Glycemic response during and after aerobic and resistance exercise training in type 2 diabetics: experimental study

Lucas Henrique Coelho[1], Paulo Roberto dos Santos Amorim[1], João Carlos Bouzas Marins[1], Robson Bonoto Teixeira[1], Yuri de Lucas Xavier Martins[1], Gustavo Ramos Dalla Bernardina[1], Lucinana Moreira Lima[2]

ABSTRACT

Objective: To evaluate the interference of supervised resistance and aerobic training in glycemic levels during and after 36 sessions, belonging to a training period of three months in patients with type 2 diabetes mellitus (T2DM), as well as the comparison of both exercise training. **Methods:** This is a experimental study with twelve T2DM patients, all sedentary and attended by the Specialized Care Center of Viçosa-MG, randomized into aerobic (n = 6.54 ± 5 years) and resisted (n = 6.58 ± 9 years) groups. Capillary glycemia was collected before (M1), during (M2) and after (M3) each exercise session for 12 weeks with a weekly frequency of three days. It was used ANOVA for repeated measures followed by Tukey and Student's test. **Results:** A mean drop in capillary glycemia was observed between M1 and M2 (p = 0.001), M2 and M3 (p = 0.001) and M1 and M3 (p = 0.001) in both groups. **Conclusion:** It is concluded that aerobic and resistance exercise training caused a decreased in the blood glucose during exercise sessions. The findings showed that both modes of exercise are important in the hyperglycemic treatment of T2DM patients.

Keywords: Diabetes Mellitus, Aerobic Exercise, Resistance Exercise, Blood Glucose.

INTRODUCTION

Chronic hyperglycemia in patients with type 2 diabetes mellitus (DM) can compromise coronary arteries[1]. In addition to causing chronic degeneration, resulting in failure of various organs, mainly in the retina and renal tissue[1]. In order to minimize complications caused by blood hyperglycemia, physical exercise has been used as a non-medicated form of DM by increasing the sensitivity of insulin action, as well as improving physical fitness and body composition[2].

Hyperglycemia is a complication of diabetes, which can alter the functionality of many organic systems[3]. Patients with type 2 diabetes mellitus (T2DM) who undergo a regular program of physical exercise can achieve beneficial results in glycemic control and may be potentiated when combined with an active lifestyle[4]. Literature shows depressant effects on blood glucose levels after an acute session of exercise. This event occurs mainly by increased glucose uptake induced by muscle contraction[5]. However, most studies evaluate a single acute exercise session[6].

Knudsen et al.[7] demonstrated that only one aerobic exercise session may not modify the anthropometric profile, but it has a positive effect on glycemia through the decrease of insulin resistance. In addition, evidence demonstrates that both aerobic and combined characteristics exercise provides a similar decrease in glycemic levels and can be maintained for up to four hours after the end of the session[8].

Positive results are also found with regard to the anaerobic characteristic exercises. Strasser and Pesta[9] demonstrated in their study that strength training in patients with T2DM promotes lean mass gains and reduces adiposity, improving as a consequence the action of insulin on glucose uptake.

Although the beneficial effects on the health and quality of life due to physical exercise in DM patients are well established, the results of programs of different types of supervised physical exercises in patients with T2DM with dangerously altered glycemic levels attended by the Unified Health System (SUS) are still scarce. Thus, it is of great importance to verify the impact of supervised aerobic and resistance physical exercise

sessions on the glycemia of patients with T2DM, in order to maximize the quality of life of these patients.

It is hypothesized that the glycemic levels of T2DM patients after exercise sessions are below pre-exercise values, regardless of the performed modality. Based on the above, the objective of this study was to evaluate the interference of supervised aerobic and resistance exercise training on the glycemic levels, during and after 36 sessions in 3 months of practice in patients with T2DM, as well as to compare these effects between both exercises.

METHODS

This study belongs to a longitudinal type research. All patients were informed about the methodology and objectives of the study and signed the Informed Consent Form, approved by the Ethics Committee on Research with Human Beings of the Federal University of Viçosa, with CAAE number 28144814.0.0000.5153.

Participants

The study sample consisted of 12 patients with T2DM, seven women and five men. All volunteers were participants in the supervised physical exercise program of the State Center for Specialized Assistance (CEAE) of Viçosa/MG, which corresponds to a secondary care health center, in order to register and monitor hypertensive resistant and/or diabetic patients through the Unified Health System (SUS), in accordance with Resolution No. 2.606 (December 7, 2010). Patients with resistant hypertension are treated in the center, i.e., patients who use combined antihypertensive drugs of at least three different classes, being a diuretic, and still blood pressure remains above optimal levels[10]. And diabetics treated at CEAE should present glycated hemoglobin (HbA1c) equal to or greater than 9%.

The inclusion criteria were: patients treated at the CEAE with T2DM; both genders; over 18 years old; not practitioners of routine and/or systematized exercise. Whereas the exclusion criteria were patients with: type 1 diabetics; peripheral arterial disease; congestive heart failure and decompensated lung disease; symptomatic cardiac arrhythmia; orthopedic or rheumatic diseases that would make it impossible to perform the proposed exercises; signs of acute cardiac ischemia during the ergometric test; and symptomatic cardiac arrhythmia, by diagnosis or by the exercise test.

Procedures

For safety reasons, all patients underwent clinical analysis performed by a doctor at CEAE, and when approved, they were evaluated by submaximal ergometric test (ET) in ramp protocol, prior to participation in the study, performed by a cardiologist at CEAE, following the guidelines of the Brazilian Society of Cardiology[11]. The use of submaximal ET was due to the high degree of comorbidities presented by patients

attended at CEAE of Viçosa/MG. All showed risk factors, related to T2DM complications, such as uncontrolled blood pressure and glycemic levels, making it impossible to use the maximal ET. In addition, the study participants presented low physical fitness, low motor coordination and low ergometer adaptation, also making it impossible to use the maximal repetition test to obtain the training loads, the same precaution taken by Teixeira *et al*[12]. After the described procedures, all patients obtained authorization to perform physical exercises.

The body mass was measured using a scale Mercy® (model LC 200, Brazil), ranging from 1 to 200 kilograms and 50 grams of accuracy. The stature was evaluated through a stadiometer Welmy® (model R110, Brazil), ranging from 0.8 to 2.00 meters and one millimeter of precision. Body mass index (BMI) was calculated using the formula BMI=body mass kg/altura (m)^2. The cut-off limits adopted for BMI were those recommended by the World Health Organization (WHO)[13]. For the conversion of body density to body fat percentage, was used the equation proposed by Siri[14], using the sum of the skin folds. All data were collected by an experienced physical evaluator, using the software Avaesporte®.

After the evaluation stage, patients started the routine of supervised physical exercises. The exercises were prescribed, respecting the limitations and potential of each patient identified in the initial evaluations, and following the international guidelines for patients with DM proposed by the American College of Sport Medicine[15] and the American Diabetes Association (ADA)[16].

The study participants underwent physical exercise three times a week for three months, totaling 36 sessions. All training sessions were supervised by physical educators, doctors and nurses from the CEAE of Viçosa/MG. An adherence of 90% to the program was determined so that the results were valid, being controlled by date annotations on the patient record sheet. Participants were randomly divided into two groups, corresponding to aerobic training (AT) and resistance training (RT). Each group was composed of 6 patients.

For the collection of capillary blood glucose was used glycosimeter Roche Accu-Check Performa® (Mannheim, Germany), together with lancets G-Tech® (Brazil). Data collection was conducted through a drop of blood in the finger, always looking for alternate them. Antisepsis was performed before and after collection with cotton soaked with 70% alcohol. The collection was performed in three moments: before the beginning of the training sessions (M1), during the sessions (M2) and after the sessions (M3), by the professionals who accompanied the training. The data from the three different moments of collection of all patients were recorded and filed until the end of the third month of training, thus fulfilling the 36 sessions of supervised physical exercises for both groups. The cycle ergometer used was the bicycle ergometer Matrix® (Germany model U1X Vertical).

After the capillary glycemia collection (M1), the RT group performed warm-up on a stationary bicycle for 10 minutes at 50% of the maximum heart rate (MHR), controled by frequency

meter Polar® with the reading belt positioned over the xiphoid process and estimated by the equation of Tanaka et al[17]. The purpose of the warm-up was to prepare the body for the execution of subsequent exercises. After the warm-up, the resisted exercises were in a circuit method, composed of the following 10 exercises: rowing neutral, squatting with dumbbells, supine with dumbbells, extension of knees with shin guards, development with dumbbells, barbell curls with dumbbells, flexion of knees with shin guards, standing plantar flexion, high pulley tricep and abdominal flexion of trunk[18].

Due to the low physical fitness presented in ET, the initial loads of each exercise were stipulated according to the perceived effort of the participants, using the scale of 6 to 20, proposed by Borg[19], in which the scale values used were from 11 to 13, representing a moderate effort. As occurred improvements in movement pattern and physical conditioning, and from the participants' own perception of effort, the loads were adjusted always trying to maintain a moderate effort (11 to 13). The patients performed two sets of 15 repetitions in the first two weeks, with the purpose of adapting the neural, articular and muscular systems[18]. In this period of training the M2 was collected at the end of the first series. From the second week on, the training of the patients was composed of three series of 12 repetitions, with a pause between the second and third to obtain the measurements of capillary glycemia (M2). At the end of the third series, the patients performed passive stretching with the purpose of stretching and relaxing the large muscle groups, and soon afterwards was collected the final capillary glycemia (M3). The mean time of each complete exercise session was 60 minutes after the second week, starting at 7 o'clock and ending at 8 o'clock in the morning.

For the AT group, also aiming a suitable physiological and motor adaptation, the duration of the main part of the sessions was 30 minutes of continuous exercises in the first two weeks, in which capillary glycemia was collected before the beginning of the exercise session (M1), with 15 minutes of training (M2), and at the end of the passive stretching exercise for the large muscle groups (M3). Evolving for 40 minutes of continuous exercise in the following weeks, until the end of the training period[18]. At this stage, M2 glycemia was collected

with 20 minutes of continuous exercises, keeping the moment of the other collections, and the cycle ergometer was used.

Initially, there was a proposal to control training intensity through the percentage of MHR, estimated by the equation of Tanaka et al.[17], as occurred in the RT group. However, in this group, five patients used adrenergic beta-blockers to control blood pressure, making it impossible to use heart rate for intensity control. Thus, as in the RT group, the scale of subjective perception of effort, proposed by Borg[19] was used respecting the values of 11 to 13 that represent a moderate effort. Thus, aiming at the safety of patients who had arterial hypertension, blood pressure measurements were taken at the same time as capillary glycemia collections. For patients who did not present arterial hypertension or did not use beta-blockers, the initial planning was maintained. Regarding the relax process, the same procedures of the RT group were used, totaling an average time of 60 minutes per training session, starting at 7 o'clock and ending at 8 o'clock in the morning.

Statistical Analysis

To characterize the sample, was used the descriptive statistics (mean and standard deviation). The Shapiro-Wilk test was used to test the normality of the data and assumed the normality assumptions. The Student's t test for independent samples was used to verify if the groups differed in age and for the comparison of glycemia between the different groups (Aerobic and Resistance). Fischer's Exact Test was used to test for possible differences between the AT and RT groups in relation to the BMI classification. The ANOVA for repeated measures followed by Tukey's test was used to compare the different moments of blood glucose collection (before, during and after the exercise sessions). The significance level adopted for the tests was $p < 0.05$. Statistical analysis was performed using SPSS software.

RESULTS

Table 1 shows the characterization of the sample studied. From the 12 patients, a higher prevalence of females (58%) was observed when compared to males (42%). There were no significant differences between groups in relation to age, with

Table 1. Characterization of the sample of hypertensive and diabetic patients attended at the CEAE of Viçosa/MG, belonging to the training program with supervised physical exercises.

	Total (n=12)	Aerobic training group (n=6)	Resistance training group (n=6)	P
Age (years)	56 ± 7	54 ± 5	58 ± 9	0.485[‡]
Males/Females	5/7	1/5	4/2	---
BMI				
Low weight	0	0	0	---
Ideal weight	1 (8%)	0 (0%)	1 (17%)	---
Overweight	4 (33%)	1 (17%)	3 (50%)	0.545[‡‡]
Obesity	7 (59%)	5 (83%)	2 (33%)	0.242[‡‡]

Note: n= sample size, BMI= body mass index, p= probability for the hypothesis tests. (‡)Student's t-test, data presented as mean ± standard deviation. (‡‡)Fisher's exact test, data presented as number of participants and percentage.

a high number of patients classified as obese, totaling more than half of the sample studied (59%).

When comparing the AT with RT group at each of the blood glucose collection moments (M1, M2 and M3), was found no significant difference (F=0.022; p=0.884). The groups were homogeneous regarding the values in M1 and it was observed that the two modalities of exercise were beneficial, in the same proportion, to reduce the glycemia values in M2 and M3.

When analyzing the three moments of capillary blood glucose collection intragroups, were found significant mean reductions (Table 2). For both AT and RT, there were reductions equal to and/or greater than 25 mg/dL between M1 and M2 and between M2 and M3. From M1 to M3 the reduction was greater than 50 mg/dL, corresponding to the decrease of 25% in the TA group and 27% in the RT group.
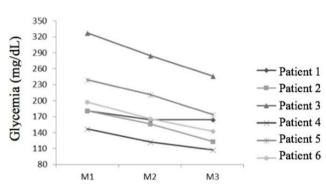
Individually, a mean decrease in capillary blood glucose was observed during all sessions of all patients, both in the AT and RT groups at the end of the three months of training. The greater mean decrease was 32% in the AT group (181 mg/dL to 123 mg/dL), and 37% in the RT group (243 mg/dL to 155 mg/dL). Whereas the lower mean decrease was 10% in the AT group (181 mg/dL to 164 mg/dL), and 22% in the RT group (193 mg/dL to 151 mg/dL). Of all the patients, only one belonging to the AT group presented mean maintenance of glycemia during M2 to M3 (164 mg/dL to 164 mg/dL), but with a decrease between moments M1 to M2 (181 mg/dL to 164 mg/dL). This can be seen in the Figure 1.

DISCUSSION

The main finding of this study was the depressive effect of supervised physical exercise on the capillary glycemia of patients with T2DM treated at CEAE in both AT group and RT group over a period of three months, totaling the analysis of the average glycemic levels of 36 sessions (before, during and after), while the majority of studies evaluated only one session.

The T2DM patients from the studied sample had high levels of obesity characterized by BMI. From the total sample, 59% were classified as obese, and only 8% presented ideal body mass (Table 1). In a study carried out with a sample of 202 T2DM patients with a mean age of 57 years, 62.9% of female, a prevalence of obesity was reported to be slightly

higher than in the current study, but equally worrying[20]. This may be explained by the fact that patients are in a high risk. Weight maintenance within normal limits is one of the factors that can prevent short-term and long-term vascular complications in patients with T2DM[21].

Despite the high degree of obesity and risk factors for T2DM patients, the positive effects of supervised physical exercise during 36 sessions were notorious, which led to an improvement in their capillary glycemia. Significant decreases in capillary glycemia were found between the M1/M2, M2/M3, and M1/M3 of both groups. Corroborating with our findings, De Lade et al[18], demonstrated that 11 sedentary patients
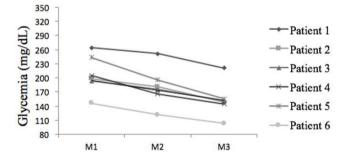

Figure 1. Demonstrative of the average glycemic behavior of the 36 exercise sessions of each patient, individually, before (M1), during (M2) and after the session (M3) of supervised physical exercises in both AT and RT groups.

Table 2. Average behavior of capillary blood glucose in 3 different moments (pre, during and post training) in aerobic and resistance training.

	Glycemic Values (mg/dL)			*p*
	M1	M2	M3	
Aerobic training (n=6)	212 ± 63	184 ± 57	159 ± 49	0.001[a, b, c]
Resistance training (n=6)	208 ± 41	181 ± 42	153 ± 38	0.001[a, b, c]
Total (n=12)	210 ± 51	182 ± 47	156.67 ± 42	0.001[a, b, c]

Note: M1= mean values of capillary glycemia before the training sessions; M2= mean values of capillary glycemia during the training sessions; M3= mean values of capillary glycemia after the training sessions; a= comparison between M1/M2; b= comparison between M2/M3; c= comparison between M1/M3; n= sample size; p= probability for the hypothesis tests; data presented as mean ± standard deviation (ANOVA for repeated measurements followed by Tukey's test).

with T2DM, who practice aerobic (54±9 years) or resistance (57±12 years) exercise, during 20 weeks, reduced the mean glucose levels from 217±56mg/dL to 165±29mg/dL in the resistance training and 202±74mg/dL to 171±49mg/dL in the aerobic training at the end of the sessions. Kang et al[22] also found favorable results regarding the decrease of glycemia in 8 women with T2DM, (mean age: 55 years), who did aerobic and resistance training for 12 weeks and 3 times a week, with no difference in the control group that did not performed exercise. Possibly this event occurs due to muscle contractions that substantially increase the activation of AMPK, which may induce a greater exocytosis and lower endocytosis of type 4 glucose transporters (GLUT 4), translocating from the sarcoplasm to the sarcolemma, independent of insulin[23].

When comparing the AT and RT groups, in relation to the capillary glycemia measurement moments, no difference was observed between them by analyzing the M1, M2 and M3 of the exercise sessions. This finding indicates that aerobic and resistance exercises are similarly effective for glycemic modulation in the evaluated subjects

Corroborating our findings, the study of Marcus et al[24], found that 15 women with T2DM, divided into a group that performed resistance and aerobic exercise, and a group that only underwent aerobic exercise, during 16 weeks, demonstrated that both exercise modalities showed a significant decrease in glycemic levels. Contrary to these results, Bacchi et al[25] concluded in a study with 25 subjects with T2DM, divided into two groups that performed aerobic and resistance exercises separately, during four months and three times a week, that both groups presented a significant decrease in capillary glycemia, including the aerobic training group. Whereas the study of Kang et al[26] with 15 postmenopausal women with a mean age of 51 years, who underwent 12-week resistance exercises in the circuit form and another group that only performed walking, concluded that the resistance exercises in the circuit form was more effective in reducing blood glucose.

These studies confirm the differences in the literature regarding the exercise modality performed and its response to glycemia in patients with T2DM. It is believed that the present study, in face of the impact of the aerobic and resistance exercises in the modulation of capillary glycemia, will add content to the literature related to this subject. This fact is strengthened by the search for studies related to glycemic behavior, in which research deficiency was detected, mainly related to the M2 moment of collection of capillary glucose in this specific population.

Sample size was a limiting factor in the present study, but it should be emphasized that since the sample was composed of high risk patients, additional inclusion criteria, such as exercise testing, were necessary for safety purposes. In this sense, this series of requirements caused a reduction in the number of subjects able to perform the proposed exercises. Also as a limitation, this study did not perform nutritional control of patients. In the study of Saslow et al[27], with DM patients, was verified that the amount of carbohydrate in the diet had a direct influence on the glycemic levels of diabetics, and it was extremely important to carry out a nutritional education with this population. So that the feeding is a factor of control of diabetes mellitus and not the opposite. The use of medication for the control of diabetes may also have been a confounding factor, however it would be impracticable any change in the medication of high risk patients for research purposes.

CONCLUSIONS

It was concluded that the two modalities of supervised aerobic and resistance training exercises were effective in the mean decrease of glycemia after 36 sessions in patients with T2DM, reinforcing the importance of supervised exercises in the non-drug treatment of T2DM and consequently in the improvement of the quality of life of patients. However, new studies should be conducted to clarify points still discordant in the literature.

AUTHORS' CONTRIBUTIONS
LHC participated in the entire writing, collecting and analyzing process of the present article; PRSA Co- adviser the work, carried out the final revision of the manuscript and approved its final version. He was co- supervisor of the research; JCBM Co- adviser the work, conducted the final manuscript revision and approved the its final version, was co- supervisor of the research; RBT participated in data collection, final text revision and submission of the manuscript; YLXM Participated in data collection and final text revision; GRDB Participated of the data analysis and final text revision; LML provided methodological and statistical guidance and final review.

CONFLICTS OF INTEREST
The authors declare no conflict of interest.

AUTHORS DETAILS
[1] Departamento de Educação Física – Universidade Federal de Viçosa – Viçosa – Minas Gerais – Brasil.

REFERENCES

1. Seino Y, Nanjo K, Tajima N, Kadowaki T, Kashiwagi A, Araki E, et al. Report of the committee on the classification and diagnostic criteria of diabetes mellitus. J Diabetes Investig. 2010;1(5):212–228.

2. Thent ZC, Das S, Henry LJ. Role of exercise in the management of diabetes mellitus: The global scenario. PLoS One. 2013;8(11):1–8.

3. Sacks DB, Arnold M, Bakris GL, Bruns DE, Horvath AR, Kirkman MS, et al. Guidelines and recommendations for laboratory analysis in the diagnosis and management of diabetes mellitus. Diabetes Care. 2011;57(6):1-47

4. Balducci S, Sacchetti M, Haxhi J, Orlando G, Zanuso S, Cardelli P, et al. The Italian Diabetes and Exercise Study 2 (IDES-2): a long-term behavioral intervention for adoption and maintenance of a physically active lifestyle. Trials [Internet]. 2015;16(1):569.

5. Way KL, Hackett DA, Baker MK, Johnson NA. The Effect of Regular Exercise on Insulin Sensitivity in Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis. Diabetes Metab J. 2016;40(4):253–271.

6. Asano RY, Sales MM, Browne RA, Moraes JF, Coelho Júnior HJ, Moraes MR, et al. Acute effects of physical exercise in type 2 diabetes: A review. World J Diabetes. 2014;5(5):659–665.

7. Knudsen SH, Karstoft K, Pedersen BK, Hall G Van. The immediate effects of a single bout of aerobic exercise on oral glucose tolerance across the glucose tolerance continuum. Physiol Rep. 2014;2(8):1–13.

8. Figueira FR, Umpierre D, Casali KR, Tetelbom PS, Henn NT, Ribeiro JP, et al. Aerobic and Combined Exercise Sessions Reduce Glucose Variability in Type 2 Diabetes: Crossover Randomized Trial. PLoS One. 2013;8(3):1–10.

9. Strasser B, Pesta D. Resistance training for diabetes prevention and therapy: experimental findings and molecular mechanisms. Biomed Res Int. 2013;2013:805217.

10. Daugherty SL, Powers JD, Magid DJ, Tavel HM, Masoudi FA, Margolis KL, O'Connor PJ, Selby JV, Ho PM. Incidence and prognosis of resistant hypertension in hypertensive patients. Circulation 2012; 125(13): 1635-1642.

11. Ghorayeb N, Costa RV, Castro I, Daher DJ, Oliveira Filho JA, Oliveira MA. Guidelines on exercise and sports cardiology from the Brazilian Society of Cardiology and the Brazilian Society of Sports Medicine. Arqu Bras Cardiol. 2013; 100 (1 Suppl 2):1-41.

12. Teixeira RB, Marins JCB, Amorim PRS, Teoldo I, Cupeiro R, Andrade MOC, et al. Evaluating the effects of exercise on cognitive function in hypertensive and diabetic patients using the mental test and training system. World J Biol Psychiatry. 2017; 28: 1–10.

13. WHo J, Consultation FE. Diet, nutrition and the prevention of chronic diseases. WHO Tech Rep Ser. 2003 (916): 1-60.

14. Siri WE. Body composition from fluid spaces and density: analysis of methods. Techniques for measuring body composition. Nutrition. 1993; 9(5):480.

15. 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-e67.

16. Association AD. Standards of medical care in diabetes—2014. Diabetes care. 2014; 37(Supplement 1): S14-S80.

17. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. J Am Coll Cardiol [Internet]. Elsevier Masson SAS 2001;37(1):153–156.

18. Lade CG De, Marins JCB, Lima LM, de Carvalho CJ, Teixeira RB, Albuquerque MR, et al. Effects of different exercise programs and minimal detectable changes in hemoglobin A1c in patients with type 2 diabetes. Diabetol Metab Syndr. 2016; 8(1): 13.

19. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982; 14(5): 377–381.

20. Pandey A, Swift DL, McGuire DK, Ayers CR, Neeland IJ, Blair SN, et al. Metabolic Effects of Exercise Training Among Fitness-Nonresponsive Patients With Type 2 Diabetes: The HART-D Study. Diabetes Care. 2015;38(8):1494–1501.

21. Wilding JPH. The importance of weight management in type 2 diabetes mellitus. Int J Clin Pract. 2014;68(6):682–691.

22. Kang SJ, Ko KJ, Baek UH. Effects of 12 weeks combined aerobic and resistance exercise on heart rate variability in type 2 diabetes mellitus patients. J Phys Ther Sci, 2016; *28*(7), 2088-2093.

23. Richter EA, Hargreaves M. Exercise, glut4, and skeletal muscle glucose uptake. Physiol Ver. 2013; 93(3): 993-1017.

24. Marcus RL, Smith S, Morrell G, Addison O, Dibble LE, Wahoff-Stice D, et al. Comparison of combined aerobic and high-force eccentric resistance exercise with aerobic exercise only for people with type 2 diabetes mellitus. Phys Ther. 2008;88(11):1345–1354.

25. Bacchi E, Negri C, Trombetta M, Zanolin ME, Lanza M, Bonora E, et al. Differences in the Acute Effects of Aerobic and Resistance Exercise in Subjects with Type 2 Diabetes: Results from the RAED2 Randomized Trial. PLoS One. 2012;7(12):6–13.

26. Kang S, Woo JH, Shin KO, Kim D, Lee HJ, Kim YJ, et al. Circuit resistance exercise improves glycemic control and adipokines in females with type 2 diabetes mellitus. J Sport Sci Med. 2009;8(4):682–688.

27. Saslow LR, Kim S, Daubenmier JJ, Moskowitz JT, Phinney SD, Goldman V, et al. A randomized pilot trial of a moderate carbohydrate diet compared to a very low carbohydrate diet in overweight or obese individuals with type 2 diabetes mellitus or prediabetes. PLoS One. 2014;9(4):e91027.