Zagazig University Medical Journal

Volume 27
Issue 1 *January, 2021*

Article 32

April 2021

Effect of vitamin D supplementation and muscular exercise on irisin serum level and related metabolic parameters in type II diabetic albino rats

Nermeen Mahmoud Ashraf Zaitoun
Physiology Department, Faculty of Medicine, Zagazig Univerity, Egypt, nermozaitoun@gmail.com

Ahmed Bahaa Eldin
Physiology Department, Faculty of Medicine, Zagazig Univerity, Egypt, ola_haggag_2000@yahoo.com

Akmal Diab
Physiology Department, Faculty of Medicine, Zagazig Univerity, Egypt, akmaldiab@yahoo.com

Mai Mohammed Hasan
Physiology Department, Faculty of Medicine, Zagazig Univerity, Egypt, omomar70@hotmail.com

Zagazig University Medical Journal
www.zumj.journals.ekb.eg

Manuscript ID ZUMJ-1906-1272 (R2)
DOI 10.21608/zumj.2019.13959.1272

ORIGINAL ARTICLE

Effect of vitamin D supplementation and muscular exercise on irisin serum level and related metabolic parameters in type II diabetic albino rats

Ahmed Bahaa Eldin[1], Akmal Ahmed Diab[2],Mai Mohamed Hasan[3] and Nermeen Mamoud Ashraf Zaitoun [4*].

[1]Professor of medical physiology, Faculty of medicine, Zagazig University.
[2]Professor of medical physiology, Faculty of medicine, Zagazig University.
[3]Assistant professor of physiology, Faculty of medicine, Zagazig University.
[4*]Assistant lecturer of physiology, Faculty of medicine, Zagazig University.

***Corresponding author:**
Nermeen Mamoud Ashraf Zaitoun

Assistant lecturer of physiology, Faculty of medicine, Zagazig University.
Email : nermozaitoun@gmail.com

ABSTRACT

Background: Irisin is a newly discovered myokine that reduces obesity and improves insulin resistance via the browning of white adipose tissues resulting in increased thermogenesis that promotes insulin sensitivity. The aim of this work was to detect the effect of Vitamin D and exercise on irisin expression in type II diabetic albino rats. The aim was to detect the effect of supplementation with Vitamin D. and the role of exercise in improving type II diabetes, investigating their effects on irisn level. **Method:** This study was carried out on Fifty adult male albino rats which were divided into two main groups: Group I "control" in which the animals were fed on normal laboratory chow diet without exercise training. The remaining forty rats were used to establish type II diabetes, group IIA (n=10 rats) as diabetic control, group IIB (n=10 rats) exercised by swimming for 6 weeks, group IIC (n=10 rats) received vitamin D and group IID (n=10 rats) exercised and received vitamin D. **Results:** The results showed that exercise and vitamin D supplementation improved serum level of irisin, HOMA-IR and lipid profile (Cholesterol, LDL and triglycerides) in diabetic rats and the best effect was found with vitamin D administration in conjunction with exercise training. **Conclusion:** Combined exercise training and vitamin D administration improved serum irisin level and lipid profile in diabetic albino rats that was reflected on insulin resistance.

Key word: Irisin, HOMA-IR, Exercise, vitamin D and Diabetes.

INTRODUCTION

Type 2 Diabetes Mellitus (DM) is an epidemic non-communicable disease that threatens human health and life quality. It is a multifactorial disease characterized by chronic hyperglycemia, altered insulin secretion, and insulin resistance [1].It affects 415 million people worldwide and is set to reach to 642 million by the year 2040. About 193 million people with diabetes remain undiagnosed especially in type 2 DM (T2DM) [2]

Many studies revealed that irisin improves insulin resistance and type 2diabetes by increasing sensitization of the insulin receptor in skeletal muscle and heart, improving hepatic glucose, lipid metabolism, pancreatic β cell functions, and transforming white adipose tissue to brown adipose tissue [3].Also, it mimics the favorable metabolic effects associated with regular exercise, through its effect on subcutaneous white, in rodents [4].

Swimming exercise is widely used in rats for evaluating the effects of aerobic activity in pathological and physiological conditions. It has been suggested that regular physical activity may prevent or delay diabetes and its

January. 2021 Volume 27 Issue 1 10.21608/zumj.2019.13959.1272

complications. Regular moderate intensity aerobic activity is recommended for healthy and diabetic people to stay healthy [5].

Vitamin D acts in the body like a hormone with a multitude of functions, many studies have demonstrated that vitamin D deficiency is associated with impaired glucose tolerance and diabetes mellitus [6]. Also, vitamin D deficiency had correlation with risk of diabetes, metabolic syndrome, insulin resistance, hyperlipidemia and cardiovascular disease [7]

The current study was conducted to evaluate the effect of swimming exercise and supplementation of vitamin D on the serum levels of irisin, insulin, blood glucose and blood lipid profile in experimentally induced type 2 DM in rats.

METHODS

The experimental protocol was approved by animal standard ethics, physiology department and by local medical ethics committee in faculty of medicine of Zagazig University (Institutional Review Board, IRB) (3234/10-1-2017).

The study was conducted on fifty adult male healthy albino rats 12-15 weeks old weighing 130-160gm.They were obtained from the animal house of faculty of Veterinary Medicine of Zagazig University.

The rats were kept in steel wire cages (5/cages) in the animal house of Faculty of Medicine of Zagazig University under hygienic conditions.

The rats had free access to water and chow, were kept at room temperature and were maintained on a 12 h light/ dark cycle. The rats were accommodated to laboratory conditions for two weeks.

The fifty animals were divided randomly into two main groups as follow:

Group I: (Normal control group): (n=10) in which the animals were fed normal laboratory chow diet which was consisted of 25.8 % protein, 62.8 % carbohydrate and 11.4 % fat[8]obtained from College of Agriculture of Zagazig University.

The remaining 40 rats were used to establish a type II diabetic model.

Group II: High fat diet- streptozotocin (HFD/STZ) induced diabetic type II group (n =40 rats): Rats were fed a high fat chow contain (40% fat, 18% protein and 41% carbohydrate, as a percentage of total kcal), for 2 weeks, then they were injected intra-peritoneal with streptozotocin (STZ, 40 mg/kg; HFD/STZ) on the 14th day [9]. The development of hyperglycemia in rats was confirmed by fasting blood glucose (FBG) estimation after 6 days of STZ injection. Only the animals that maintained fasting blood glucose higher than 140 mg/dl were considered diabetic and used for the study [10].

Then, rats were randomly subdivided into 4 subgroups each contains 10 rats:

Group II A: (n=10): vehicle treated diabetic type 2 group (T2DM): Rats in this group were injected with buffer only (rats were infused with 0.2 mL physiological saline) in the tail vein (positive control).

Group II B (n=10) : Diabetes and exercise group: rats underwent swimming exercise for 6 weeks.

Group II C (n=10): Diabetes and received vitamin D (Oral drops, 500IU/kg per day by oral gavage for 6weeks):

Group II D (n=10): Diabetic exercised group received vitamin D: rats underwent exercise training for 6 weeks combined with vitamin D.

Swimming exercise protocol and Sampling of blood:

The swimming moderate exercise protocol used included 2 phases: adaptation and training. The adaptation phase included the first week of training. On the first day, the animals exercised in the pool (area 100 cm2, with water depth 35–45 cm at 37 _C) for 15 min. The exercise period was extended by 15 min each day until animals were swimming for 60 min. The training phase consisted of 60 min session, 5 times a week for 5 weeks, Each rat had a weight attached (5% body weight) to its tail for the duration of the swimming [11] At the end of the experiment, rats were decapitated; blood samples were obtained from orbital sinus through the following procedure (the animal was scruffed with thumb and forefinger, a capillary was inserted and slight pressure was enough to puncture the tissue and enter the sinus then the blood was collected through capillary

January. 2021 Volume 27 Issue 1 10.21608/zumj.2019.13959.1272

tube) Collection and centrifugation (for 20 minutes at approximately 500rpm) used immediately for assay of biochemical measurements. The separated serum was stored at -70 ° C. until assayed for irisin, in addition to insulin, glucose, cholesterol, triglycerides, LDL and HDL levels [12]. Kits used (INS-EASIA, KAP1251 for insulin and blood glucose, 201-11-1713 for irisin, 8-A-1340 for HDL and LDL, 8-C- 1150 for triglycerides and 8-B- 1400 for total cholesterol) BioSource Europe S.A.-Rue de l'Industrie

[HOMA-IR =insulin (μU/mL) x glucose (mg/dl) /405]

Statistical analysis:

In statistical analysis, SPSS version 18 program for Windows (SPSS Inc. Chicago, IL, USA) was used. Quantitative variables were expressed as the mean ± standard deviation (SD) while the qualitative variables were expressed as a number and percentage and Anova test was used for comparing the groups. The results were considered statistically significant when the significant probability (P value < 0.05*).

RESULTS

This randomized interventional study was performed on 50 male albino rats. In group I (control) serum Irisin level (11.6 ±0.57 ng/ml) was significantly higher (P <0.05) than group IIA (diabetic control) (8.63±0.69 ng/ml). The level of Irisin was found to be significantly higher (P <0.001) in groups IIB (diabetic and exercise) (11.48±1.14 ng/ml), IIC (diabetic and vitamin D) (12.03±0.91 ng/ml) and group IID (diabetic, vitamin D and exercise) (14.02±0.72 ng/ml) when compared to diabetic control as shown in **[Figure 1].**

Regarding blood glucose, cholesterol and LDL respectively, were significantly higher (P <0.05) in groups IIA(280.7±20, 275.6±14.39 mg/dL, 213.8±26.2 mg/dL), IIB (246.7±17.81mg/dL, 246.7±17.81 mg/dL, 178.95±21.43 mg/dL), IIC (254±8.71 mg/dL, 254±8.71 mg/dL, 194.8±19.95 mg/dL) and IID (230±19.38 mg/dL, 230±19.38 mg/dL, 166.1±15.48 mg/dL) than control group (132.8±9.1 mg/dL, 132.8±9.1 mg/dL, 101.8±11.2 mg/dL), these parameters were significantly reduced(P <0.05) in groups IIB, IIC and IID when compared to group IIA with highest reduction in group IID **[table 1]** .

Serum insulin levels, HOMA-IR and HDL respectively, were significantly difference (P <0.05) in groups IIA(8.31±0.64 Mu/ml, 5.76±0.64, 30.69±1.54 mg/dL), IIB (7.21±0.671 Mu/ml, 4.59±0.6, 33.8±2.71mg/dL) and IIC (7.47±0.97 Mu/ml, 4.72±0.55, 32.7±2.23mg/dL) than control group (6.41±1.02 Mu/ml, 1.17±0.02 , 36.25±2.96mg/dL), while group IID showed only significant reduction (P <0.05) in serum insulin (6.11±0.60 Mu/ml) versus group IIB and group IIC. These parameters were significantly elevated (P <0.05) in groups IIB, IIC and IID when compared to group IIA with nearly normal level in group IID **[table 1]**

Triglyceride level was significantly elevated (P <0.05) in group IIA (194.7±10.14 mg/dL) compared to control group (71.3±11.11 mg/dL), while significant reduction (P <0.05) in TG level groups IIB (75.90±10.45 mg/dL), IIC (78.9±7.46 mg/dL) and IID (68.6±9 mg/dL) compared to group IIA**[table 1]**

There was a significant negative correlation (P <0.05) between serum insulin, blood glucose, cholesterol, TG, LDL and serum irisin level in all studied groups, while HOMA-IR and HDL showed significant positive correlation (P <0.05) with serum irisin level in all studied groups**[table 2]**

Stepwise Logistic regression analysis showed that serum insulin, cholesterol and TG were the main predictors of serum irisin levels among other laboratory biomarkers **[table 3]**

January. 2021 Volume 27 Issue 1 10.21608/zumj.2019.13959.1272

Table 1. Effect of exercise and Vitamin D on the following parameters in all studied groups

	Group (I) (control)	Group (IIA) (Diabetic Control)	Group (IIB) (Diabetic and Exercise)	Group (IIC) (Diabetic and Vit D)	Group (IID) (Diabetic, Vit D and Exercise)
BGL (mg/dL)	132.8±9.1	275.6±14.39*	246.7±17.81$^{*\#}$	254±8.71$^{*\#}$	230±19.38$^{*\#@\$}$
Insulin (Mu/ml)	18.3±1.002	8.31±0.64*	7.21±0.67$^{*\#}$	7.47±0.97$^{*\#}$	6.11±0.60$^{*\#@\$}$
HOMA-IR	3.35 ±0.38	5.76±0.64*	4.59±0.6$^{*\#}$	4.72±0.55$^{*\#}$	3.36±0.46$^{\#@\$}$
Cholesterol(mg/dl)	132.8±9.1	275.6±14.39*	246.7±17.81$^{*\#}$	254±8.71$^{*\#}$	230±19.38$^{*\#@\$}$
TG(mg/dl)	71.3±11.11	194.7±10.14*	75.90±10.45$^{\#}$	78.9±7.46$^{\#}$	68.6±9$^{\#\$}$
LDL(mg/ dl)	101.8±11.28	213.8±26.20*	178.95±21.43$^{*\#}$	194.8±19.95$^{*\#}$	166.1±15.48$^{*\#\$}$
HDL(mg/ dl)	36.25±2.96	30.69±1.54*	33.8±2.71$^{*\#}$	32.7±2.23$^{*\#}$	36.6±1.91$^{\#@\$}$

FBG: Fasting blood glucose

* P <0.05 Vs I; $^{\#}$P<0.05 Vs IIA; $^{@}$ P <0.05 Vs IIB; $^{\$}$ P <0.05 Vs IIC

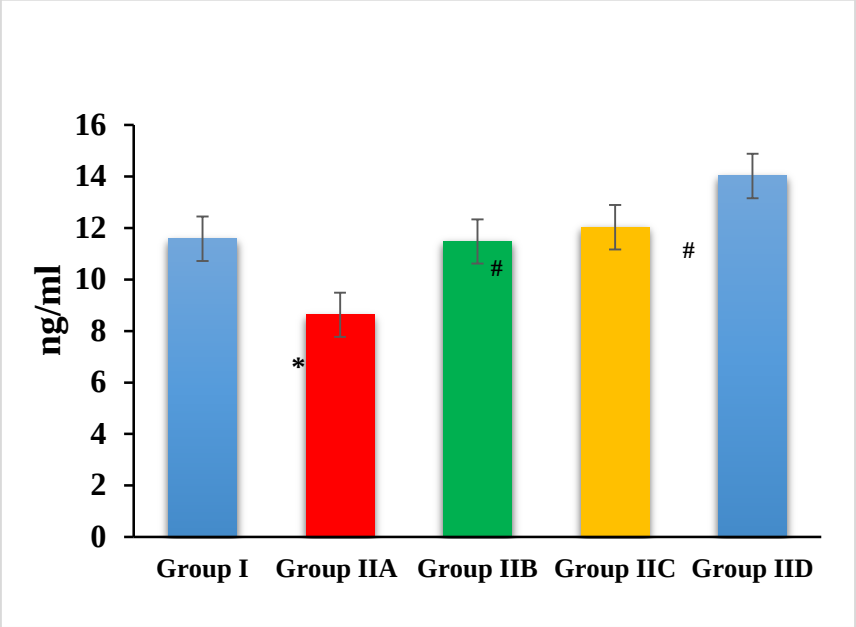
Table 2. Pearson correlation between serum Irisin level and lipid profile (HOMA-IR, Cholesterol, Triglycerides, LDL and HDL) in all studied groups.

	Group (IIA) (Diabetic and Sedentary)		Group (IIB) (Diabetic and Exercise)		Group (IIC) (Diabetic and Vit D)		Group (IID) (Diabetic, Vit D and Exercise)	
	r	P	R	P	R	P	r	P
HOMA-IR	0.862	<0.05	0.946	<0.001	0.938	<0.001	0.919	<0.001
Insulin(Mu/ml)	-0.958	<0.001	-0.676	<0.05	-0.658	<0.05	-0.947	<0.001
BGL(mg/dl)	-0.686	<0.05	-0.838	<0.05	-0.854	<0.05	-0.973	<0.001
Cholesterol (mg/dl)	-0.962	<0.001	-0.825	<0.05	-0.965	<0.001	-0.923	<0.001
TG(mg/dl)	-0.879	<0.05	-0.855	<0.05	-0.957	<0.001	-0.931	<0.001
LDL(mg/dl)	-0.948	<0.001	-0.876	<0.05	-0.886	<0.05	-0.945	<0.001
HDL(mg/dl)	-0.789	<0.05	0.781	<0.05	-0.938	<0.001	-0.936	<0.001

Table 3. Stepwise Logistic regression analysis of significant factors affected Irisin level.

Risk Factors	B	SE	Beta	T	Sig
Triglycerides	0.021	0.004	0.536	4.640	<0.001**
Cholesterol	0.034	0.011	0.920	3.049	<0.05*
Insulin	0.604	0.241	1.455	2.509	<0.05*
LDL	0.013	0.008	0.288	1.527	0.134
HDL	0.019	0.066	0.031	0.281	0.780
Glucose	0.21	0.017	0.852	1.205	0.235
HOMA-IR	0.571	0.661	0.315	0.864	0.391

January. 2021 Volume 27 Issue 1 10.21608/zumj.2019.13959.1272



* P <0.05 Vs I; # P <0.001 Vs IIA; @ P <0.05 Vs IIB; $ P <0.05 Vs IIC

Figure 1.Bar chart showed effect of exercise and Vitamin D on serum Irisin level (ng/ml) on diabetic rats.

DISCUSSION

This study was done to detect the effect of Vitamin D and exercise on irisin level in type II diabetic albino rats by investigating the role of Vitamin D supplementation and the role of exercise in improving insulin sensitivity in type II diabetes. At the end of experimental period all animals were investigated for serum irisin, insulin, glucose, triglycerides, cholesterol, LDL and HDL and HOMA-IR.

Serum level of irisn in this study showed significant decrease in diabetic control group (group IIA) compared to control group, this is agreed with a study done by Kucukkaraca and Sogut, which detect the effect of exercise and vitamin D on diabetic rat models, which showed decrease serum level of irisin in typeII diabetic group with mean 1.9±0.5 compared to control group with mean 2.6±1.6 [13], Similarly [14-16] found significantly decreased concentration of irisin in adults with T2DM, it was attributed to insulin resistance in the skeletal muscle that may change irisin expression, secretion or impaired action [17].

This was disagreed by [18] who investigated plasma irisin concentrations in T2DM individuals, that were significantly higher than levels noted in healthy volunteers. They explained increased level of irisin in such patients due to activated PGC1α that may increase expression of FNDC5 (mRNA released induced browning of subcutaneous fat in mice and mediates beneficial effects of exercise on metabolism), as a precursor of irisin which promote irisin secretion into blood. Thus, irisin secretion may be compensatively enhanced through a fat-derived feedback mechanism in those patients [19].

Many studies have investigated the effect of exercise on irisin secretion and have reported contradictory results. In this study, exercise produced significant increase in the serum level of irisin compared to diabetic non-exercising group, this agreed with a previous study on rats where chronic exercise for eight weeks produced significant increase in serum level of irisin in type2diabetic compared with control group [20]and in human[21].

While other studies showed increased circulating irisin levels in extremely obese sedentary women[22]; increased the serum level of irisin in non-runners group compared to runners[4]. Probably, most of these controversies may depend on the type of exercise, its duration, as it changes the

January. 2021 Volume 27 Issue 1 10.21608/zumj.2019.13959.1272

expression of PPARGC1A (Peroxisome proliferator-activated receptor gamma coactivator 1-alpha) or FNDC5 in skeletal[23].

In this study, we examined the impact of vitamin D and exercise on circulating irisin in diabetic rats, found increase in the level of irisin in diabetic rats with vitamin D than diabetic control and also increase its level in vitamin D administration in conjunction with exercise compared to diabetic control and normal control group, in line with a preceding study that detected elevated serum level of irisin after administration on vitamin D and also after conjunction with exercise [13]

We detected a negative correlation between irisin level and Cholesterol, triglycerides and LDL in the studied groups and positive correlation with HDL.

The study of [4] found significant positive correlations between irisin versus BMI, triglycerides and total body fat(g) which is not agreed with our study in exercise group, while, [24], proved negative correlation between irisin and lipid profile (cholesterol & triglycerides) in different athletics groups, suggesting that this hormone may be involved in metabolic regulation.

In this study, there is positive correlation between serum level of irisin and HOMA-IR in diabetic control group, was also noted in women with normal weight and women with diabetes mellitus [22] and in Japanese patients in both sexes [25]. This may be attributed to increased serum level of irisin that may promote energy consumption, leading to weight loss, fat reduction and improved insulin resistance.

CONCLUSION

We could conclude that, Irisin has a direct effect in attenuating metabolic derangements in insulin resistance and type 2 diabetes and exercise effects in the abnormal metabolic condition might be more adaptable in maintaining the irisin levels in skeletal muscle and induce the irisin uptake from circulation into adipose tissue. Exercise training and application of vitamin D in diabetic groups partially corrected the reduction in serum irisin induced by diabetes mellitus. Moreover, irisin level had a significant positive correlation with HOMA-IR and HDL. There is still need for more researches about this hormone and also about the influence of vitamin D and exercise over the irisin secretion in diabetes.

Conflict of interest: Nothing to declare
Financial disclosure: Nothing to declare

REFERENCES

1. **Satin L, Butler P, Ha J and Sherman A**. Pulsatile insulin secretion, impaired glucose tolerance and type 2 diabetes. Mol Aspects Med J 2015;42: 61–77
2. **AI-Lawati J**. Diabetes mellitus: A local and Global public health emergency, Oman Medical Journal, 2017; 32(3):177-79
3. **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): 66-72.
4. **Butler T, Piwowar K, Byrd G, Seimer M, Seigneurie N, Byrd B et al.** Plasma irisin in runners and non-runners: no favorablemetabolic association in humans, Physiological Reports, 2015; 3(10) : 114-20.
5. **Alaca N, Uslu S, Suyen G, Ince U, Sertesser M and Kurtel H.**Effects of different aerobic exercise frequencies on streptozotocin-nicotinamide-induced type 2 diabetic rats: Continous versus short bouts and weekend warrior exercise, Journal of Diabetes. 2018; 10(1).
6. **Jorde R and Grimnes G.**Vitamin D and metabolic health with special reference to the effect of vitamin D on serum lipids. Prog Lipid Res 2011; 50(4):303–12
7. **Namakin K, Tavakoli F and Zardast M.** Effect of Vitamin D supplementation on Lipid Profile in Children Aged 10-14 Years Old. Int J Pediatr. 2015; 3: 987-94.
8. **Messier C, Whately K, Liang J, Du L and Puissant D.** The effects of a high-fat, high-fructose, and combination diet on learning, weight, and glucose regulation in C57BL/6 mice. Behavioural brain research, 2007;178(1): 139–45.
9. **Avasthi S. Srivastava N, Singh A and Manoj Srivastava.**Stem Cell: Past, Present and Future. Internet Journal of Medical Update, 2007;Vol. 3(1), 22-30
10. **Graham M, Janecek J, Kittredge J and Hering B.** The Streptozotocin-Induced Diabetic Nude Mouse Model: Differences between Animals from Different Sources.Comp Med 2011; 61(4): 356–60.

January. 2021 Volume 27 Issue 1 10.21608/zumj.2019.13959.1272

11. He B, Shi M, Zhang L, Li G, Zhang L , Shao H et al. Beneficial effect of galanin on insulin sensitivity in muscle of type 2 diabetic rats, Physiology & Behavior, 2011;103, (3-4):284-9.

12. Nishizawa H, Shimomura I and Kishida K. Androgens decrease plasma adiponectin, an insulin-sensitizing adipocyte-derived protein. Diabetes, 2002;51: 2734–41

13. Kucukkaraca H and Sogut M: Effect of exercise and vitamin d supplementation on the level of irisin hormone in diabetic rats; clinical nutrition J, 2018; 37, S314-17.

14. Dozio E, Passer E, Cardani R, Benedini S, Aresta C, Valaperta R et al.: Circulating irisin is reduced in male patients with typr 1 and type 2 myotonic dystrophies; Frontiers in Endocinology, 2017; 8, art 38.

15. Liu J, Wong M, Toy W, Tan C, Liu S, Sum C et al.: Lower circulating irisin is associated with type 2 diabetes mellitus, Journal of Diabetes and its Complications, 2013 27(4):365–69.

16. Choi Y, Kim M, Bae, K, Seo H, Jeong J,Lee W et al. Serum irisin level in new-onset type2 diabetes, J Diabetes research and Clinical practice, 2013;100,(1) 96-101.

17.Gamas L, Matafome P and Seica R.Irisin and Myonectin Regulation in the Insulin Resistant Muscle:Implications to Adipose Tissue: Muscle Crosstalk, Journal of Diabetes Research, 2015; 8pages.

18. Rana K, Pararasa C, Afzal I and Nagel D. Plasma irisin is elevated in type 2 diabetes and is assosciated with increased E-selection levels, Cardiovasc Diabetol 2017; 16:147.

19. Kurdiova T, Balaz M, Mayer A, Maderova D, Belan V ,Wolfrum C et al. Exercise-mimicking treatment fails to increase Fndc5 mRNA and irisin secretion in primary human myotubes; J. Peptides 2014;56, 1–7.

20. Abd El-Salam M and. Habib M. Effect of Swimming Exercise on Irisin Levels in Streptozotocin Induced Type 1 and Type 2 Diabetes Mellitus in Rats; Med. J. Cairo Univ., 2017; 85(7) 2625-34.

21) Young H,. Siopi, A. Mougios, V. and Park H. Irisin in response to exercise in humans with and without metabolic syndrome," Journal of Clinical Endocrinology and Metabolism, 2015;100, (3): E453–7.

22. Pardo M, Crujeiras A and Amil M. Association of irisin with fat mass, resting energy expenditure, and daily activity in conditions of extreme body mass index, International Journal of Endocrinology, Article ID 857270,2014; vol., 9 pages.

23) Pekkala S, Wiklund P, Hulmi J, Ahtianinen J, Horttanainen M, Pollanen E et al. Are skeletal muscle FNDC5 gene expression and irisin release regulated by exercise and related to health? J. Physiol. 2013;591, 5393–400.

24) Benedini S, Dozio E, Invernizzi P, Vianello E, Banfi G ,Terruzzi I et al. Irisin: A Potential Link between Physical Exercise and Metabolism—An Observational Study in Differently Trained Subjects, from Elite Athletes to Sedentary People, Journal of Diabetes Research Volume 2017; Article ID 1039161, 7 pages, https://doi.org/10.1155/2017/1039161

25) Fukushima Y, Kurose S, Shinno H, Thi Thu C, Tamanoi A , Hasegawa T et al. Relationships between serum irisin levels and metabolic parameters in Japanese patients with obesity; Obesity Science& Practice J 2016; 43: 203-9.

Cite This Article

Zaitoun, N., Bahaa Eldin, A., Diab, A., Hasan, M. Effect of vitamin D supplementation and muscular exercise on irisin serum level and related metabolic parameters in type II diabetic albino rats. *Zagazig University Medical Journal*, 2021; (97-103): -. doi: 10.21608/zumj.2019.13959.1272