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**The Effect of Aerobic Training on Serum Levels of Adiponectin, Hypothalamic-Pituitary-Gonadal Axis and Sperm Quality in Diabetic Rats**

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**Keywords:** Adiponectin; Diabetes mellitus type 2; Aerobic training; Sex hormones; Sperm parameters.

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## **Abstract**

**Purpose:** The present study aims to investigate the effects of aerobic training on adiponectin, sex hormones, and sperm parameters in Streptozotocin–Nicotinamide induced diabetic rats.

**Material and Methods:** In the experiment, 52 eight-week-old Sprague Dawley rats (200-250 g) were randomly assigned into three groups: healthy control, diabetic control, and diabetic aerobic training. Diabetes was induced by intraperitoneal injection of nicotinamide solution and STZ solution. The aerobic training protocol was performed for ten weeks. Finally, blood serum was used to assess FSH, LH, testosterone and adiponectin levels. Data were analyzed using ANOVA and Tukey's post hoc test using SPSS-22 software at 0.05 level of significance.

**Results:** Results showed an increase in serum adiponectin levels in aerobic training group, which led to a significant difference between aerobic training group and diabetic control group ( $3.8 \pm 1.1$  vs  $1.6 \pm 0.6$ ,  $P = .42$ ). In addition, aerobic training caused significant increases in serum testosterone level and LH in diabetic aerobic training group, so that significant differences were observed between serum testosterone ( $5.7 \pm 2.3$  vs  $6.6 \pm 1.8$ ,  $P = .117$ ), LH ( $4.7 \pm 1$  vs  $5.6 \pm 2.8$ ,  $P = .746$ ) and FSH ( $5.9 \pm 5$  vs  $4.4 \pm 1$ ,  $P = .596$ ) of diabetic aerobic training group and healthy control group. Sperm parameters in the diabetic aerobic training group including sperm count ( $26 \pm 13.2$  vs  $11.7 \pm 5.7$ ,  $P = .03$ ), motility ( $40 \pm 6.5\%$  vs  $32.5 \pm 1.1\%$ ,  $P = .41$ ) and viability ( $41.7 \pm 7.2\%$  vs  $29.78 \pm 16.2\%$ ,  $P = .000$ ) presented significant differences compared to diabetic control group.

**Conclusion:** Short term aerobic training can improve serum adiponectin levels and sperm parameters, including sperm count and sperm motility through increasing serum testosterone, LH and FSH levels in type 2 diabetic rats.

## **INTRODUCTION**

Diabetes mellitus (DM) is one of the greatest threats to current worldwide health. In a study in 2017, the number of diabetics in the world was 451 million which is anticipated to increase by 693 million in 2045 <sup>(1)</sup>. DM may influence male reproductive function at multiple levels as a result of its impacts on endocrine control of spermatogenesis, spermatogenesis itself or by damaging penile erection and ejaculation <sup>(2)</sup>. Data from animal studies strongly suggest that DM impairs male fertility <sup>(3)</sup>. On the other hand, fertility is regulated by two gonadotropic hormones, luteinizing hormone (LH) and follicle-stimulating hormone (FSH), which modulate testosterone synthesis in leydig cells and its aromatization to estradiol in sertoli cells respectively <sup>(4)</sup>. In a study by Aziz et al (2018) Remarkable differences between the levels of testicular and pituitary hormones in diabetic rat compared with non-diabetic rat have been recognized <sup>(5)</sup>. The findings regarding sperm quality in diabetic rat indicate a decrease in sperm motility and sperm count, and an increase in sperm abnormalities <sup>(6)</sup>.

Adiponectin plays an important role in metabolic disorders such as obesity, type 2 diabetes, coronary heart disease, and metabolic syndrome <sup>(7)</sup>. Discovery of the metabolic adiponectin hormone has been a main development not only in energy balance but more generally in fields including reproduction, inflammation, and immunology <sup>(8)</sup>.

Regarding the relationship between serum level of adiponectin and its possible effects on fertility a few studies have been conducted. Francisca et al, (2007) suggested that the pituitary constitutes a relevant place of action for adiponectin and supports a role for this adipokine as a connection in the regulation of metabolism, growth, and reproduction <sup>(9)</sup>. Olga et al. (2008) also indicated that adiponectin and its receptors are expressed in the chicken testis, where they are likely to affect steroidogenesis, spermatogenesis, sertoli cell function as well as spermatozoa motility <sup>(10)</sup>.

Exercise training (ET) is believed to be an important element in the treatment strategy for rats with type 2 diabetes <sup>(11)</sup>. Physical exercise increases glucose disposal into the contracting muscles leading to a significant decrease in blood glucose concentrations <sup>(12)</sup>.

Despite the beneficial effects of physical exercise on different metabolic aspects of diabetic rats, to the best of our knowledge no study has been conducted concerning the effects of physical exercise on fertility of diabetic rats. Therefore, it can be a noteworthy study to investigate the effects of a period of aerobic training on serum levels of adiponectin, sex hormones and sperm parameters in type 2 diabetic rats.

## **MATERIALS AND METHODS**

### ***Experimental animals and protocols***

Fifty four eight-week-old Sprague Dawley rats (200-250g) were housed in cages in groups of controlled temperature ( $22\pm 2^{\circ}\text{C}$ ) and light/dark (12/12h) conditions with free access to water and rat chow. All experimental procedures were guided by regulations approved by Ministry of Public Health, medical care and medical education. The rats were randomly divided to four groups: Control (C) (n=12), Diabetic control (DC) (n=15), Diabetic aerobic training (DAT) (n=15) and Healthy aerobic training (HAT) (n=12) groups. The groups were treated according to experimental protocol for duration of 60 days. All experiments were operated in the Medical Science University of Arak.

During the implementation of the training 3 rats were excluded from the study because of diabetic complications in the diabetic control group, 2 rats were died during training protocol and 1 rat was removed from the diabetic aerobic training due to failure to perform the training protocol.

### ***Diabetic induction***

Diabetes was induced after a 12 h fast. The rats were injected with Nicotineamid (Sigma Chemical Co) dissolved in normal saline at a dose of 120 mg/kg, and after 15 minutes, streptozotocin (STZ, Sigma Chemical Co) dissolved in 0.1 M citrate buffer at a dose of 65 mg/kg was given in a single intraperitoneal injection. 72 hours after injection, animals' blood glucose levels were evaluated. Those animals that had blood glucose levels higher than 250mg/dl were considered diabetic. Blood glucose levels of the rats were being measured by a glucometer after a 12 h fast. Further, the healthy control rats were given intraperitoneal injections of normal saline at a dose of 1cc to be in the same condition as diabetic groups <sup>(13)</sup>.

### ***Aerobic training protocol***

The aerobic exercise was performed on a rodent motor-driven treadmill at a 0° slope. The rats exercised for 5 d/w for 10 weeks. Training blocks consist of 3 phases of familiarization, overload, and finally preservation and stabilization of exercise intensity. In the familiarization phase (first week), the rats walked on treadmill at a speed of 8m/min for 10-15min every day. In the overload phase (second to fourth weeks), the rats initially ran on treadmill at a speed of 27m/min for 20min, and then during 3 weeks the time of exercise increased (2min in each session) gradually until reached 60 minutes. Finally, in the preservation and stabilization stage of exercise intensity, the rats did the aerobic exercise for 7 weeks with a speed of 27m/min for 60 min (Table 1). Each exercise session began with 5min of warm up (16m/min) and 5min was allocated to cooling down (16m/min and gradual decrease of intensity to the least amount) <sup>(14)</sup>.

### ***Procedure***

Twenty four hours after the last exercise session, all of the rats were anaesthetized by the injection of chloroform and sacrificed. Blood samples were collected by cardiac puncture (5cc) and centrifuged at 3500rpm for 10 min and the serum samples were stored at -70°C for future analysis. Serum levels of testosterone, LH, FSH, adiponectin and insulin were assayed using various kits according to their manufacturer's instructions. Testosterone (Rat ELISA Kit, Eastbiopharm Cat. No Ck-E90243, China, sensitivity: 0.25nmol/L, Assay range: 0.5-100nmol/L), LH (Rat ELISA Kit, Eastbiopharm Cat. No Ck-E90904, China, sensitivity: 0.11mIU/L, Assay range: 0.2-60mIU/L), FSH (Rat ELISA Kit, Eastbiopharm Cat. No Ck-E30597, China, sensitivity: 0.12mIU/L, Assay range: 0.2-60mIU/L), Adiponectin (Rat ELISA Kit, Eastbiopharm Cat. No Ck-E30584, China, sensitivity: 0.16mg/L, Assay range: 0.2-60mg/L) and insulin (Rat ELISA Kit, Eastbiopharm Cat. No Ck-E30620, China, sensitivity: 0.5mIU/L, Assay range: 0.1-40mIU/L).

### ***Sperm count***

The excised left testis was weighed and the dissected epididymis was transferred into 5cc (DMEM) medium and cut into small slices in order to swim out the sperm into the medium. After 10 min of diffusion in 27°C temperature, 1ml of the solution was diluted with 9ml formaldehyde fixative. The diluted solution was transferred into each chamber of Neubauer hemocytometer and sperm heads were manually counted under a microscope. Sperm count was carried out according to WHO guidelines and data were expressed as the number of sperm per ml <sup>(15)</sup>.

### ***Sperm motility***

Measurement of sperm motility was performed according to WHO protocol. 10µl of the sperm suspension was located on a microscope slide and covered. A minimum of five microscope fields were investigated to evaluate sperm motility on at least 200 sperm for each animal, then the percentage of sperm motility was computed <sup>(15)</sup>.

### ***Sperm viability***

Eosin-nigrosin staining was used to evaluate sperm viability according to WHO protocol (figure 1b). In this protocol, eosin (1%, Merk, Germany) and nigrosin (10%, Merk, Germany) were prepared in distilled water. At first, one volume of sperm suspension was blended with two volume of 1% eosin, then after 30 seconds an equal volume of nigrosin was added to this mixture. Finally, thin smears were assembled and observed under a light microscope with a magnification of 100X and the ratio of the live sperms percentage in different groups was computed. In this method, viable sperms appeared white while nonviable sperms stained purple <sup>(15)</sup>.

### ***Sperm morphology***

Before morphologic investigation of the sperm of each group, smears prepared from sperm suspension stained by the way of papanicolao and then were air dried and utilized according to WHO. In each sample, 100 sperms with a magnification of 100X were investigated and existing abnormalities were reported as a percentage <sup>(15)</sup>.

### ***Statistical analysis***

A Shapiro-Wilk test was applied to determine the normality of distribution of measures which were found to be normally distributed. Then a Leven test indicated that the variances were homogeneous. A one-way analysis of variance (ANOVA) and post hoc test (Tukey) was performed to determine differences among the groups. Data were expressed as means  $\pm$  SD and significance was set at the alpha level  $p < .05$  correlation between variables was also determined by Pearson correlation coefficient.

## RESULTS

### *Fasting blood glucose, Body weight and testis weight left*

For each animal, body weight was recorded at the beginning and end of a 70 day period.

Comparison of weight factor in posttest showed a significant difference between healthy control group with diabetic training group ( $p = .012$ ) and healthy training group ( $p = .032$ ) (Table 2).

Also there were significant differences in the mean left testis weight of rats in healthy control group compared to diabetic control group ( $p = .021$ ) (Table 2). There was no significant difference in fasting blood glucose levels of diabetic control group and diabetic aerobic training group in the beginning of the period ( $p = .311$ ), but after 10 weeks of aerobic training there was a significant decrease in fasting blood glucose of diabetic aerobic training group compared to diabetic control group ( $p = .013$ ) (Table 2).

### *Sperm count*

The results showed a significant decrease in epididymal sperm number of diabetic control group compared to healthy control group ( $p = .000$ ). The results also showed that the average sperm number of diabetic aerobic training group ( $26 \pm 13 \times (10^6)$ ) was significantly higher than that of diabetic control group ( $11.75 \pm 5 \times (10^6)$ ) ( $p = .03$ ). Furthermore, the difference between healthy control group and diabetic aerobic training group was not significant ( $p = .065$ ) (Table 3).

### *Sperm viability*

The mean percentage of viable sperms in the diabetic control group was significantly lower than that of the healthy control group ( $p = .000$ ). Also there was a significant increase in



sperm viability in diabetic aerobic training group compared to diabetic control group ( $p=.000$ ) (Table 3).

### ***Sperm morphology***

There was a significant difference in the mean percentage of morphologic natural sperms between the rats of healthy control group and diabetic control group ( $p=0.007$ ), but the difference between diabetic control group and diabetic aerobic training group was not significant ( $p = .566$ ) (Table 3).

### ***Sperm motility***

The mean percentage of sperm motility in diabetic control group was significantly lower than that in healthy control group ( $p = .000$ ) while there was a significant increase in sperm motility in diabetic aerobic training group compared to diabetic control group ( $p = .041$ ) (Table 3).

### ***Adiponectin and hormonal levels***

The mean of serum testosterone ( $p = 0.028$ ) and LH ( $p = 0.047$ ) concentrations decreased significantly in diabetic control group compared with healthy control group. The differences between means of serum testosterone ( $p = .117$ ), LH ( $p = .746$ ) and FSH ( $p=.596$ ) concentrations healthy control group and diabetic aerobic training group were also not significant.

Unlike the mean of serum adiponectin levels the healthy control group, that of the diabetic control group decreased significantly ( $p = .000$ ). Also the differences between means of serum adiponectin concentrations healthy control group and diabetic aerobic training group were not significant ( $p = .269$ ). Therefore, after a 10 week protocol, aerobic training increases serum adiponectin of diabetic rats (Table 4).

The mean of serum insulin levels of diabetic control group increase significantly compared to healthy control group ( $p = .008$ ). The differences between means of serum insulin concentrations healthy control group and diabetic aerobic training group were also not significant ( $p = .12$ ). Therefore 10 weeks aerobic training reduced serum levels of insulin in diabetic rats (Table 4).

### ***Correlation of serum adiponectin and hormonal levels***

Significant correlations were observed between serum adiponectin and serum LH ( $r = .495$ ,  $p = .049$ ) and serum testosterone ( $r = .406$ ,  $p = .014$ ) in diabetic type 2 rats (Table 5).

### **DISCUSSION**

The present study examined the effects of 10 weeks of aerobic training on serum levels of adiponectin and the sex hormones (testosterone, LH, and FSH) as well as sperm parameters in type 2 diabetic rats. During the last decade diabetes and infertility have increased simultaneously<sup>(16)</sup>. But, scientific reports regarding the relationship between diabetes and infertility are limited. The results generally affirm that diabetes has negative effects on sperm parameters<sup>(3)</sup>. According to WHO, sperm parameters include sperm count, sperm viability, sperm motility and sperm morphology<sup>(17)</sup>. Also confirmed that sperm parameters in the diabetic control group were significantly lower than those in healthy control group<sup>(18)</sup>. The proposed mechanism is such that diabetes induces testicular changes through apoptosis, atrophy of seminal tubes, decreasing the diameter of seminal tubes, and decreasing the cellular complex of spermatogenesis, and the harmful effects on The production of natural sperm and spermatogenesis<sup>(19)</sup>. Also experimental studies have shown that diabetes and insulin resistance result in a decrease in GnRH, LH, FSH, and testosterone via the effect on hypothalamic-pituitary-gonadal axis<sup>(20)</sup>. The increase of blood glucose results in a decrease in sex hormones including testosterone and sperm parameters through mechanisms such as an

increase in oxidative stress in testis tissue and destroying productive cells of GnRH in hypothalamus<sup>(21)</sup>. The present study also revealed that the amounts of reproductive hormones of LH, FSH, and testosterone in diabetic rats were lower than those in healthy rats. These results are in agreement with the results of Mohamed et al (2018)<sup>(22)</sup> and Erdemir et al. (2018)<sup>(21)</sup>. In fact, our study supports the idea that a reduction in androgenic hormones is probably one of the main mechanisms in disrupting fertility of diabetic rat.

This experiment showed that 10 weeks of aerobic training caused a significant reduction in blood glucose of experimental group. physical exercise has been suggested as an effective and non-medicinal strategy in preventing and treating infertility. Observing consumed calories, adopting a healthy diet and a moderate physical activity help improve the quality of sperm<sup>(23)</sup>. Alhashem et al. (2014) also reported that fattening rats with a high- calorie diet decreased their fertility capacity and a following aerobic training improved their spermatogenesis<sup>(24)</sup>. In sum, studies have indicated that exercise at a moderate intensity can increase male fertility, probably through mechanisms such as improving endocrine system status, oxidative stress and body composition<sup>(25)</sup>. The current study indicated that aerobic training in diabetic rats increased the sex hormones (testosterone and LH) significantly when compared to diabetic control group. In other words, a decrease in blood glucose after ten weeks of aerobic training was associated to the return of testosterone and LH hormones to normal levels and no significant difference between the healthy control group and the experimental group was observed.

The study also revealed a significant increase in sperm parameters, including sperm count and sperm viability in diabetic aerobic training group when compared to diabetic control group. The findings of the research indicate that doing exercise increases the efficiency of sperm fertility in diabetic rats probably through improving blood glucose levels and sex hormones status. In line with aforementioned findings in non-diabetic subjects<sup>(25, 26)</sup>, our

results showed that exercise improves fertility in diabetic rats. Taken together, our results are in agreement with the reports which state physical exercises at moderate intensity may cause improvements in metabolic function and sex hormones, including testosterone <sup>(27)</sup>.

The findings also showed that adiponectin serum has positive effects on fertility. Kasimanickam et al. (2013), showed that concentrations of adiponectin and testosterone were greater for high fertility bulls compared with average and low fertility bulls. Furthermore, sperm DNA fragmentation index was greater for low fertility compared with both average and high fertility bulls. They also concluded that the mRNA abundance of adiponectin and its receptors, AdipoR1 and AdipoR2, were greater for high fertility bulls compared with average and low fertility bulls <sup>(28)</sup>. Our study demonstrated that serum adiponectin levels of diabetic rats were significantly lower in comparison to healthy rats, which is confirmed by previous reports <sup>(29, 30)</sup> indicating that low levels of adiponectin may be an effective factor in type 2 diabetes disease.

The effect of aerobic training on serum adiponectin levels of diabetic rats was investigated and indicated that adiponectin levels increased following a period of aerobic training. The results showed no significant difference between serum adiponectin levels of the diabetic aerobic training group and healthy control group indicating the beneficial effects of aerobic training on adiponectin concentrations. Also our study also showed that there is a positive and significant correlation between serum adiponectin, LH and testosterone in rats. Therefore, it seems that a decrease in adiponectin concentration due to diabetes may contribute to infertility.

The emergence of the metabolic hormone of adiponectin as a key endocrine signal is a major improvement not only in energy balance, but also in areas such as reproduction, inflammation and immunology. Adiponectin, regulating pleiotropic, has a large number of biological functions, including gonadal steroidogenesis <sup>(8)</sup>. As mentioned before, the means of

testosterone, LH and adiponectin concentrations were higher after the aerobic training. These findings are in line with the findings of Kasimanickam et al. (2013). They reported that adiponectin and testosterone concentrations were greater in high fertility bulls <sup>(28)</sup>. In the present study there were improvements on fertility of diabetic rats after 10 weeks of aerobic training. Our findings indicated that in addition to changes in sex hormones and sperm parameters, the effects of serum adiponectin may also be associated with these improvements. The present study suggests that a short period of aerobic training improves the profile of sex hormones and serum adiponectin concentrations which may be related to an increase in fertility capacity of diabetic rats. Therefore, it is suggested that this research be replicated on diabetic rats with other kinds of exercises which decline diabetes effects following changes in serum levels of adiponectin and sex hormones in order to find suitable strategies in improving fertility in diabetic rats.

Also, the limitations of this study can be our diabetic model, so that Streptozotocin–Nicotinamide induced diabetes is a type I imitation, and this model does not exactly simulate type II diabetes in humans. Although various pathophysiological and molecular aspects of Type 1 diabetes and type II diabetes are prevalent, some of the characteristics may vary and may generally restrict this pattern to type II diabetes and insulin resistance.

## **CONCLUSIONS**

Serum adiponectin, testosterone and LH concentrations were higher in trained diabetic rats. In addition, the quality of sperm in the parameters of count and viability in trained diabetic rats was improved. In the present study, increasing adiponectin was associated with increased gonadotropic steroidogenesis (increased serum testosterone concentration). Therefore, adiponectin plays an important role in the structural and functional of the sperm and thus can have an effect on fertility in trained diabetic rats.

## **ACKNOWLEDGMENTS**

The present research is based on a research project approved by the Deputy Director of Research and Technology at Arak University. The code of ethics is also included in the description (IR.Arakmu.rec.1394.329) in the ethics committee of the research projects of Arak University of Medical Sciences. Also, the authors declare their gratitude to all those who helped us along the way.

## **CONFLICT OF INTEREST**

The authors report no conflict of interest.

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**Table 1:** Aerobic training (AT) protocol (14)

Weeks	Day	AT
	1	20 min, 27 m/min
	2	22 min, 27 m/min



<b>Week1</b>	<b>3</b>	<b>24 min, 27 m/min</b>
	<b>4</b>	<b>24 min, 27 m/min</b>
	<b>5</b>	<b>28 min, 27 m/min</b>
	<b>6</b>	<b>30 min, 27 m/min</b>
<b>Week2</b>	<b>1</b>	<b>32 min, 27 m/min</b>
	<b>2</b>	<b>34 min, 27 m/min</b>
	<b>3</b>	<b>36 min, 27 m/min</b>
	<b>4</b>	<b>38 min, 27 m/min</b>
	<b>5</b>	<b>40 min, 27 m/min</b>
	<b>6</b>	<b>42 min, 27 m/min</b>
<b>Week3</b>	<b>1</b>	<b>44 min, 27 m/min</b>
	<b>2</b>	<b>46 min, 27 m/min</b>
	<b>3</b>	<b>48 min, 27 m/min</b>
	<b>4</b>	<b>50 min, 27 m/min</b>
	<b>5</b>	<b>52 min, 27 m/min</b>
	<b>6</b>	<b>54 min, 27 m/min</b>
<b>Week4</b>	<b>1</b>	<b>56 min, 27 m/min</b>
	<b>2</b>	<b>58 min, 27 m/min</b>
	<b>3</b>	<b>60 min, 27 m/min</b>
	<b>4</b>	<b>60 min, 27 m/min</b>
	<b>5</b>	<b>60 min, 27 m/min</b>
	<b>6</b>	<b>60 min, 27 m/min</b>
<b>Week5-10</b>	<b>1-6</b>	<b>60min, 27 m/min to end of 10th week</b>

Table 2. Body and left testis weight (Means±SD)

Groups	Body Weight (g)		Fasting blood glucose (mg/dl)		Testis Weight left (g)
	Pre test	Post test	Pre test	Post test	
<b>HC</b>	242.9(±21)	280.3(±35)	88.4(±10)	100.2(±12)	1.58(±0.19)
<b>DC</b>	232.6(±36)	253.2(±46)	299.3(±46) <sup>a</sup>	366.4±102 <sup>a</sup>	1.31±0.25 <sup>a</sup>
<b>DAT</b>	238.7(±20)	227.4(±38) <sup>a</sup>	354.2(±86) <sup>a</sup>	188.8±115 <sup>b</sup>	1.34(±.32)
<b>HAT</b>	248.7(±19)	250.1(±25) <sup>a</sup>	85.6(±8) <sup>c</sup>	76.1±4 <sup>b</sup>	1.57)17. (± <sup>b</sup>

**a.** The significant difference with healthy control group ( $p < 0.05$ ). **b.** The significant difference with diabetic control group ( $p < 0.05$ ). **c.** The significant difference with diabetic aerobic training group ( $p < 0.05$ ). **Abbreviations:** HC, healthy control group; DC, diabetic control group; DAT, diabetic aerobic training group; HAT, healthy aerobic training group.

Table 3. Epididymal sperm number, sperm motility, sperm viability, and sperm morphology in studied groups.

Groups	Sperm count( $10^6$ )	Sperm Viability (%)	Sperm Motility (%)	Sperm Morphology (%)
<b>HC</b>	39.3 (±13)	77.5 (±4.6)	60.8 (±6.5)	95.4 (±1.3)
<b>DC</b>	11.75 (±5.7) <sup>a</sup>	29.78 (±16.2) <sup>a</sup>	32.5 (±1.1) <sup>a</sup>	85.25 (±7.5) <sup>a</sup>
<b>DAT</b>	26 (±13.2) <sup>ab</sup>	41.7 (±7.2) <sup>ab</sup>	40 (±6.5) <sup>a</sup>	88 (±8.8)
<b>HAT</b>	46.2 (±3.3) <sup>bc</sup>	87.8 (±2.9) <sup>abc</sup>	66.1 (±4.1) <sup>abc</sup>	90.4 (±9.1) <sup>bc</sup>

**a.** The significant difference with healthy control group ( $p < .05$ ). **b.** The significant difference with diabetic control group ( $p < .05$ ). **c.** The significant difference with diabetic aerobic training group ( $p < .05$ ).

**Abbreviations:** HC, healthy control group; DC, diabetic control group; DAT, diabetic aerobic training group; HAT, healthy aerobic training group.

**Table 4.** The level of follicle stimulating hormone (FSH), mIU/ml; luteinizing hormone (LH), mIU/ml; testosterone, nmol/l; adiponectin, mg/l and Insulin, (mIU/L) in different groups of rats.

Groups	LH (mIU/ml)	FSH (mIU/ml)	Testosterone (nmol/L)	Adiponectin (mg/L)	Insulin (mIU/L)
HC	5.6 ( $\pm 2.8$ )	4.4 ( $\pm 1$ )	6.6 ( $\pm 1.8$ )	5.6 ( $\pm 2.2$ )	3.4 ( $\pm .52$ )
DC	3.9 ( $\pm .7$ ) <sup>a</sup>	3.5 ( $\pm 1.1$ )	4.6 ( $\pm 1.6$ ) <sup>a</sup>	1.6 ( $\pm .6$ ) <sup>a</sup>	4.5 ( $\pm .96$ ) <sup>a</sup>
DAT	4.7 ( $\pm 1$ )	5.9 ( $\pm 5$ )	5.7 ( $\pm 2.3$ )	3.8 ( $\pm 1.1$ ) <sup>ab</sup>	3.1 ( $\pm .58$ ) <sup>b</sup>
HAT	9.8 ( $\pm 1.6$ ) <sup>abc</sup>	4.3 ( $\pm 1$ )	7.9 ( $\pm 1.7$ ) <sup>bc</sup>	5.3 ( $\pm .7$ ) <sup>bc</sup>	3.3 ( $\pm .78$ ) <sup>bc</sup>

**a.** The significant difference with healthy control group ( $p < .05$ ). **b.** The significant difference with diabetic control group ( $p < .05$ ). **c.** The significant difference with diabetic aerobic training group ( $p < .05$ ). **Abbreviations:** HC, healthy control group; DC, diabetic control group; DAT, diabetic aerobic training group; HAT, healthy aerobic training group.

**Table 5.** Correlation of serum Adiponectin and serum LH, FSH, T and Insulin in diabetic rats.

Variable	LH (mIU/ml)		FSH (mIU/ml)		Testosterone (nmol/L)		Insulin (mIU/L)	
	r	p	r	p	r	p	r	p
Adiponectin (mg/L)	.495	.049	-.103	.552	.406	.014	-.103	.552