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M. Bostani , S.A. Noaein

Department of Physical Education, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

Physical activity as a non-pharmacological and useful strategy in controlling of the apoptotic symptoms in diabetic model rats

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Abstract. Background. In recent years, diabetes has become a global health problem. Apoptosis of pancreatic beta cells plays an important role in the pathogenesis of type 1 diabetes. Exercise as a non-pharmacological strategy to reduce the diabetic-induced complications has always been of interest to researchers. Therefore, the purpose of this study was to investigate the effect of aerobic exercise on levels of Bax, Bcl-2 and Bax/Bcl-2 ratio in pancreatic tissue of streptozotocin (STZ)-induced diabetic rats. **Materials and methods.** A total number of 40 male Wistar rats (10 weeks old, 200–250 gr weight) were randomly divided into healthy control (HC), healthy trained (HT), diabetic control (DC), and diabetic trained (DT) groups. Diabetes was also induced by a single intraperitoneally injection of streptozotocin (45 mg/kg). The training groups performed the exercise on the treadmill for five consecutive days within six weeks. The pancreatic tissue levels of the Bax and the Bcl-2 proteins were further determined via ELISA method. **Results.** The results showed that the induction of diabetes had significantly decreased the levels of Bcl-2 protein and increased the levels of Bax protein and Bax/Bcl-2 ratio in the pancreatic tissue ($p < 0.05$). As well, the findings showed that six weeks of aerobic exercise training had significantly increased the levels of Bcl-2 and significantly decreased the levels of Bax protein in DT group. Also, the Bax/Bcl-2 ratio reduced significantly in DT group ($p < 0.05$). The increase in displacement and transmission of apoptosis inducing factor (AIF) that have seen in oxidative stress status, is reduced in the tissues of trained individuals which indicating of the inhibition in the apoptotic signaling. **Conclusions.** According to the results of this study, exercise can be considered as an effective strategy to reduce the rate of diabetic-induced apoptosis and control its complications. **Keywords:** exercise; Bax; Bcl-2; apoptosis; diabetes mellitus

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder of the endocrine glands that has affected millions of people around the world and often associated with the functional and structural complications in various organs [1]. Pancreatic beta cell apoptosis plays an important role in the pathogenesis and development of Type 1 Diabetes mellitus (T1DM) [2, 3]. Mitochondrial apoptosis pathway involves the loss of mitochondrial homeostasis especially changes in the outer mitochondrial membrane. Mitochondrial outer membrane dysfunction causes proliferation of proapoptosis factors including cytochrome c. The release of cytochrome c activates the apoptosome. After the formation of this apoptosome and especially the activation of caspase 9, other important caspases are activated. Eventually, apoptosis culminates in cell

death [4, 5]. Bax and Bcl-2 are two important proteins that involved in the process of apoptosis through the formation of the apoptosome complex as well as the activator and inhibitor of caspases. Bax/Bcl-2 ratio is known to determine the survival and death of the cell [6]. The Bcl-2 family proteins play a vital role in transmission of intracellular apoptotic signals by regulating the permeability of the mitochondrial membrane. These proteins are divided into two categories: Anti-apoptotic proteins such as Bcl-2 and pro-apoptotic proteins such as Bax [7]. Bcl-2 is attached to the outer mitochondrial membrane and can inhibit the release of cytochrome c to cytosol, while the Bax protein damage the outer membrane of the mitochondria and cause the release of cytochrome c to the cytosol. It is also well established that the Bax protein can be attached to the Bcl-2 and prevent its anti-apoptotic role [8].

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For correspondence: Mehdi Bostani, PhD, Department of Physical Education, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran; e-mail: Bostanim@yahoo.com; contact phone: +989167017668

Full list of author information is available at the end of the article.

Exercise and physical activities have been recommended for the decrease of complications in patients with diabetes [9–11]. Cheng et al. [12] in their study showed that exercise training with increases the levels of Bcl-2 protein, enhances the cell survival in the heart of diabetic mice. N. Ramezani et al. [13] in their study reported that high-intensity interval training It caused a significant increase in Bcl-2 and decreased significantly in Bax after the four-week training intervention in heart of diabetic rats.

According to various studies, the effect of physical activity on apoptotic factors in diabetic pancreatic tissue has not been studied, therefore **the aim of this study** was to examine the levels of Bax protein, Bcl-2 protein and Bax/Bcl-2 ratio and studying the effect of aerobic exercise training in pancreas tissue of streptozotocin (STZ)-induced diabetic rats.

Materials and methods

Animals

A total number of 40 adult male Wistar rats were supplied from Razi Institute (Karaj, Iran) and housed four-per-cage in an animal lab under standard conditions (12-hour light/dark cycle in a room at a temperature of 20–25 °C) with access to food and water ad libitum. All the institutional (as registered under the code LUNS.REC.1395.170 at Lorestan University of Medical Sciences) and animal research health guidelines were also observed. The animals were randomly divided into four groups: 1) healthy control (HC, N = 10); 2) healthy trained (HT, N = 10); 3) diabetic control (DC, N = 10), and 4) diabetic trained (DT, N = 10) followed by inducing diabetes in DT and DC groups.

Diabetes induction

For the purpose of acclimatization and reaching optimal weight (at least 250 gr), all of the rats were kept in an animal lab for two weeks prior to the experiments. Subsequently, following an overnight fasting, diabetes was induced through a single intraperitoneal injection of streptozotocin (STZ) (45 mg/kg; Sigma, St. Louis, MO) solution (dissolved in 0.5 mol/l citrate buffer at pH 4.0). Two days later, diabetes was confirmed through measuring tail vein blood glucose level (> 350 mg/dl.) by Accu-Chek Compact Plus blood glucometer (Roche Diagnostics K.K., Tokyo, Japan). In this respect, the animals without any trace of hyperglycemic were excluded from the rest of the samples. In addition, blood glucose levels were controlled all along the study course, once every week [29].

Treadmill training protocol

The treadmill training protocol was developed based on previous protocols which consisted of 6 weeks of moderate-intensity endurance aerobic exercise on a leveled motor-driven treadmill (Model T510E, Diagnostic and Research, Taoyuan, Taiwan). The aerobic power of the animals in terms of VO₂max was further obtained based on the rela-

tionship between VO₂max to speed and treadmill slope [14]. Within the first week, the speed and the duration of the treadmill running were 10 m/min and 10 min per day, respectively. The figures were then gradually increased until the fifth week, ending up with training speed and duration of 18 m/min and 30 min per day, respectively. To stabilize the obtained adaptations, training speed and duration were kept constant at the sixth week [15].

Tissue extraction

Two days after the last exercise session in the sixth week of training, the animals were anesthetized by inhalation of 2 % halothane in a mixture of 20 % O₂ and 80 % CO₂. For the analysis of the levels of Bax and the Bcl-2 pancreatic tissue, total rats in four-groups were removed immediately and separated pancreatic tissue were stored at –80 °C until the analysis process was completed.

Evaluation of Bax and Bcl-2

To measure the expression of the Bax and the Bcl-2 proteins, the ELISA kits were used (Cusabio-Japan). At the first step, the Bax and the Bcl-2 levels of the pancreatic were homogenized (1 : 10 in PBS 10 Mm, pH 7.4 in 4 °C) and then centrifuged (20,000 rpm in 45 min). After that, using special kits of rats (Bax; 15.6 pg/ml and Bcl-2; 0.078 pg/ml), the levels of proteins were measured and spectrophotometrically read by an Autobio Elisa Reader (China).

Statistical analysis

Statistical analyses were conducted using SPSS Statistics software (Version 21, SPSS Inc., Chicago, IL, USA). Normality and homogeneity of the data were also assessed via Shapiro-Wilk test and Levene's test, respectively. One-way analysis of variance (ANOVA) followed by Bonferroni post-hoc test was further employed to compare the Bax and the Bcl-2 levels in the HC, HT, DC, and DT groups. The data were reported as mean ± standard error of measurement (SEM) values and the statistical significance level was set by $p < 0.05$.

Results

Figure 1 illustrated the average of blood glucose levels during the six-week endurance training intervention in the diabetic groups. As shown, blood glucose levels within six weeks in the diabetic group were more than 300 mg/dl which was considered as the threshold for diabetes. In the diabetic control group, the blood glucose levels had been also rising since the injection of the STZ by the end of the sixth week; but in the diabetic trained group, a decreasing trend was observed which revealed a significant reduction started at the beginning of the fourth week of the study ($p < 0.05$).

As shown in Figure 2, the levels of the Bax protein in the DC group significantly increased compared to the HC group ($p < 0.05$). There was also a significant reduction in Bcl-2 protein levels in the diabetic control (DC) group com-

Table 1. Endurance Training Protocol

	First week	Second week	Third week	Forth week	Fifth week	Sixth week
Training duration (minute)	10	20	20	30	30	30
Treadmill speed (m/min)	10	10	15	15	18	18

pared to the healthy group (HC). Also, the Bax/Bcl-2 ratio in the diabetic rats increased significantly ($p < 0.05$).

In the diabetic group that performed aerobic exercise on a treadmill for six weeks, there was a significant decrease in the levels of Bax protein, significant increase in Bcl-2 protein and significant reduction in the Bax/Bcl-2 ratio compared to the diabetic control group ($p < 0.05$).

Discussion

In the present study, we found that in the streptozotocin (STZ)-induced diabetic rats, the levels of the Bax pro-apoptotic protein increased, but the levels of the Bcl-2 anti-apoptotic protein decreased. In addition, Bax/Bcl-2 ratio was increased also. This means that pro-apoptosis processes have overcome anti-apoptosis processes in diabetic pancreas tissue.

However, six-weeks of aerobic exercise led to an increase in Bcl-2 anti-apoptosis protein and a decrease in the Bax pro-apoptosis protein and the Bax/Bcl-2 ratio.

The mechanism of the relationship between cell death and hyperglycemia is not yet well understood. Diabetes-induced oxidative stress may play an important role in the development of apoptosis in hyperglycemic state. Oxidative stress is created by an imbalance between the production of reactive oxygen species (ROS) and antioxidant factors. The role of the free radicals in the dysfunction of beta cells has been well established, in fact increment of the oxidative stress plays an important role in the spread of diabetic-induced cell death in most tissues [16, 17]. It is believed that the oxidative stress to be a major factor of the adverse effects of diabetes on tissues, which can trigger or accelerate apoptosis in affected cells [18].

The results of the various studies have shown that physical activity can reduce the amount and speed of cellular apoptosis. Some of these studies have suggested that the mechanism of the reduction in cellular death related to the increase in body's antioxidant capacity [19], reduction in the cytokines such as TNF- α [20], the decrease in the levels of pre-apoptotic proteins such as Bax protein [21], increasing the anti-apoptotic factors (Bcl-2, Hsp70), increasing the some of DNA regeneration enzymes and reduction in ROS production [22]. It seems that the mitochondria play an essential role in regulating of the apoptotic events. in this regard, the members of Bcl-2 family, including Bax

Figure 1. Blood glucose levels during the six weeks
Note: * — $P < 0.05$ significant decrease in blood glucose levels in diabetic trained (DT) versus the diabetic control (DC) group.

and Bcl-2 proteins as the main proteins, are involved in the formation of apoptotic channels, mitochondrial permeability regulation, and mitochondrial apoptosis signaling [23]. The Bax/Bcl-2 ratio is also an indicator for the determine of the mitochondrial apoptosis potential, which Bcl-2 through preventing of Bax-Bax oligomerization, opposes the pro-apoptotic activity of Bax. As soon as the Bax protein enters to mitochondria, it forms the pores in the mitochondrial membrane, that results in the release of proteins such as cytochrome C into the cytosol and triggers the downstream apoptotic signaling caspase cascade such as caspases-3 and caspases-9 [24]. The importance of the mitochondrial permeability has been explained in the J. Fang et al. study in 2008. They showed that the blocking of the mitochondrial permeability pores reduces the rate of apoptosis [25]. Moreover, the Bcl-2 protein by entering the mitochondrial outer membrane, maintains the integrity of the membrane and through the removing of H ions from the ion channels and via binding to apaf-1, inhibits caspase activation [26, 27].

In response to exercise, the levels of oxidative stress are associated with the less phosphorylation of c-Jun-N-terminal kinase (JNK). This is accompanied by a reduction in the expression of Bax protein and its transfer to mitochondria, as well as an increase in the levels of Bcl-2 protein.

Figure 2. Diabetes decreased the levels of the Bcl-2 protein and increased the Bax protein in the pancreatic tissue, while aerobic exercise training for six weeks significantly increased the Bcl-2 and decreased the Bax protein

Note: * — Significantly different, $p \leq 0.01$.

Figure 3. Diabetes increased the Bax/Bcl-2 ratio in the pancreatic tissue, however aerobic exercise training for six weeks significantly decreased this ratio

Note: * — Significantly different, $p \leq 0.01$.

In addition, the increase in displacement and transmission of apoptosis inducing factor (AIF) that have seen in oxidative stress status, is reduced in the tissues of trained individuals which indicating of the inhibition in the apoptotic signaling [28, 29].

Conclusions

According to the results of the present study, it can be concluded that aerobic exercise as a non-pharmacological, low-cost and useful strategy can be considered by reducing the levels of pro-apoptosis and increasing the amounts of anti-apoptosis factors, and can control diabetes-induced cell death and its complications.

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References

1. Zhao L, Gu Q, Xiang L, et al. Curcumin inhibits apoptosis by modulating Bax/Bcl-2 expression and alleviates oxidative stress in testes of streptozotocin-induced diabetic rats. *Ther Clin Risk Manag.* 2017 Aug 28;13:1099-1105. doi:10.2147/TCRM.S141738.
2. Atkinson MA. ADA Outstanding Scientific Achievement Lecture 2004. Thirty years of investigating the autoimmune basis for type 1 diabetes: why can't we prevent or reverse this disease? *Diabetes.* 2005 May;54(5):1253-1263. doi:10.2337/diabetes.54.5.1253.
3. Kim KA, Lee MS. Recent progress in research on beta-cell apoptosis by cytokines. *Front Biosci (Landmark Ed).* 2009 Jan 1;14:657-664. doi:10.2741/3271.
4. Kroemer G, Galluzzi L, Brenner C. Mitochondrial membrane permeabilization in cell death. *Physiol Rev.* 2007 Jan;87(1):99-163. doi:10.1152/physrev.00013.2006.
5. Susnow N, Zeng L, Margineantu D, Hockenbery DM. Bcl-2 family proteins as regulators of oxidative stress. *Semin Cancer Biol.* 2009 Feb;19(1):42-49. doi:10.1016/j.semcancer.2008.12.002.
6. Raisova M, Hossini AM, et al. The Bax/Bcl-2 ratio determines the susceptibility of human melanoma cells to CD95/Fas-mediated apoptosis. *J Invest Dermatol.* 2001 Aug;117(2):333-340. doi:10.1046/j.0022-202x.2001.01409.x.
7. Youle RJ, Strasser A. The BCL-2 protein family: opposing activities that mediate cell death. *Nat Rev Mol Cell Biol.* 2008 Jan;9(1):47-59. doi:10.1038/nrm2308.
8. Wattenberg B, Lithgow T. Targeting of C-terminal (tail)-anchored proteins: understanding how cytoplasmic activities are anchored to intracellular membranes. *Traffic.* 2001 Jan;2(1):66-71. doi:10.1034/j.1600-0854.2001.20108.x.
9. Asa C, Maria S, Katharina SS, Bert A. 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.
10. Selagzi H, Buyukakilli B, Cimen B, Yilmaz N, Erdogan S. Protective and therapeutic effects of swimming exercise training on diabetic peripheral neuropathy of streptozotocin-induced diabetic rats. *J Endocrinol Invest.* 2008 Nov;31(11):971-978. doi:10.1007/BF03345634.
11. Kadoglou NP, Vrabas IS, Kapelouzou A, et al. The impact of aerobic exercise training on novel adipokines, apelin and ghrelin, in patients with type 2 diabetes. *Med Sci Monit.* 2012 May;18(5):CR290-5. doi:10.12659/msm.882734.
12. Cheng SM, Ho TJ, Yang AL, et al. Exercise training enhances cardiac IGF1-R/PI3K/Akt and Bcl-2 family associated pro-survival pathways in streptozotocin-induced diabetic rats. *Int J Cardiol.* 2013 Jul 31;167(2):478-485. doi:10.1016/j.ijcard.2012.01.031.
13. Vsdna Nagesh S, Muniappan M, Kannan I, Viswanathan S. Erratum for Nagesh et al., phytochemical analysis and docking study of compounds present in a polyherbal preparation used in the treatment of dermatophytosis. *Curr Med Mycol.* 2018 Mar;4(1):34. doi:10.18502/cmm.4.1.33.
14. Høydal MA, Wisløff U, Kemi OJ, Ellingsen O. Running speed and maximal oxygen uptake in rats and mice: practical implications for exercise training. *Eur J Cardiovasc Prev Rehabil.* 2007 Dec;14(6):753-760. doi:10.1097/HJR.0b013e3281eacef1.
15. Chae CH, Jung SL, An SH, et al. Treadmill exercise improves cognitive function and facilitates nerve growth factor signaling by activating mitogen-activated protein kinase/extracellular signal-regulated kinase1/2 in the streptozotocin-induced diabetic rat hippocampus. *Neuroscience.* 2009 Dec 29;164(4):1665-1673. doi:10.1016/j.neuroscience.2009.09.075.
16. Devine PJ, Perreault SD, Luderer U. Roles of reactive oxygen species and antioxidants in ovarian toxicity. *Biol Reprod.* 2012 Feb 9;86(2):27. doi:10.1095/biolreprod.111.095224.
17. Agarwal A, Aponte-Mellado A, Premkumar BJ, Shaman A, Gupta S. The effects of oxidative stress on female reproduction: a review. *Reprod Biol Endocrinol.* 2012 Jun 29;10:49. doi:10.1186/1477-7827-10-49.
18. Nayki U, Onk D, Balci G, Nayki C, Onk A, Gunay M. The Effects of Diabetes Mellitus on Ovarian Injury and Reserve: An Experimental Study. *Gynecol Obstet Invest.* 2016;81(5):424-429. doi:10.1159/000442287.
19. Gomez-Cabrera MC, Viña J, Ji LL. Interplay of oxidants and antioxidants during exercise: implications for muscle health. *Phys Sportsmed.* 2009 Dec;37(4):116-123. doi:10.3810/psm.2009.12.1749.
20. Batista ML Jr, Rosa JC, Lopes RD, et al. Exercise training changes IL-10/TNF-alpha ratio in the skeletal muscle of post-MI rats. *Cytokine.* 2010 Jan;49(1):102-108. doi:10.1016/j.cyto.2009.10.007.
21. Siu PM, Bryner RW, Martyn JK, Alway SE. Apoptotic adaptations from exercise training in skeletal and cardiac muscles. *FASEB J.* 2004 Jul;18(10):1150-1152. doi:10.1096/fj.03-1291fj.
22. Fisher-Wellman K, Bloomer RJ. Acute exercise and oxidative stress: a 30 year history. *Dyn Med.* 2009 Jan 13;8:1. doi:10.1186/1476-5918-8-1.
23. Dejean LM, Martinez-Caballero S, Manon S, Kinnally KW. Regulation of the mitochondrial apoptosis-induced channel, MAC, by BCL-2 family proteins. *Biochim Biophys Acta.* 2006 Feb;1762(2):191-201. doi:10.1016/j.bbdis.2005.07.002.
24. Peterson JM, Bryner RW, Sindler A, Frisbee JC, Alway SE. Mitochondrial apoptotic signaling is elevated in cardiac but not skeletal muscle in the obese Zucker rat and is reduced with aerobic exercise. *J Appl Physiol (1985).* 2008 Dec;105(6):1934-1943. doi:10.1152/jappphysiol.00037.2008.
25. Fang J, Wu L, Chen L. Postconditioning attenuates cardio-

cyte ultrastructure injury and apoptosis by blocking mitochondrial permeability transition in rats. *Acta Cardiol.* 2008 Jun;63(3):377-387. doi:10.2143/AC.63.3.1020316.

26. García-Sáez AJ. The secrets of the Bcl-2 family. *Cell Death Differ.* 2012 Nov;19(11):1733-1740. doi:10.1038/cdd.2012.105.

27. Kwak HB. Effects of aging and exercise training on apoptosis in the heart. *J Exerc Rehabil.* 2013 Apr;9(2):212-219. doi:10.12965/jer.130002.

28. Vainshtein A, Kazak L, Hood DA. Effects of endurance training on apoptotic susceptibility in striated muscle. *J Appl Physiol* (1985). 2011 Jun;110(6):1638-1645. doi:10.1152/jappphysiol.

ol.00020.2011.

29. Bostani M, Rahmati M, Mard SA. The effect of endurance training on levels of LINC complex proteins in skeletal muscle fibers of STZ-induced diabetic rats. *Sci Rep.* 2020 May 26;10(1):8738. doi:10.1038/s41598-020-65793-5.

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Information about authors

Mehdi Bostani, PhD, Department of Physical Education, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran; <https://orcid.org/0000-0002-4904-0690>

Seyed Aenollah Noaein, Department of Physical Education, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

Bostani M., Noaein S.A.

Department of Physical Education, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

Фізична активність як нефармакологічна та ефективна стратегія в контролі симптомів апоптозу у щурів з експериментальним діабетом

Резюме. Актуальність. За останні роки цукровий діабет (ЦД) став глобальною проблемою охорони здоров'я. Апоптоз бета-клітин підшлункової залози відіграє важливу роль у патогенезі ЦД 1-го типу. Фізична активність як нефармакологічна стратегія для зменшення частоти ускладнень, спричинених ЦД, завжди цікавила дослідників. Тому метою цього дослідження було встановлення впливу аеробних вправ на рівні Вах, Bcl-2 та Вах/Bcl-2 у тканині підшлункової залози стрептозоцин-індукованих діабетичних щурів. **Матеріали та методи.** Самців щурів лінії Wistar (віком 10 тижнів, вага 200–250 г) загальною кількістю 40 рандомізовано розподілили на групи здорового контролю (ЗК), здорових тренуваних (ЗТ), з діабетом (контроль, ДК) та з діабетом із фізичним навантаженням (ДН). Діабет був індукований одноразовою інтраперитонеальною ін'єкцією стрептозоцину (45 мг/кг). Тренувальні групи виконували вправу на біговій доріжці п'ять днів поспіль протягом шести тижнів. Рівні тканин підшлункової

залози в білках Вах та Bcl-2 додатково визначали методом ІФА. **Результати.** Індукція діабету суттєво знизила рівень білка Bcl-2 та збільшила рівень білка Вах та співвідношення Вах/Bcl-2 у тканині підшлункової залози ($p < 0,05$). Окрім того, результати показали, що шість тижнів аеробних тренувань значно підвищили рівень білка Bcl-2 та знизили рівень білка Вах у групі ДН. Також співвідношення Вах/Bcl-2 суттєво знизилось у групі ДН ($p < 0,05$). Посилення виділення та передачі фактора, що індукує апоптоз, який спостерігається в стані окислювального стресу, зменшується в тканинах тренуваних осіб, що вказує на гальмування в сигналізації апоптозу. **Висновки.** Згідно з результатами цього дослідження, фізичні вправи можна розглядати як ефективну стратегію зменшення частоти спричиненого діабетом апоптозу та контролю його ускладнень.

Ключові слова: фізичні вправи; Вах; Bcl-2; апоптоз; цукровий діабет

Bostani M., Noaein S.A.

Department of Physical Education, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

Физическая активность как нефармакологическая и эффективная стратегия в контроле симптомов апоптоза у крыс с экспериментальным диабетом

Резюме. Актуальность. За последние годы сахарный диабет (СД) стал глобальной проблемой здравоохранения. Апоптоз бета-клеток поджелудочной железы играет важную роль в патогенезе СД 1-го типа. Физическая активность как нефармакологическая стратегия для уменьшения частоты осложнений, вызванных диабетом, всегда интересовала исследователей. Поэтому целью данного исследования было установление влияния аэробных упражнений на уровни Вах, Bcl-2 и Вах/Bcl-2 в ткани поджелудочной железы стрептозоцин-индуцированных диабетических крыс. **Материалы и методы.** Самцы крыс линии Wistar (в возрасте 10 недель, вес 200–250 г), общее количество 40, были рандомизированы на группы здорового контроля (ЗК), здоровых тренированных (ЗТ), с диабетом (контроль, ДК) и с диабетом с физической нагрузкой (ДН). Диабет был индуцирован однократной интраперитонеальной инъекцией стрептозоцина (45 мг/кг). Тренировочные группы выполняли упражнения на беговой дорожке пять дней подряд в течение шести недель. Уровни

тканей поджелудочной железы в белках Вах и Bcl-2 дополнительно определяли методом ИФА. **Результаты.** Индукция диабета существенно снизила уровень белка Bcl-2 и увеличила уровень белка Вах и соотношение Вах/Bcl-2 в ткани поджелудочной железы ($p < 0,05$). Кроме того, результаты показали, что шесть недель аэробных тренировок значительно повысили уровень белка Bcl-2 и снизили уровень белка Вах в группе ДН. Также соотношение Вах/Bcl-2 существенно снизилось в группе ДН ($p < 0,05$). Усиление выделения и передачи фактора, индуцирующего апоптоз, который наблюдается в состоянии окислительного стресса, уменьшается в тканях тренированных лиц и указывает на торможение в сигнализации апоптоза. **Выводы.** Согласно результатам этого исследования, физические упражнения можно рассматривать как эффективную стратегию уменьшения частоты апоптоза, вызванного диабетом, и контроля его осложнений.

Ключевые слова: физические упражнения; Вах; Bcl-2; апоптоз; сахарный диабет