EVALUATION OF HIGH LEVELS OF SPORTS ACTIVITY AND THE BENEFICIAL EFFECT ON POSTPRANDIAL BLOOD GLUCOSE PROFILES

ORIGINAL ARTICLE
ARTIGO ORIGINAL
ARTÍCULO ORIGINAL

AVALIAÇÃO DOS ALTOS NÍVEIS DE ATIVIDADE ESPORTIVA E O EFEITO BENÉFICO NOS PERFIS DE GLICEMIA PÓS-PRANDIAL

EVALUACIÓN DE LOS NIVELES ELEVADOS DE ACTIVIDAD DEPORTIVA Y EL EFECTO POSITIVO EN LOS PERFILES DE GLUCEMIA POSTPRANDIAL

Cuifeng Gu[1]
(Physical Education Professional)
Guojian He[1]
(Physical Education Professional)
Chenhong Lin[2]
(Physical Education Professional)

1. Hebei University of Economics and Business, Physical Education Department, Hebei, Heibei, China.
2. Hebei Sport University, Department of Human Sports Science, Hebei, Heibei, China.

Correspondence:
Cuifeng Gu
Shijiazhuang, China. 050067.
cuifenggu@163.com

ABSTRACT

Introduction: Hyperglycemia is the principal characteristic component of type 2 diabetes. High blood glucose concentrations for long periods can be countered with postprandial exercise by increasing glucose retention involuntary muscles. However, no research is present on the relationship between exercise time and glucose levels. Objective: This study evaluates the relationship between sports activity and postprandial glycemia levels. Methodology: Forty-five individuals were included in the study, 10 males and 35 females with an age of 27.11±2.8 years; a body fat percentage of 25.02% ±5.04%; and a body mass index of 22.74±4.55 kg/m2. Participants were included via WhatsApp for daily information on postprandial activity levels. WhatsApp messages were forwarded to a total of 2,500 people at different colleges and universities. Out of the total 60 active people (2.40%) who responded, 45 individuals participated in the study. They were divided into three categories based on self-reported postprandial activity: not very active (15), quite active (15), highly active (15). All active individuals completed an oral glucose intake test with blood samples obtained for evaluation at 15, 30, 45, 60, 90, and 120 minutes post-rest. On a gender basis, the groups could not be associated (P =.057). Results: All active groups showed a remarkable effect on blood glucose level at one hour (P =.031). A mean increase in blood glucose level in the first hour of 1.50 mmol/L was observed for every extra 1.0 mmol/L of standard glycemic amount, on average, women had a higher blood glucose amount of 1.35 mmol/L than men. Conclusion: It can be concluded that a high amount of postprandial activity generates a good outcome on glycemic parameters. ***Evidence Level II; Therapeutic Studies – Investigating the results.***

Keywords: Blood Glucose; Glucose Tolerance Test; Exercise.

RESUMO

Introdução: A hiperglicemia é o principal componente característico na diabetes tipo 2. Altas concentrações de glicose por longos períodos podem ser combatidas com o exercício pós-prandial, aumentando a retenção de glicose nos músculos voluntários. Porém, ainda não há estudos sobre a relação entre o tempo de exercício e os níveis de glicose. Objetivo: Este estudo tem como objetivo avaliar a relação entre a atividade esportiva e os dados temporais de glicemia pós-prandial. Metodologia: Foram incluídos 45 indivíduos no estudo, sendo 10 do sexo masculino e 35 do sexo feminino com idade de 27,11± 2,8 anos; percentual de gordura corporal de 25,02% ±5,04%; e índice de massa corporal de 22,74±4,55 kg/m2. Os participantes foram incluídos via WhatsApp para obter informações diárias sobre os níveis de atividade pós-prandial. As mensagens de WhatsApp foram encaminhadas para um total de 2.500 pessoas em diferentes faculdades e universidades. No total de 60 pessoas ativas (2,40%) que responderam, participaram do estudo 45 indivíduos. Eles foram divididos em três categorias com base na atividade pós-prandial autorrelatada: pouco ativos (15), bastante ativos (15), altamente ativos (15). Todos os indivíduos ativos finalizaram um teste de ingestão de glicose oral com amostras de sangue obtidas para avaliação em 15, 30, 45, 60, 90 e 120 minutos pós-repouso. Na base de gênero, os grupos não puderam ser associados (P =.057). Resultados: Todos os grupos ativos revelaram um efeito notável do nível de glicose no sangue em uma hora (P =.031). Foi observado um aumento médio no nível de glicemia na primeira hora de 1,50 mmol/L para cada 1,0 mmol/L extra de quantidade glicêmica padrão, em média, as mulheres tiveram uma quantidade glicêmica no sangue de 1,35 mmol/L superior aos homens. Conclusão: Conclui-se que a alta quantidade de atividade pós-prandial gera um bom desfecho nos parâmetros glicêmicos. ***Nível de evidência II; Estudos Terapêuticos - Investigação de Resultados.***

Descritores: *Glicemia; Teste de tolerância à glucose oral; Exercício Físico.*

RESUMEN

Introducción: La hiperglucemia es el principal componente característico de la diabetes de tipo 2. Las concentraciones elevadas de glucosa durante largos periodos pueden combatirse con el ejercicio postprandial, aumentando la retención de glucosa en los músculos voluntarios. Sin embargo, todavía no hay estudios sobre la relación entre el tiempo de ejercicio y los niveles de glucosa. Objetivo: Este estudio pretende evaluar la relación entre la actividad deportiva y los

datos de glicemia postprandial. Metodología: Se incluyeron 45 individuos en el estudio, siendo 10 hombres y 35 mujeres con una edad de 27,11±2,8 años; un porcentaje de grasa corporal de 25,02% ±5,04%; y un índice de masa corporal de 22,74±4,55 kg/m2. Se inscribió a los participantes a través de WhatsApp para obtener información diaria sobre los niveles de actividad postprandial. Se enviaron mensajes de WhatsApp a un total de 2.500 personas de diferentes colegios y universidades. Del total de 60 personas activas (2,40%) que respondieron, 45 individuos participaron en el estudio. Fueron divididos en tres categorías basadas en la actividad postprandial auto declarada: poco activos (15), bastante activos (15), muy activos (15). Todos los individuos activos completaron una prueba de ingesta de glucosa oral con muestras de sangre obtenidas para su evaluación a los 15, 30, 45, 60, 90 y 120 minutos después del reposo. En lo que respecta al género, los grupos no pudieron asociarse (P = 0,057). Resultados: Todos los grupos activos revelaron un efecto notable del nivel de glucosa en la sangre a una hora (P = 0,031). Se observó un aumento medio del nivel de glucosa en la sangre en la primera hora de 1,50 mmol/L por cada 1,0 mmol/L adicional de la cantidad de glucemia estándar; por término medio, las mujeres tuvieron una cantidad de glucosa en la sangre más alta de 1,35 mmol/L que los hombres. Conclusión: Se concluye que la elevada actividad postprandial genera un buen resultado en los parámetros glucémicos. ***Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.***

Descriptores: *Glucemia; Prueba de Tolerancia a la Glucosa; Ejercicio Físico.*

DOI: http://dx.doi.org/10.1590/1517-8692202228052022_127 Article received on 02/14/2022 accepted on 02/16/2022

INTRODUCTION

In type 2 diabetes, hyperglycemia is the main characteristic component. High glucose concentrations for longer time play an important part in the evaluation of diabetes-associated risks.[1] The glycemic control also decreases in CVD[2] to maintain glycemic control. There are a lot of options, still glycemic control continues to be a challenge for us. The extensive result of hypoglycemic component is disappointing.[3,4]

HbA_1C, fasting glucose, and postprandial glucose are traditional markers for glycemic control. Sugar gets much remembrance as a main glycemic goal for medicinal mediation. It's a good CVD predictor than HbA_1C [5-7] as well as fasting glucose[8] Other studies also show that the reduction of postprandial glucose is better than glycemic control and help to deplete CVD danger factor in persons with type 2-diabetes.[10] According to IDF guidelines for post meal glucose management, there is a link between postprandial sugar and CVD, notably, goal of glucose level after one to two hrs of bite ingestion is 160 mg/dL.[11] The use of postprandial sugar include non-pharmacological master plan.[11] Important of exercise for both prevention and treatment of type 2 diabetes is highlighted by American College of Sports Medicine and the American Diabetes Association.[12] These instructions are not particular to postprandial glucose, and they do not explain exercise timing in connection to meal ingestion. The less knowledge about exercise timing in treatment requires much more research on post meal exercise.

Type 2 diabetes postprandial exercise is safe and effective. It increases glucose retention in voluntary muscles. The contraction of muscle act as a signal for GLUT-4 receptor translocation on the plasma membrane of voluntary muscle.[13] The right timing for post- meal exercise has been proposed to be 30 min after the start of a meal.[14,15]

MATERIAL AND METHODS

Total 45 individuals were included in this study, 10 were male and 35 were female aged 27.11±2.8 years with body fat percentage 25.02%±5.04% and BMI body mass index 22.74±4.55 kg/m^2. The whatsApp messages were sent to a total of 2500 different colleges and universities. A total of 60 sports persons (2.40%) responded, out of them 45 actively participated in this study. Sports persons were classified into 3 groups based on activity: less active: person who did less than 30 min per day of postprandial activity at or under average power; average active: sports persons with thirty minute per day of postprandial activity and highly activity person with sixty minute/day of postprandial activity at high power. The SPAQ[16] and the average power of exercise studied by using a 1-10 Borg scale[17] were based of the level of activity classification.

The Scottish Physical Activity Questionnaire collects information regarding postprandial activity performed by individuals at houses and workplace during the last month via a phone call. The average metabolic equivalents were studied from the mean minutes of postprandial activity and the average rating of perceived exertion amounts using the compendium of postprandial activity.[18] Individuals of age less than 18 years and above 60 years, diabetic persons according to WHO[19] persons with food allergies, chronic illness and pregnant women were excluded from the study.

Methodology

All sports persons present in the lab observed 12-hour fasting on two events separated by 7 days. They were directed to eat the same meal at the same time in the evening and to avoid alcohol and limit postprandial activity on the day prior to each test.

Weight and height of the individuals were measured. For good results, individuals were made to wear the same clothes at all visits. Measurements of height were made at normal breath inspiration with the head orientated in the Frankfort horizontal plane. BMI was calculated and rounded to the nearest 0.1 kg/m^2. All the parameters were measured after 5 min of spine rest.

The evaluation of glycated hemoglobin (HbA1c) was made from the blood sample. A touchstone blood sugar measure was taken. Within 15 of the touchstone glucose test, individuals ingested fifty grams of glucose with 200 mL water. Estimates were made at 15, 30, 45, 60, 90 and 120 minutes from the 1st sip of sugar. Sports persons came back to the lab after one week and the oral glucose test was repeated. Blood samples were obtained in sterile tubes and measured with glucose meters.[20] to verify the validity of the glucose meters. A control solution was used.

Statistical analysis

iAUC was studied with the trapezoidal method given by Wolever et al.[21] Age, BMI, body fat percentage, HbA1c, duration and intensity of PA, and touchstone glucose amount were measured by ANOVA. ANOVA were used to compare glucose concentration after one hr and iAUC, together with top time, top sugar amount, and final glucose concentration (after two hrs). For analysis of p value SPSS Version 25.0 was used. Below 0.05 were used as a significant level.

RESULTS

Table 1 shows the general characteristics of all participants. Both intensity and duration PA differed across the group ($p < 0.001$). However, remarkable differences at touchstone between category for blood sugar amount (.004) and, BMI (.064), average active group having the low value of mean result was seen in one and all cases. On the gender basis, the groups could not be associated ($P = 0.057$). Intensity and Duration of postprandial activity were found to be highly associated.

The result of the blood sugar amount across the three active groups is shown in Table 2. All result estimates differ remarkably between groups with the deviation of the 2 hrs after test. The less active group showed no significant result. In the average active and high active groups, results were similar, with the deviation of time to peak and iAUC, where the high active group has a much-reduced mean amount.

The sky high one hr blood glucose amount is related with bigger touchstone glucose level (0.005) and less active category shows contrast with the highly active category (.003). It's related to duration or power of postprandial activity, both of which are separately significant (Table 3). High %age of body fat, higher HBA1c, and gender issues were related with higher one hr blood glucose level. The relationship between BMI or one hr blood glucose level and age ($P = .31$) does not appear.

Table 4 shows that the linear model for one hrs sugar amount (with the deviation of postprandial activity intensity and duration, which were evaluated by and highly correlated with activity category). The relationship between BMI or one hr blood glucose level and age ($P = .31$) does not appear. All the active groups have a remarkable effect on one hr blood glucose level ($P = .031$). An average growth in 1- hr blood sugar level of 1.50 mmol/L for every extra 1.0 mmol/L of touchstone sugar amount and on mean, females have one hrs blood sugar amount of 1.35 mmol/L higher than males, the less active category has on an average one hr blood sugar level 1.35 mmol/L, higher than those in the highly active category, though the contrast between less active or average active category is not associated($P = .34$).

A same evaluation was done on iAUC, time to top and top blood glucose level. For iAUC there was no remarkable outcome of activity category on the basis of gender and percentage of body fat. For top blood glucose level, the effect of activity group was not quite remarkable, once gender and touchstone sugar amount had been considered, groups activity was associated with time to top (.007), with HbA_1c not quite associated (.06). Those in the less active category took 15 min longer to reach peak glucose level than those in the highly active category (.015); the difference between the average active and highly active category was on average, 14.1 min.

Table 1. Basic parameter of participant.

Parameter	less activity =15	Average active=15	highly active =15	p-value
Age (year)	29.1 ± 8.7	21.9 ±3.3	27.5 ± 5.3	0.15
BMI (kg/m^2)	26.1 ± 4.5	22.3 ± 2.3	25.21 ± 3.6	0.064
Body fat (%)	24.9 ± 4.9	24.1 ± 2.8	22.4 ± 2.9	0.17
HbA1c (%)	5.5 ± 0.5	5.5 ± 0.6	5.5 ± 0.6	0.85
Physical activity (min/day)	25.54 ± 4.6	81.25 ±2.9	105.45 ± 6.85	<0.001
Baseline sugar	4.9 ± 0.7	4.5 ±0.12	4.4 ± 0.41	0.004
Intensity (MET)	2.9 ± 0.9	4.9 ±0.8	7.2 ± 0.7	<0.001

Table 2. Measurement of blood glucose.

	less activity =15	Average active=15	highly active =15	p-value
1-h post-test (mmol/L)	7.12 ± 2.03	6.22 ± 1.07	5.44 ± 1.01	0.005
Peak glucose (mmol/L)	7.98 ± 1.44	6.88 ± 0.47	6.66 ± 0.69	0.007
2-h post-test (mmol/L)	5.02 ± 1.08	4.58 ± 1.24	4.33 ± 0.52	0.401
iAUC	169.19 ± 69.29	159. 12± 71.88	69.69 ± 39.55	0.011
(mmol/L/120 min) Time to peak (min)	47.11 ± 10.33	46.55 ± 13.69	29.89 ± 7.88	0.015

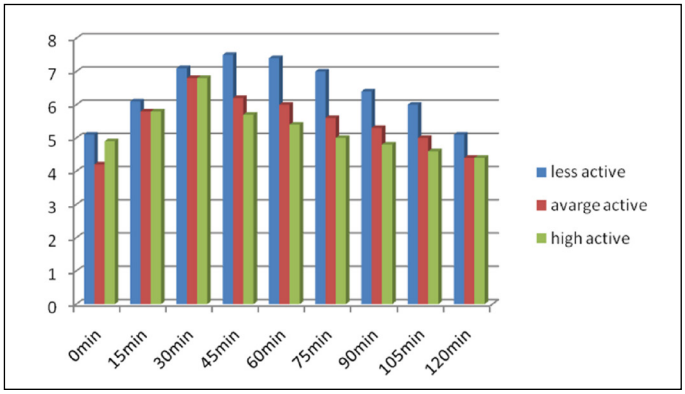

Figure 1. Shows the average blood glucose level for the three categories over 120 minutes. The highly active, average active and less active groups show the blood sugar category peaked, on an average, at thirty minute after the test. In the less active group, the top amount was much higher than the other two groups.

Table 3. Estimation of parameter for 1-h glucose level (linear model).

Profile	Parameter	S.E.	P-value
Age in year	0.039	0.039	0.31
BMI	.077	.069	.33
Body fat (%)	.11	.059	.087
HbA1c	2.21	1.122	.077
Physical activity (min/day)	—.45	.14	.003
touchstone glucose (mmol/L)	1.63	.63	.005
Female/ Male	1.14	.63	.065
Intensity	.027	.006	.001
Average active / less active	.62	.60	.41
Activity group highly active/less active	1.88	.61	.003

Table 4. Estimation of parameter for 1-h glucose level in linear model.

Profile	Parameter	S.E.	P-value
Intercept	—2.33	2.44	.31
touchstone glucose	1.58	.493	.005
Female / male	1.48	.477	.006
Group activity			0.031
Highly active / less active	1.41	.466	.006
Average active / less active	.53	.588	0.34

DISCUSSION

This study shows that the average active group had lower BMI than the less active and highly active category. On most of the days, the less active group did not cross the WHO value for young people to execute a min of 30 minute postprandial activity. All individuals in all groups had healthy HbA1c parameter. A reduction in HbA1c level is present in diabetic persons, when they tackle an exercise rule.[16] In this study, the blood glucose value is not similar to a low HbA1c amount.

After 50 g of carbohydrate taken by the individual, the maximum data shows reflection at the peak point, it was maximum in this study for the less active group, less in the average active category and still less in the highly active category.

In our study, the time to top is steady, the top is bigger, and the come back to touchstone is steady among the less active persons. This variance shows less glucose tolerance in the less active category than the average active and highly active category.[22,23]

In iAUCs of the average or less activity category, there was no association. The iAUCs of highly active and the other 2 categories in response

to fifty grams dose of glucose was significant; however, this difference doesn't persisted in terms of sex and % age of body fat.

HbA1c and glucose concentrations were measured for all our participants. This finding doesn't gives complete feedback to carbohydrate gain because the touchstone sugar amount partly evaluate the parameter at one hr and two hrs post ingestion.[24] Another author proposed that one hr glucose amount is a standard anticipate in type 2 diabetes danger. In this study, the less active category blood sugar amount increase was understandably higher than the two study categories. Another study also indicates that the one hr amount had a higher guessing perfection for type 2 diabetic than HbA_1c. In our study 8 of the 15 less active persons had an amount of 7.8 mmol/L at one hr and no one had an amount of 7.8 mmol/L at one hr in both the average and high active groups. Another authors have given an inkling structure of the glucose graph and raised one hr parameter of danger for diabetes, for example individual with graph close to the less active group for evaluation were established to be at five times the risk for diabetes compared to normal glucose tolerance 6 -7 years' post-analysis.[25] The value and powers of postprandial activity is the main basis of blood glucose reaction to a fifty grams dose of glucose. Our study shows a comparably weakened glucose tolerance in the less active person, which may propose a sequence from high danger to low risk by frequency, intensity and duration of postprandial activity.

The proof that the danger of type 2 diabetic is letdown, and that due to the control of their condition is by PA, is large and geipping.[26-30] The postprandial activity is both anaerobic or aerobic.[30] It has been avocatory that the pattern of exercise fuse (aerobic exercise resistance training) provides largest protection.[26] This activity has been shown to be important tool in the prevention of T2D.

Exercise upgrades blood sugar control mechanisms, this fact is yet to be completely explained. Aerobic exercise enlarge insulin sensitivity through changes in adipokine parameter or reduce the concentrations of intra myocellular lipid intermediates, such as various ceramides and di-acylglycerol that interfere with insulin signaling,[31,32]

CONCLUSION

It is concluded that the highly amount of postprandial activity have a good outcome on postprandial blood sugar parameter when set side by side to less and average amount of activity.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript GH: conception. CG: knowledge content. CL: design an d drafted. All the authors contributed equally in execution and writing of this manuscript.

REFERENCES

1. Diabetes Control and Complications Trial Research Group, Nathan DM, Genuth S, Lachin J, Cleary P, Crofford O et al. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. N Engl J Med. 1993;329(14):977-86.
2. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. Lancet. 1998;352(9131):837-53.
3. Turner RC, Cull CA, Frighi V, Holman RR. Glycemic control with diet, sulfonylurea, metformin, or insulin in patients with type 2 diabetes mellitus: progressive requirement for multiple therapies (UKPDS 49). UK Prospective Diabetes Study (UKPDS) Group. JAMA. 1999;281(21):2005-12.
4. DeFronzo RA. Current issues in the treatment of type 2 diabetes. Overview of newer agents: where treatment is going. Am J Med. 2010;123(Suppl 3):S38-48.
5. Jackson CA, Yudkin JS, Forrest RD. A comparison of the relationships of the glucose tolerance test and the glycated haemoglobin assay with diabetic vascular disease in the community. The Islington Diabetes Survey. Diabetes Res Clin Pract. 1992;17(2):111-23.
6. de Vegt F, Dekker JM, Ruhe HG, Stehouwer CD, Nijpels G, Bouter LM et al. Hyperglycaemia is associated with all-cause and cardiovascular mortality in the Hoorn population: the Hoorn Study. Diabetologia. 1999;42(8):926-31.
7. Meigs JB, Nathan DM, D'Agostino Sr RB, Wilson PW. Fasting and post- challenge glycemia and cardiovascular disease risk: the Framingham Off- spring Study. Diabetes Care. 2002;25(10):1845-50.
8. Glucose tolerance and mortality: comparison of WHO and American Diabetes Association diagnostic criteria. The DECODE Study Group. European Diabetes Epidemiology Group. Diabetes Epidemiology: collaborative analysis of diagnostic criteria in Europe. Lancet. 1999;354(9179):617-21.
9. Holman RR, Thorne KI, Farmer AJ, Davies MJ, Keenan JF, Paul S et al. Addition of biphasic, prandial, or basal insulin to oral therapy in type 2 diabetes. N Engl J Med. 2007;357(17):1716-30.
10. Hanefeld M, Cagatay M, Petrowitsch T, Neuser D, Petzinna D, Rupp M. Acarbose reduces the risk for myocardial infarction in type 2 diabetic patients: meta-analysis of seven long-term studies. Eur Heart J. 2004;25(1):10-6.
11. National Diabetes Statistics Report. Estimates of Diabetes and Its Burden in the United States. Centers for Disease Control and Prevention (2014). [Last accessed February 22, 2022]. Available at: https://www.cdc.gov/diabetes/data/statistics-report/index.html
12. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes Care. 2010;33(12):e147-67.
13. Goodyear LJ, Kahn BB. Exercise, glucose transport, and insulin sensitivity. Annu Rev Med. 1998;49:235–61.
14. Haxhi J, Scotto di Palumbo A, Sacchetti M. Exercising for metabolic control: is timing important?. Ann Nutr Metab. 2013;62(1):14-25.
15. Daenen S, Sola-Gazagnes A, M'Bemba J, Dorange-Breillard C, Defer F, Elgrably F et al. Peak-time determination of post-meal glucose excursions in insulin-treated diabetic patients. Diabetes Metab. 2010;36(2):165-9.
16. Lowther M, Mutrie N, Loughlan C, McFarlane C. Development of a Scottish physical activity questionnaire: a tool for use in physical activity interventions. Br J Sports Med. 1999;33(4):244-9.
17. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377-81.
18. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32(Suppl 1):S498-516.
19. World Health Organization (WHO). Definition, diagnosis and classification of diabetes mellitus and its complications. Geneva: WHO;1999.
20. Boyd JC, Bruns DE. Quality specifications for glucose meters: assessment by simulation modeling of errors in insulin dose. Clin Chem. 2001;47(2):209-14.
21. Wolever TMS, Jenkins DJA, Jenkins AL, Josse RG. The glycemic index: methodology and clinical implications. Am J Clin Nutr. 1991;54(5):846-54.
22. Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. Diabetes Care. 2007;30(3):744-52.
23. Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH. A prospective study of exercise and incidence of diabetes among U.S. male physicians. JAMA 1992;268(1):63-7.
24. Schwingshackl L, Missbach B, Dias S, Konig J, Hoffmann G. Impact of different training modalities in glycaemic control and blood lipids in patients with type 2 diabetes: a systematic review and network meta-analysis. Diabetologia. 2014;57(9):1789-97.
25. Alyass A, Almgren P, Akerlund M, Dushoff J, Isomaa B, Nilsson P et al. Modelling of OGTT curve identifies 1-h plasma glucose level as strong predictor of incident type 2 diabetes: results from two prospective studies. Diabetologia. 2015;58(1):87-97.
26. Abdul-Ghani M, Lyssenko V, Tiinamaija T, DeFronzo RA, Groop L. The shape of plasma glucose concentration curve during OGTT predicts future risk of type 2 diabetes. Diabetes Metab Res Rev. 2010;26(4):280-6.
27. Hawley JA. Molecular responses to strength and endurance training: are they incompatible?. Appl Physiol Nutr Metab. 2009;34(3):355-61.
28. Mann S, Beedie C, Balducciu S, Zanuso S, Allgrove J, Bertiato F et al. Changes in insulin sensitivity in response to different modalities of exercise: a review of the evidence. Diabetes Metab Res Rev. 2014;30(4):257-68.
29. LeBrasseur NK, Walsh K, Arany Z. Metabolic benefits of resistance training and fast glycolytic skeletal muscle. Am J Physiol Endocrinol Metab. 2011;300(1):E3-10.
30. Grøentved A, Rimm EB, Willett WC, Andersen LB, Hu FB. A prospective study of weight training and risk of type 2 diabetes mellitus in men. Arch Intern Med. 2012;172(17):1306-12.
31. Maiorana A, O'Driscoll G, Goodman C, Taylor R, Green D. Combined aerobic and resistance exercise improves glycemic control and fitness in type 2 diabetes. Diabetes Res Clin Pract. 2002;56(2):115-23.
32. Hardie DG. Energy sensing by the AMP-activated protein kinase and its effects on muscle metabolism. Proc Nutr Soc. 2011;70(1):92-9.