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Evaluation of Milk Consumption after Resistance Training on the Glycemic Control and Irisin Levels of Type II Diabetic Men: A Quasi-experimental Study

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ABSTRACT

Introduction: The consumption of high-protein foods after resistance training increases training achievement, which may benefit diabetic patients. The present study aimed to investigate the effects of milk consumption after resistance training on the glycemic control and irisin levels of type II diabetic (T2D) men.

Methods: This quasi-experimental study was conducted on 36 male patients with T2D, mean age of 53.6±4.8 years and mean body mass index of 27.1±3.6 kg/m². The patients were randomly divided into three groups of control, resistance training (RT), and resistance training and milk consumption (RTM). Eight weeks of RT was performed in three sets of 12 maximum repetitions three days per week. The RTM group consumed 500 milliliters of low-fat milk after the exercise. Fasting blood glucose, insulin, HbA1c, irisin, weight, waist-to-hip ratio, muscle strength, and limb circumference were measured before and after the intervention. Data analysis was performed using repeated measures analysis of variance (ANOVA).

Results: Compared to the RT group, the leg strength (mean±95% CI: -49.80±31.53; P<0.001), arm circumference (mean±95% CI: -3.41±1.97; P<0.001), and thigh circumference (mean±95% CI: -5.16±2.98; P<0.001) improved significantly in the RTM group. However, no significant interaction effects were observed for the other variables between the RT and RTM groups.

Conclusion: Despite more improvement in the muscle strength and circumference, the beneficial effects of RT were not augmented by additional post-exercise milk consumption in the male patients with T2D.

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Introduction

Regular physical activity and a healthy diet are beneficial strategies for the prevention and management of diabetes (1, 2). Various physical activities and exercises have been reported to be effective in this regard, including walking, running, yoga, aerobics, and resistance training (RT) (3-7). According to the literature, RT may positively influence glucose control and insulin resistance by improving muscle mitochondrial function and muscle volume (8). In addition, RT has been shown to increase the glucose uptake by the muscles through augmented muscle mass (9). On the other hand, protein intake in combination with RT could enhance RT-induced muscle gain (10). The consumption of approximately 20 grams of protein after a training session for the young and 40 grams for the elderly and middle-aged has been reported to maximize muscle protein synthesis (11). Furthermore, evidence suggests that milk consumption after RT could significantly increase the lean body mass in young healthy men and women (12, 13).

Considering that muscle loss is inevitable in diabetic patients (14), protein intake in combination with RT (or other types of training) could reinforce the beneficial effects of training in patients with type II diabetes (T2D), while no supporting evidence has been proposed in this regard. For instance, Wycherley et al. reported that a high-protein diet along with RT could improve weight loss and body composition without a significant change in the glycemic control (GC) of overweight and obese patients

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with T2D (15). In addition, the findings of Francois et al. demonstrated that post-exercise milk consumption cannot increase the GC benefits of high-intensity interval training (HIIT) in T2D patients (16). Previous findings have also indicated the non-significant effects of excess dietary protein with RT on the glucose tolerance and content of the insulin-signaling proteins of skeletal muscles in healthy elderly individuals (17). However, some studies have shown correlations between low-fat dairy consumption and the improvement of insulin resistance (18) and the risk of T2D (19).

Recent findings have confirmed the association between irisin and insulin resistance in patients with T2D (20, 21). Furthermore, it has been suggested that irisin plays a pivotal role in glucose utilization and lipid metabolism in T2D through the regulation of the AMPK signaling pathway (22). Studies have also demonstrated that exercise training could increase irisin levels (23-25), and evidence attests to the association between irisin and fat-free mass (26).

Due to the limited studies and contradictions of some of the findings in this regard, a comprehensive approach could not be found to determine the effects of post-exercise milk consumption on the indicators of T2D. The present study aimed to assess the effects of milk intake after RT sessions on the GC and irisin levels of T2D patients.

Materials and Methods

Subjects

Subjects were selected from the T2D patients referring to Ghazvin Diabetes Association, Iran. The sample population included 36 male patients within the age range of 45-60 years, who were invited and enrolled in the study. The inclusion criteria were as follows: 1) absence of diabetic complications (e.g., neuropathy, nephropathy, and retinopathy); 2) no insulin treatment; 3) no regular participation in sports activities and RT within the past six months; 4) no changes in the oral antiglycemic medications within the past two months; 5) no weight changes over 5% for a minimum of two months; 6) absence of extreme obesity (body mass index>40 kg/m^2); 7) no use of hormonal medications or hormone therapy (e.g., thyroid) and 8) no alcohol consumption, smoking or drug abuse.

The participants completed the health history questionnaire and provided written informed consent. The study protocol was approved by the Ethics Committee of Qazvin University of Medical Sciences (code: IR.QUMS.REC.1397.221). Eligible participants were selected and allocated to three groups of RT (n=12), resistance training with milk consumption (RTM) (n=12), and control (n=12).

RT Protocol

The training groups performed three sessions of resistance exercises per week for eight weeks under professional supervision. The RT program consisted of seven exercises, including bench press, leg press, shoulder press, abs crunch, seated cable rows, leg extension, and lat pull-down, which were carried out after 10 minutes of overall warm-up. The exercises were performed in three sets of 10-12 repetitions at 70-75% of 1RM every session (27). If the participants were able to complete more than 12 repetitions, the weights were increased in order to reduce the number of the repetitions to less than 12. The rest interval between the exercise sets was 30-60 seconds, and the duration of each training session was approximately 45 minutes. 1RM was measured before and after the training using an indirect method (28) for seven exercises, and the values were used for the setting of the exercise intensity. The waist-to-hip ratio (WHR) and limb circumference were also measured before and after the training program. The subjects in control group received no regular exercises during the protocol.

Diet and Supplementation

The subjects were asked to sustain their routine dietary habits during the study period. The RTM group consumed 500 milliliters of milk containing 1.5% fat (Pajan Co., Iran) immediately after each RT session. Medications at baseline and the changes throughout the study were recorded, and physicians were allowed to change the antidiabetic medications of the patients only if necessary to avoid hypoglycemia.

Blood Analysis

Blood samples were collected before and 48 hours after the training program in a fasting state (10 hours). Blood glucose, insulin, and HbA1c were measured using enzymatic, electrochemiluminescence, and chromatography methods, respectively. In addition, the ELISA human kit (Zellbio GmbH

Company) was utilized for the measurement of irisin.

Statistical Analysis

Data analysis was performed in SPSS version 24.0 (SPSS Inc., Chicago, Illinois) using the Shapiro-Wilk test to assess the normality of the data distribution for each variable. In addition, repeated measures analysis of variance (ANOVA) was applied for the intergroup assessment, and the differences between the variables were considered significant at the P-value of less than 0.05.

Table 1. Anthropometrics, Muscle Strength, Limb circumference, and Diabetes indicators before and after eight weeks in Control, Resistance Training and Resistance Training & Milk Groups.

		Con (n=12)	RT (n=12)	RTM(n=12)	*P*-value		
					Time	Interaction	RT&RTM Interaction
Anthropometrics							
Age (year)		54.5±4.9	53.8±5.1	52.6±4.7			
Height (m)		1.74±0.05	1.72±0.04	1.72±0.06			
Weight (Kg)	pre	81.2±11.5	83.1±14.6	81.0±10.5	0.923	0.792	0.630
	post	81.4±11.5	82.9±13.5	81.2±10.7			
BMI (Kg/m^2)	pre	26.4±2.7	27.8±5.2	27.0±2.6	0.750	0.974	0.872
	post	26.5±2.7	27.8±4.8	27.0±2.6			
WHR	pre	1.00±0.08	0.99±0.06	1.01±0.04	0.025[a]	0.028[b]	0.110
	post	1.00±0.08	0.98±0.06	0.98±0.03			
Muscle Strength (Kg)							
1RM Chest	pre	18.6±6.5	21.81±3.6	24.81±2.9	<0.001[a]	<0.001[b]	0.663
	post	19.0±6.3	44.0±5.7	45.8±6.4			
1RM Leg †	pre	28.1±5.7	39.3±10.3	31.4±6.6	<0.001[a]	<0.001[b]	0.028c
	post	28.5±5.7	65.2±9.3	81.2±32.1			
1RM Shoulder	pre	13.5±3.6	16.9±4.4	19.2±4.6	<0.001[a]	<0.001[b]	0.467
	post	13.7±3.7	29.2±4.5	32.9±5.9			
Limb Circumference (cm)							
Arm †	pre	36.7±5.2	31.8±3.2	31.0±3.1	<0.001[a]	<0.001[b]	0.014[c]
	post	36.7±5.2	33.5±3.3	34.5±3.0			
Thigh ††	pre	46.9±5.6	50.0±6.7	48.0±3.1	<0.001[a]	<0.001[b]	<0.001[c]
	post	47.0±5.6	51.3±6.4	53.1±4.8			
Neck	pre	42.9±2.3	41.4±3.2	40.8±2.7	0.116	0.157	0.152
	post	42.8±2.3	41.4±3.9	40.0±1.9			
Diabetes Indicators							
FBG (mg/dL)	pre	200.8±15.9	194.7±13.3	203.3±27.4	<0.001[a]	<0.001[b]	0.919
	post	199.2±15.6	122.0±14.6	131.1±18.3			
HbA1c (%)	pre	10.3±0.9	9.9±1.0	9.8±1.2	<0.001[a]	<0.001[b]	0.170
	post	10.2±0.9	6.2±1.0	6.6±0.8			
Insulin (micIU/mL)	pre	12.2±2.3	10.5±2.1	11.7±2.8	<0.001[a]	<0.001[b]	0.649
	post	12.1±2.2	5.8±1.3	6.7±1.8			
Irisin (ng/mL)	pre	163.0±1.8	162.2±1.8	163.0±2.2	<0.001[a]	<0.001[b]	0.311
	post	163.5±1.7	175.5±3.5	178.5±4.0			

Con, Control Group; RT, Resistance Training Group; RTM, Resistance Training &Milk Group; BMI, Body Mass Index; WHR, Waist Hip Ratio; 1RM, One Repetition Maximum; FBG, Fasting Blood Glucose; HbA1c, Glycosylated Hemoglobin.
a Significant Time Effect.
b Significant Interaction Group×Time.
c Significant Interaction Group×Time, Comparison Between RT&RTM Groups.

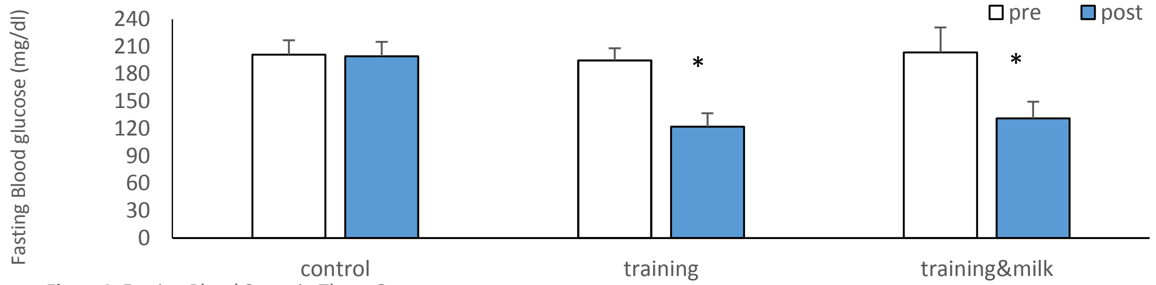

Figure1. Fasting Blood Suger in Three Groups.
* Significant Diferences to Pre test

Results

The obtained results indicated the significant time and interaction effects on the WHR, chest, leg, and shoulder strength, arm and thigh circumference, and the levels of fasting blood glucose, HbA1c, insulin, and irisin. Despite the significant interaction effects in leg strength, and arm and thigh circumference, no significant interaction effects were observed on the diabetes indicators in the comparison of the RT and RTM groups (Table 1).

Discussion

According to the results of the present study, eight weeks of RT could improve muscle strength and circumference in the T2D patients. Furthermore, low-fat milk consumption after RT increased some of the training adaptation achievements. Despite the improvement in the GC of both training groups, the consumption of milk had no additional effects on this parameter. The previous studies conducted on overweight/obese individuals with T2D have indicated that an energy-restricted, high-protein diet combined with RT could not further improve GC compared to RT control (15). In the mentioned study, the differences in the weight and body composition changes of the subjects could be due to the restriction in the energy intake compared to our research although similar responses were observed in terms of GC. Another difference is the timing of the dietary intervention; in the mentioned research, a high-protein diet was implemented, while we used low-fat milk immediately after training. Moreover, our subjects were male only; nevertheless, the findings have proven similar in many aspects.

Consistent with the results of the present study, Francois et al. examined the effects of post-exercise milk supplementation after HIIT in T2D patients, concluding that the benefits of HIIT were not augmented with the addition of post-exercise milk consumption (16). Therefore, it could be inferred that without calorie restriction, no changes would be observed in the weight, waist circumferences or body composition.

Strong evidence suggests that dairy intake reduces insulin resistance and the risk of T2D (18, 19, 29). The comparison of the available evidence in this regard reveals that the beneficial effects of dairy consumption and exercise training on T2D are not cumulative since hypertrophy is not the only mechanism proposed to improve glucose uptake. For instance, the calcium-dependent signaling pathway and the subsequent glucose uptake are impaired in T2D (30). As a result, this pathway is reinforced by milk consumption and exercise training simultaneously (31, 32). Such similarities in the pathways of effects could also be implied for weight changes, indicating that the non-accumulative effects of milk and exercise on T2D may be associated with the similar pathways to effectiveness.

According to the literature, irisin could improve insulin resistance and T2D by increasing the insulin receptor sensitivity of the skeletal muscles and heart, which in turn enhances hepatic glucose and lipid metabolism, promoted pancreatic β cell function, and converts the white adipose tissue into the brown adipose tissue (21, 33, 34). In the present study, irisin levels increased after RT without the additional effects of milk consumption. This is consistent with the previous studies in this regard (35-37). Despite the greater increase in the muscle circumference and strength, no further increase was observed in irisin in the RTM group, and the changes in irisin were consistent with the changes in glucose, insulin, and HbA1c in the intervention groups.

Irisin is regulated by peroxisome-proliferator-activated receptor-gamma coactivator (PGC-1α) and has been suggested to increase the beneficial effects of exercise on metabolism and thermogenesis (38). On the other hand, the abnormalities in the exercise-dependent pathway that regulates the expression of PGC-1α have been reported in patients with early-onset T2D (39). Therefore, the lack of irsin change in the present study may be due to the resistance of the patients to exercise.

With regard to our findings about the further improvement in the muscle strength and circumference of the RTM group without significant differences in the other variables, Egger et al. reported that more muscle strength gains with specific maximal RT compared to endurance resistance training did not lead to further GC improvement in patients with T2D (40). In addition, evidence suggests that increased muscle mass with RT is not the only influential factor in the enhancement of muscle metabolism in T2D (41). Therefore, it could be concluded that the difference in the muscle mass and strength gains was not sufficient to alter GC in the present study.

Limitations of the Study

Due to the limited choice of the subjects, the study was conducted with a quasi-experimental design. Another limitation was the small sample size and male-only assessments. In addition, the training continued for eight weeks only, and more prominent outcomes would be achieved by increasing the duration of training. Not recording the energy consumption and food composition of the patients was another limitation of the current research.

Conclusion

According to the results, RT with or without post-exercise milk consumption could improve GC in the T2D patients. Despite the further muscle improvement, milk intake after RT did not intensify the beneficial metabolic effects of RT on the T2D patients.

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References

1. Psaltopoulou T, Ilias I, Alevizaki M. The role of diet and lifestyle in primary, secondary, and tertiary diabetes prevention: a review of meta-analyses. Rev Diabet Stud. 2010;7(1):26.
2. Tudor-Locke CE, Bell RC, Myers AM. Revisiting the role of physical activity and exercise in the treatment of type 2 diabetes. Can J Appl Physiol. 2000;25(6):466-91.
3. Ebrahimi M, Guilan-Nejad TN, Pordanjani AF. Effect of yoga and aerobics exercise on sleep quality in women with Type 2 diabetes: A randomized controlled trial. Sleep Sci. 2017;10(2):68.
4. Nazari GT, Ebrahimi M, Haghshenas R, Saeidi ZT. The effect of 12-week yoga selected exercise on fasting glucose, glycosylated hemoglobin and lipid profile in patients with type 2 diabetes. Physiology of Exercise and Physical Activity. 2014;14:1119-38.
5. Karstoft K, Winding K, Knudsen SH, Nielsen JS, Thomsen C, Pedersen BK, et al. The effects of free-living interval-walking training on glycemic control, body composition, and physical fitness in type 2 diabetic patients: a randomized, controlled trial. Diabetes Care. 2013;36(2):228-36.
6. Kelley G, Kelley K. Effects of aerobic exercise on lipids and lipoproteins in adults with type 2 diabetes: a meta-analysis of randomized-controlled trials. Public Health. 2007;121(9):643-55.
7. DiPenta JM, Green-Johnson JM, Murphy RJ. Type 2 diabetes mellitus, resistance training, and innate immunity: is there a common link?. Appl Physiol Nutr Metab. 2007;32(6):1025-35.
8. Pesta DH, Goncalves RL, Madiraju AK, Strasser B, Sparks LM. Resistance training to improve type 2 diabetes: working toward a prescription for the future. Nutr Metab. 2017;14(1):24.
9. Yang J. Enhanced skeletal muscle for effective glucose homeostasis. Progress in molecular biology and translational science. 121: Elsevier; 2014. p. 133-63.
10. Pasiakos SM, McLellan TM, Lieberman HR. The effects of protein supplements on muscle mass, strength, and aerobic and anaerobic power in healthy adults: a systematic review. J Sports Med. 2015;45(1):111-31.
11. Churchward-Venne TA, Holwerda AM, Phillips SM, van Loon LJ. What is the optimal amount of protein to support post-exercise skeletal muscle reconditioning in the older adult? Sports Medicine. 2016;46(9):1205-12.
12. Hartman JW, Tang JE, Wilkinson SB, Tarnopolsky MA, Lawrence RL, Fullerton AV, et al. Consumption of fat-free fluid milk after resistance exercise promotes greater lean mass accretion than does consumption of soy or carbohydrate in young, novice, male weightlifters. Am J Clin Nutr. 2007;86(2):373-81.
13. Josse AR, Tang JE, Tarnopolsky MA, Phillips SM. Body composition and strength changes in women with milk and resistance exercise. Med Sci Sports Exerc. 2010;42(6):1122-30.
14. Park SW, Goodpaster BH, Lee JS, Kuller LH, Boudreau R, De Rekeneire N, et al. Excessive loss of skeletal muscle mass in older adults with type 2 diabetes. Diabetes Care. 2009;32(11):1993-7.
15. Wycherley TP, Noakes M, Clifton PM, Cleanthous X, Keogh JB, Brinkworth GD. A high-protein diet with resistance exercise training improves weight loss and body composition in overweight and obese patients with type 2 diabetes. Diabetes Care. 2010;33(5):969-76.
16. Francois ME, Durrer C, Pistawka KJ, Halperin FA, Chang C, Little JP. Combined interval training and post-exercise nutrition in type 2 diabetes: a randomized control trial. Front Physiol. 2017;8:528.
17. Iglay HB, Thyfault JP, Apolzan JW, Campbell WW. Resistance training and dietary protein: effects on glucose tolerance and contents of skeletal muscle insulin signaling proteins in older persons. Am J Clin Nutr. 2007;85(4):1005-13.
18. Rideout TC, Marinangeli CP, Martin H, Browne RW, Rempel CB. Consumption of low-fat dairy foods for 6 months improves insulin resistance without adversely affecting lipids or bodyweight in healthy adults: a randomized free-living cross-over study. Nutr J. 2013;12(1):56.
19. Aune D, Norat T, Romundstad P, Vatten LJ. Dairy products and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. Am J Clin Nutr. 2013;98(4):1066-83.

20. Elizondo-Montemayor L, Gonzalez-Gil AM, Tamez-Rivera O, Toledo-Salinas C, Peschard-Franco M, Rodríguez-Gutiérrez NA, et al. Association between Irisin, hs-CRP, and Metabolic Status in Children and Adolescents with Type 2 Diabetes Mellitus. Mediators Inflamm. 2019;2019.
21. Shoukry A, Shalaby SM, Bdeer SEA, Mahmoud AA, Mousa MM, Khalifa A. Circulating serum irisin levels in obesity and type 2 diabetes mellitus. IUBMB life. 2016;68(7):544-56.
22. Xin C, Liu J, Zhang J, Zhu D, Wang H, Xiong L, et al. Irisin improves fatty acid oxidation and glucose utilization in type 2 diabetes by regulating the AMPK signaling pathway. Int J Obes. 2016;40(3):443.
23. Andrade PA, Silveira BS, Rodrigues AC, da Silva FO, Rosa CB, Alfenas RG. Effect of exercise on concentrations of irisin in overweight individuals: a systematic review. Sci Sports. 2018;33(2):80-9.
24. Winn NC, Grunewald ZI, Liu Y, Heden TD, Nyhoff LM, Kanaley JA. Plasma irisin modestly increases during moderate and high-intensity afternoon exercise in obese females. PLoS One. 2017;12(1):e0170690.
25. Miyamoto-Mikami E, Sato K, Kurihara T, Hasegawa N, Fujie S, Fujita S, et al. Endurance training-induced increase in circulating irisin levels is associated with reduction of abdominal visceral fat in middle-aged and older adults. PloS one. 2015;10(3):e0120354.
26. Elizondo-Montemayor L, Mendoza-Lara G, Gutierrez-DelBosque G, Peschard-Franco M, Nieblas B, Garcia-Rivas G. Relationship of circulating irisin with body composition, physical activity, and cardiovascular and metabolic disorders in the pediatric population. Int J Mol Sci. 2018;19(12):3727.
27. Oliveira VNd, Bessa A, Jorge MLMP, Oliveira RJdS, de Mello MT, De Agostini GG, et al. The effect of different training programs on antioxidant status, oxidative stress, and metabolic control in type 2 diabetes. Appl Physiol Nutr Metab. 2012;37(2):334-44.
28. Reynolds JM, Gordon TJ, Robergs RA. Prediction of one repetition maximum strength from multiple repetition maximum testing and anthropometry. J Strength Cond Res. 2006;20(3):584-92.
29. Kalergis M, Yinko L, Lan SS, Nedelcu R. Dairy products and prevention of type 2 diabetes: implications for research and practice. Front Endocrinol. 2013;4:90.
30. Lanner JT, Bruton JD, Katz A, Westerblad H. Ca2+ and insulin-mediated glucose uptake. Curr Opin Pharmacol. 2008;8(3):339-45.
31. Wright DC, Hucker KA, Holloszy JO, Han DH. Ca2+ and AMPK both mediate stimulation of glucose transport by muscle contractions. Diabetes. 2004;53(2):330-5.
32. Pittas AG, Lau J, Hu FB, Dawson-Hughes B. The role of vitamin D and calcium in type 2 diabetes. A systematic review and meta-analysis. J Clin Endocrinol Metab. 2007;92(6):2017-29.
33. Liu S, Du F, Li X, Wang M, Duan R, Zhang J, et al. Effects and underlying mechanisms of irisin on the proliferation and apoptosis of pancreatic β cells. PloS one. 2017;12(4):e0175498.
34. Fox J, Rioux B, Goulet E, Johanssen N, Swift D, Bouchard D, et al. Effect of an acute exercise bout on immediate post-exercise irisin concentration in adults: a meta-analysis. Scand J Med Sci Sports. 2018;28(1):16-28.
35. Zhao J, Su Z, Qu C, Dong Y. Effects of 12 weeks resistance training on serum irisin in older male adults. Front Physiol. 2017;8:171.
36. Kim H-J, Lee H-J, So B, Son JS, Yoon D, Song W. Effect of aerobic training and resistance training on circulating irisin level and their association with change of body composition in overweight/obese adults: a pilot study. Physiol Res. 2016;65(2):271.
37. Khademi S, Ranjbar R, Ghanbarzadeh M. Effect of 8 weeks of circuit training on serum Irisin levels and Insulin Resistance Index in overweight girls. Scientific Journals Management System. 2015;13(10):91-101.
38. Boström P, Wu J, Jedrychowski MP, Korde A, Ye L, Lo JC, et al. A PGC1-α-dependent myokine that drives brown-fat-like development of white fat and thermogenesis. Nature. 2012;481(7382):463-8.
39. Hernández-Alvarez MI, Thabit H, Burns N, Shah S, Brema I, Hatunic M, et al. Subjects with early-onset type 2 diabetes show defective activation of the skeletal muscle PGC-1α/mitofusin-2 regulatory pathway in response to physical activity. Diabetes Care. 2010;33(3):645-51.
40. Egger A, Niederseer D, Diem G, Finkenzeller T, Ledl-Kurkowski E, Forstner R, et al. Different types of resistance training in type 2 diabetes mellitus: effects on glycaemic control, muscle mass and strength. Eur J Prev Cardiol. 2013;20(6):1051-60.
41. Pesta DH, Goncalves RL, Madiraju AK, Strasser B, Sparks LM. Resistance training to improve type 2 diabetes: working toward a prescription for the future. Nutr Metab . 2017;14(1):1-10.