled Trial Comparing Psychoeducation, Physical Exercise, and Enhanced Treatment as Usual. Int J Endocrinol. 2015:210406. DOI:10.1155/2015/210406.

Moraes H, Deslandes A, Ferreira C, Fernando AMS, Pompeu PR, Jerson L. 2017 Jan. O Exercício físico no tratamento da depressão em idosos: revisão Sistemática. Rev Psiq RGS. 29:70–79. doi:10.1590/s0101-81082007000100014.

Morrison S, Colberg SR, Parson HK, Vinik AI. 2012 Apr. Relation between risk of falling and postural sway complexity in diabetes. Gait Posture. 35:662–668. DOI:10.1016/j.gaitpost.2011.12.021.

Naicker K, Overland S, Johnson JA, Manuel D, Skogen JC, Sivertsen B, Colman I. 2017 Oct. Symptoms of anxiety and depression in type 2 diabetes: associations with clinical diabetesmeasures and self-management outcomes in the Norwegian HUNT study. Psychoneuroendocrinology. 84:116–123. DOI:10.1016/j.psyneuen.2017.07.002.

Netto A, Alevatto L. 2014. Manual do profissional de fitness Aquático/Associação de exercícios físicos aquáticos (AEA). São Paulo: Fitness Aquático um guia completo para profissionais.

Oliveira RD, Araújo AP, Bertolini SM. 2015. Correlação entre autonomia funcional e qualidade de vida em idosas. Rev Rene. 16:872–880. doi:10.18511/0103-1716.

Osama AJ, Shehab AK. 2015. Psychological wellbeing and biochemical modulation in response to weight loss in obese type 2 diabetes patients. Afr Health Sci. 15:503–511. doi:10.4314/ahs.v15i2.25.

Pernambuco CS, Borba-Pinheiro CJ, Vale RG, Di Masi F, Monteiro PKP, Dantas EHM. 2013 May. Functional autonomy, bone mineral density (BMD) and serum osteocalcin levels in older female participants of an aquatic exercise program (AAG). Arch Gerontol Geriatr. 56:466–471. DOI:10.1016/j.archger.2012.12.012.

Podsiadlo D, Richardson S. 1991 Feb. The timed "up & go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 39:142–148. DOI:10.1111/j.1532-5415.1991.tb01616.

Ramos AR, Wallace DM, Pandi-Perumal SR, Williams NJ, Castor C, Sevick MA, Mcfarlane SI, Jean-Louis G. 2015 May. Associations between sleep disturbances and diabetes mellitus among blacks with metabolic syndrome: results from the metabolic syndrome outcome study (MetSO). Ann Med. 47:233–237. DOI:10.3109/07853890.2015.1015601.

Roberts CK, Sindhu KK. 2009. Oxidative stress and metabolic syndrome. Life Sci. 84:705–712. doi:10.1016/j.lfs.2009.02.026.

Robinson DJ, Coons M, Haensel H, Vallis, Yale JF. 2018 Apr. Diabetes and mental health. Can J Diabet. 42:130–141. doi:10.1016/j.jcjd.2017.10.031.

Rochette L, Zeller M, Cottin Y, Vergely C. 2014 Sep. Diabetes, oxidative stress and therapeutic strategies. Biochm Biophys. 1840:2709–2729.

Ruzene JRS, Navega MT. 2014 Jun. Avaliação do equilíbrio, mobilidade e flexibilidade em idosas ativas e sedentárias. Rev Bras Geriat Geront. 17:785–793. DOI:10.1590/1809-9823.2014.13105.

Seyyedebrahimi S, Khodabandehloo H, Nasli EE, Meshkani R. 2018 Oct. The effects of resveratrol on markers of oxidative stress in patients with type 2 diabetes: a randomized, double-blind, placebo-controlled clinical trial [published correction appears in Acta Diabetol. Acta diabetologica. 55:341–353. DOI:10.1007/s00592-017-1098-3.

ShadiSadat S, Hadi K, Ensieh NE. 2018 Apr. The efects of resveratrol on markers of oxidative stress in patients with type 2 diabetes: a randomized, double blind, placebo controlled clinical trial. Acta Diabetol. 55:341–353. doi:10.1007/s00592-017-1098-3.

Shumway-Cook A, Brauer S, Woollacott M. 2002 Sep. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. Phys Ther. 80:896–903. DOI:10.1093/ptj/80.9.896.

Silva LA, Menguer L, Motta J, Dieke B, Mariano S, Tasca G, Zacaron RP, Silveira PCL, Aurino PR. 2017 Nov. Effect of aquatic exercise on mental health, functional autonomy, and oxidative dysfunction in hypertensive adults. Clin Exp Hypertens. 40:547–553. DOI:10.1080/10641963.2017.1407331.

Silva LA, Tortelli L, Motta J, Menguer L, Mariano S, Tasca G, de Bem Silveira G, Pinho RA, Silveira PCL. 2019 Jun. Effects of aquatic exercise on mental health, functional autonomy and oxidative stress in depressed elderly individuals: a randomized clinical trial. Clinics. 74:322. DOI:10.6061/clinics/2019/e322.

Steffen TM, Hacker T, Mollinger L. 2002 Feb. Age- and gender-related test performance in community-dwelling elderly people: six-minute walk test, berg balance scale, timed up & go test, and gait speeds. Phys Ther. 82:128–137. DOI:10.1093/ptj/82.2.128.

Van der Heijden MM, Van Dooren FE, Pop VJ, Pouwer F. 2013 Jun. Effects of exercise training on quality of life, symptoms of depression, symptoms of anxiety and emotional well-being in type 2 diabetes mellitus: a systematic review. Diabetologia. 56:1210–1225. DOI:10.1007/s00125-013-2871-7.

Volpato S, Maraldi C, Fellin R. 2010 Jun. Type 2 diabetes and risk for functional decline and disability in older persons. Curr Diabetes Rev. 6:134–143. DOI:10.2174/157339910791162961.