Research Article

Comparison of different intensities of resistance training on glucose, insulin, adiponectin, and HbA1C levels in male patients with type 2 diabetes

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Abstract

The purpose of this research is to determine the effect of different methods of resistance training on diabetes in men with type 2 diabetes. This is a semi-experimental and practical study. Forty-four subjects with type 2 diabetes, randomly divided to 4 groups. The three experimental groups of 11, 11, and 12 people and a control group of 10 people, were performed the pre-test and post-test of after 12 weeks of training intervention under high intensity, moderate intensity and low intensity programs. The research variables were glucose, insulin, adiponectin, insulin resistance and glycated hemoglobin. ELISA kit was used to test adiponectin. For analyzing the data, one-way ANOVA statistical test of gain scores and LSD post hoc test was used. All tree Exercise protocols had a positive effect and caused a significant decrease in glucose (P>0.001), insulin (P>0.001), insulin resistance (P>0.001), adiponectin (P>0.001) and serum HbA1C (P>0.001), which had a significant difference with the control group (P>0.05). But there was no difference between the three training groups. Calculating the effect size on the serum factors of diabetes showed that the low intensity had the greatest effect on insulin (ES = 1.11), insulin resistance (ES = 1.39) and HbA1C (ES = 2.05), while glucose (ES = 1.09) and adiponectin (ES = 0.38) were affected more by high intensity. According to the effect sizes, it is recommended to clinician to prescribe high intensity programs to reduce glucose and low intensity programs to improve insulin, insulin resistance and serum HbA1C in type 2 diabetic male patients.

Key Words: **Resistance training, Diabetes, Insulin, Adiponectin, HbA1C**

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Received 15 October 2024; Accepted 26 December 2024

Introduction

Diabetes is a metabolic disorder characterized by chronic hyperglycemia due to insulin resistance or inadequate insulin secretion. Type 2 diabetes is a wide range of disorders that ultimately lead to hyperglycemia (Cox et al., 2020; Delevatti et al., 2020). The global number of people with T2DM was 445 million in 2020, and it is projected to increase in 2050 to 730 million. Due to the prevalence of type 2 diabetes in the world, mortality and heavy economic costs, regular exercise in its control or treatment is of great importance (Xiang & Hester, 2016). Previous studies have shown that reducing environmental insulin resistance during exercise leads to increased environmental glucose absorption, while liver glucose production remains constant. In the muscle of patients with type 2 diabetes, a significant increase in insulin resistance has been reported. Insulin resistance is a condition where the body's cells become less responsive to insulin, a hormone that helps regulate blood sugar levels. In muscle tissues, insulin normally facilitates the uptake of glucose from the bloodstream by promoting the translocation of glucose transporter type 4 (GLUT4) to the cell membrane. However, in insulin-resistant states, this signaling pathway is impaired. In patients with these conditions, exercise leads to increased glucose absorption, indicating that insulin resistance doesn't entirely block blood glucose uptake by cells. However, insulin resistance impairs insulin's ability to promote glucose absorption, maintain glucose levels, and decrease glucose production by the liver (Kang, 2018). Studies have shown that exercise can affect various factors, such as glucose, insulin, or insulin resistance, depending on its type and severity of exercises (Golshan et al., 2020; Malekinezhad et al., 2019).

Resistance exercises are one of the types of exercises that can have favorable effects on effective indicators in diabetic patients. The results of some studies have shown that resistance exercise can improve fasting glucose levels and a significant reduction in insulin resistance in diabetic patients (AminiLari et al., 2017; boroomand et al., 2023; Ouerghi et al., 2017; Zarei et al., 2020; Zehsaz et al., 2016). One of the main fatty tissue hormones is adiponectin, which regulates many biological activities, which, in contrast to other adipocytokines, decreases in obesity, diabetes, coronary artery disease and high blood pressure (Kelly et al., 2007). Adiponectin is the only adipokine which has negative related with the body's fat mass and is involved in the balance of blood glucose and blood lipids and in the pathogenesis of insulin resistance and diabetes (Kao et al., 2021). The results of some studies suggest that the implementation of the resistance exercises can lead to a significant increase in the serum levels of the adiponectin (Dehrashid et al., 2018; Montrezol et al., 2014; Steki Oregani & Valipour Dehnou, 2016). Jiménez-Martínez and their colleagues in a systematic review study has reported that the different types of resistance exercises (both high intensity and low intensity resistance exercises) have been effect on adiponectin (Jimenez-Martinez et al., 2023). Resistance training influences adiponectin serum levels through several mechanisms (de Mello et al. 2011):

Muscle Contraction: When you engage in resistance training, muscle contractions stimulate the release of adiponectin from adipose tissue into the bloodstream.

Reduction in Fat Mass: Resistance training helps reduce body fat, which can lead to an increase in adiponectin levels.

Inflammation Reduction: Consistent resistance training lowers systemic inflammation, which is associated with higher adiponectin levels.

Improved Insulin Sensitivity: Resistance training enhances insulin sensitivity, which can positively influence adiponectin secretion.

Overall, regular and consistent resistance training promotes higher adiponectin levels, contributing to better metabolic health and reduced inflammation.

There are some recommendation for diabetes patients to help manage their condition and improve overall health by involving all major muscle groups at least 2 days per week. This can include exercises with free weights, weight machines, or resistance bands (Colberg et al. 2016). Since studies have been conducted on resistance exercises, they have not been introduced any gold or standard exercise protocols for diabetes patients. The effect of different resistance exercise, varies according to the intensity of the exercise, the volume of exercise, the rest time between the sets and the rest time between the movements. Therefore, the purpose of this study was to investigate the effect of different type of resistance training on the sugar profile and serum levels of adiponectin in men with type 2 diabetes, to better understand interaction of intensity, volume and diabetes indices.

Materials and Methods

Study design overview

This study was semi-experimental with control group and applied in terms of purpose. The statistical population of this study included patients suffering from type 2 diabetes in Yazd province, of the 100 volunteered to participate in this research through a call word of mouth at the Diabetes Research Center and Clinics and the association for the support of diabetic patients in Yazd province. The sample size was determined by power calculation performed with G*Power v.3.1.9.2, the following input parameters: mean anticipated effect size for a comparison between two dependent means extracted from Montrezol et al. 2014 for glogus and adiponectin (f = 0.7-1.9) statistical power 1−β = 0.80 and α = 0.05. Based on these calculations, the target sample size determined for the present study was 40. The selection and statistical sample of this research, it included 48 diabetic patients with an average age of 52.36 years, who were divided into four groups of 12 people. Four groups were randomly divided into three training groups and one control group by drawing lots. After examining the medical records of the patients by the relevant specialist doctor and ensuring that they have all the conditions for entering the study, the methods of work implementation were explained to the patients during a briefing session (Table 1).

Blood tests were performed in a laboratory under the supervision of the Diabetes Association by a laboratory technician, and routine tests were performed. The research variables were glucose, insulin, adiponectin, insulin resistance and hemoglobin glycosity. Adiponectin was measured with a Swedish ELISA kit (Mercodia, Uppsala, Sweden) according to the manufacturer's instructions with assay sensitivity of 1.25 (µg/ml) and the rest was frozen and stored. HOMA-IR was calculated according to the formula:

HOMA-IR = fasting insulin (microU/L) × fasting glucose (mmol/L) / 22.5

HOMA-IR is a relevant and widely used index for assessing insulin resistance due to its simplicity, strong correlation with gold-standard methods, and predictive value for metabolic and cardiovascular diseases (Wallace et al. 2004).

The subjects were randomly divided into three experimental groups and one control group, then the pre-test was performed and post-test stages 48 hours after 12 weeks of interventions were measured for all four groups. Inclusion criteria include type 2 diabetes, fasting glucose under 300 and not having regular exercises and sports activity in the last 6 months. Exclusion criteria included cardiovascular and respiratory diseases, high blood pressure, using alcohol and anti-oxidant and anti-inflammatory supplements, unwillingness to continue working, absence of more than two training sessions.

Experimental groups

The training intervention program was implemented under three resistance training protocols 3 days a week for 12 weeks, the protocols included resistance training to increase endurance (low intensity), increase volume (moderate intensity) or increase strength (high intensity). The details of training protocol including: exact exercises, duration, frequency, and intensity levels clearly indicate separate for every protocols presented in table 2-5. The training protocols are attached. The intensity of training increased every three weeks. Brzycki's formula was used to determine a maximum repetition.

$$Brzycki's\ formula = M = \frac{W}{1.0278 - 0.0278n}.$$

it applies for up to 10 repetitions.

The control group was asked to live their normal lives and report any changes in medication, diet, or physical activity.

Statistical analysis

In order to check the normal distribution of the data, because of sample size less than 50, the Shapiro-Wilk statistical test was used. To determine the effect of training and to compare the pre-test and post-test, the pair t-test was used. Since some data had not normal distribution, gain score was calculated and to compare the groups, the one-way statistical test was used on gain score to determine the difference between the pre-test and post-test, and to determine the difference between the groups, the LSD post hoc test was used. Homogeneity of variance controlled by Leven test. A significance level of 0.05 was considered for all statistical tests. Also, to compare the effect size of each protocol on the measured factors, the effect size was calculated, which is presented in Table 6. The effect size was calculated with the following formula:

$$SD_{pooled} = \sqrt{\frac{SD_1^2 + SD_2^2}{2}} \qquad d = \frac{M_1 - M_2}{SD_{pooled}}$$

Results

The present study investigated the effect of 12 weeks of different resistance training protocols on serum levels of sugar, insulin, insulin resistance, adiponectin and HbA1C. The number of 4 people from the subjects dropped out due to the absence of more than two training sessions (2 people) and 2 people of the control group didn't continued cooperation in the study. The demographic characteristics of the present samples are presented in Table 1.

Table 1. Characteristics of age, weight, and body mass index of the samples.

Groups	variable	Pre-test	Post-test
		Mean ± sd	Mean ± sd
Control =10	Age (years)	53.20 ± 2.66	
	Weight (kg)	78.29 ± 6.59	77.99 ± 6.69
	BMI	27.11 ± 2.23	27.00 ± 2.29
high intensity =12	Age (years)	53.50 ± 4.60	
	Weight (kg)	75.94 ± 4.87	72.83 ± 5.27
	BMI	26.43 ± 1.29	25.16 ± 1.22
low intensity =11	Age (years)	52.27 ± 3.98	
	Weight (kg)	80.12 ± 6.75	77.35 ± 6.67
	BMI	27.11 ± 1.54	26.17 ± 1.34
moderate intensity =11	Age (years)	50.45 ± 4.37	
	Weight (kg)	80.94 ± 6.35	78.11 ± 5.79
	BMI	25.80 ± 1.61	24.90 ± 1.48

There was no significant difference between the subjects in the pre-test in terms of age, weight, and BMI or body mass index. In the post-test in all three exercise groups, the weight of the subjects as well as their body mass index decreased significantly ($P < 0.001$). Blood glucose levels were measured in the three training groups and the control group in the pre-test and post-test, and the results are shown in Figure 1.

Although all three training groups caused a significant decrease in the blood glucose levels of men with type 2 diabetes.

The amount of blood insulin was measured in the three training groups and the control group in the pre-test and post-test, and the results can be seen in Figure 2.

Table 2. Movements with machines, dumbbells, barbells and halter.

The first session of the week	The 2nd session of the week	The 3th session of the week
rowing	lat pulldown	rowing + lat pulldown
leg press	leg press	leg press
hamstring curls	hamstring curls	hamstring curls
biceps curls	triceps extension	biceps curls + triceps extension
knee extension	knee extension	knee extension
chest press	chest press	chest press
hack squat	hack squat	hack squat
overhead press	lateral shoulder raises	overhead press
calf raise	calf raise	calf raise
abdominal crunch	abdominal side crunch	abdominal twist
lower back	lower back	lower back

Table 3. Low intensity resistance training program (increase endurance)

The 1st three weeks	The 1st two weeks of movement training	The 3rd week of testing 1RM
The 2nd three weeks	2 sets of 30 repetitions + 10 auxiliary (10 + 30 × 2) 30% of 1RM	30% 1RM
The 3rd three weeks	2 sets of 30 repetitions + 10 auxiliary (10 + 30 × 2) 40% of	40% 1RM
The 4th three weeks	2 sets of 30 repetitions + 10 auxiliary (10 + 30 x 2)	50% 1RM

Rest between sets 1 to 2

Table 4. Moderate intensity resistance training program (increase volume)

The 1st three weeks	The 1st two weeks of movement training	The 3rd week of testing 1RM
The 2nd three weeks	2 sets (auxiliary 3) + 8-12 repetitions (3k + 8-12 × 2)	75% 1RM
The 3rd three weeks	2 sets (5 auxiliary) + 8-12 repetitions (5k + 8-12 x 2)	75% 1RM
The 4th three weeks	2 sets (6 auxiliary) + 10-12 repetitions (6 k + 10-12 × 2)	75% 1RM

90 seconds rest between sets

Table 5. High intensity resistance training program (increase strength)

The 1st three weeks	The 1st two weeks of movement training	The 3rd week of testing 1RM
The 2nd three weeks	2 sets of 4-6 repetitions (2 × 4-6)	85-90% 1RM
The 3rd three weeks	2 sets of 4-6 repetitions (2 × 4-6)	+ 5% of the record
The 4th three weeks	2 sets of 4-6 repetitions (2 × 4-6)	+ 10% of the record

Rest between sets 3-5 minutes

Table 6. The effect size of three exercises type on the measured factors.

Groups	Glucose	Insulin	Adiponectin	HOMAIR	HbA1C
Control	-0.08	-0.01	0.22	0.02	0.20
High Intensity	1.22	0.56	-0.49	0.96	1.40
Low Intensity	1.09	1.11	-0.38	1.39	2.05
Moderate Intensity	0.85	1.04	-0.42	1.35	2.05

One-way ANOVA on gain scores showed that there is a significant difference between these four groups ($F_{3, 40} = 3.62$, $P < 0.021$), which the LSD post hoc test revealed this difference between the control group and the low intensity groups (0.003 = P) and moderate intensity ($P = 0.024$) were significant, but not with the high intensity program group ($P < 0.1$). The three exercise groups did not have a significant difference in blood insulin levels ($P < 0.1$).

The amount of adiponectin was measured in the three training groups and the control group in the pre-test and post-test, and the results are shown in Figure 3.

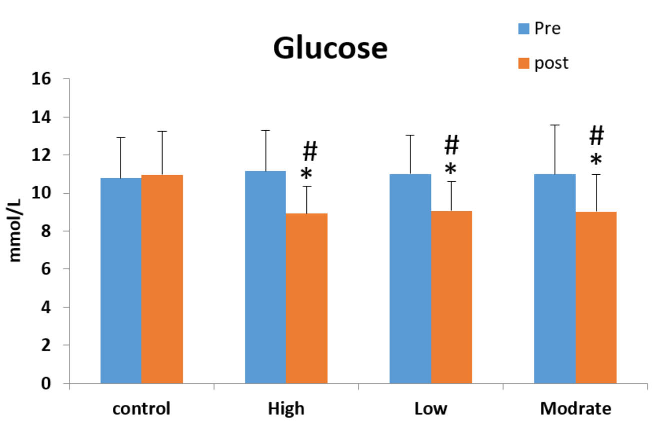

Figure 1. The mean of Blood glucose levels in all groups at the pre and post-test. *: Significant difference with the control group (p<0.05). #: Significant difference with the pre-test (p<0.05).

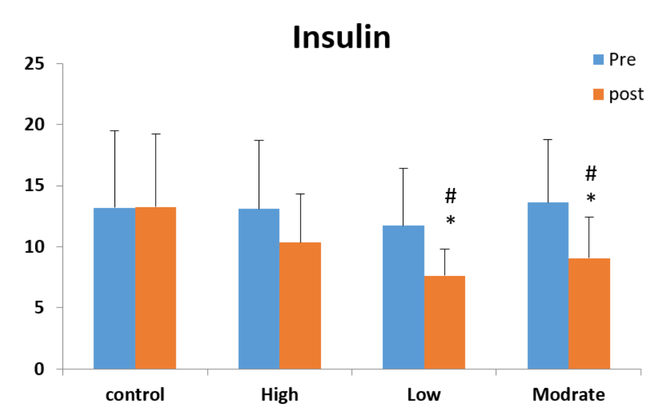

Figure 2. The mean of Blood glucose levels in all groups at the pre and post-test. *: Significant difference with the control group (p<0.05). #: Significant difference with the pre-test (p<0.05).

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One-way ANOVA on gain scores showed that there is a significant difference between these four groups in the adiponectin ($F_{3, 40} = 3.18$, $P = 0.034$), which the LSD post hoc test revealed this difference between the control group and the moderate intensity group (p = 0.019), the other two groups, high intensity (P = 0.056) and low intensity (P = 0.061) had border line not significant differences in adiponectin levels with the control group. However, considering that no significant difference was found between the three training groups (P > 0.2), different resistance training protocols have the same effect on adiponectin

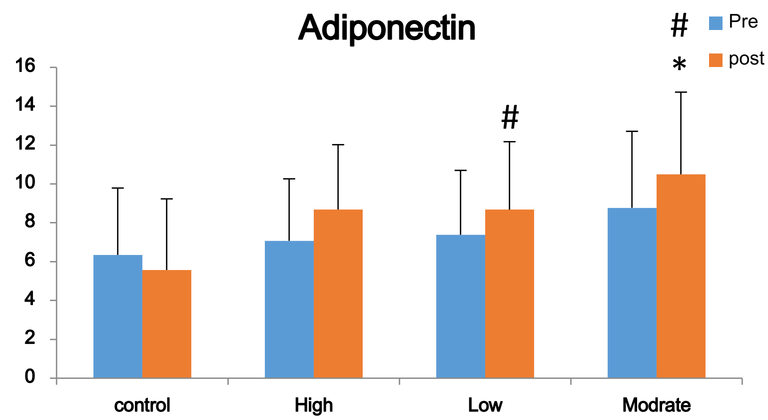

Figure 3. The amount of adiponectin in all groups at the pre and post-test. *: Significant difference with the control group (p<0.05). #: Significant difference with the pre-test (p<0.05).

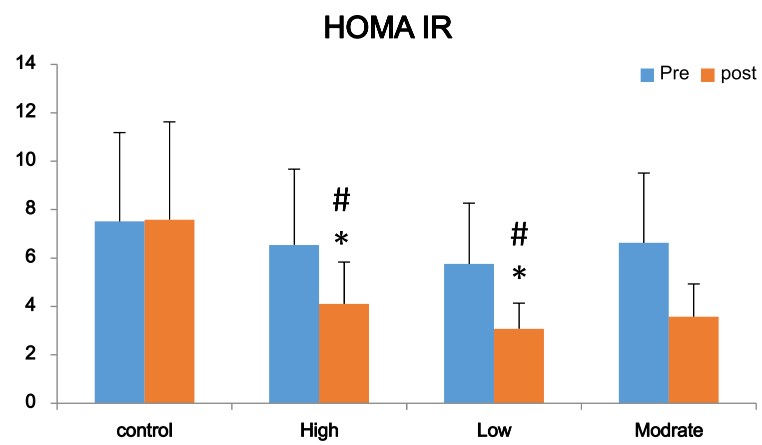

Figure 4. HOMA IR insulin resistance in the groups at the pre and post-test. *: Significant difference with the control group (p<0.05). #: Significant difference with the pre-test (p<0.05).

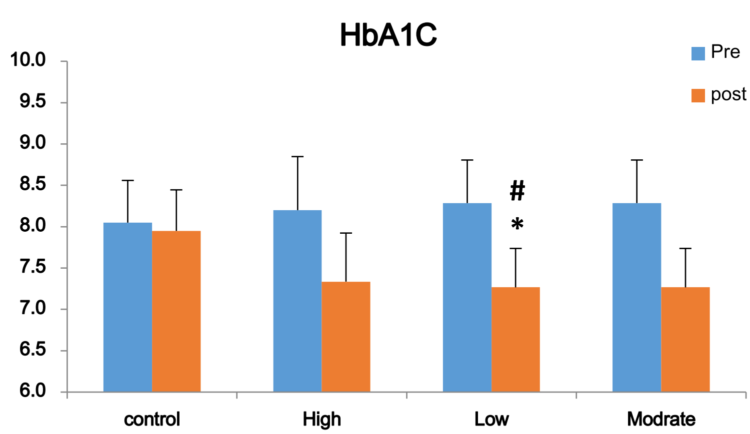

Figure 5. The level of HbA1C in all groups at the pre and post-test. *: Significant difference with the control group (p<0.05). #: Significant difference with the pre-test (p<0.05).

in men with type 2 diabetes.

HOMA IR insulin resistance was measured in the three training groups and the control group in the pre-test and post-test, and the results are shown in Figure 4. One-way ANOVA on gain scores showed that there is a significant difference between these four groups in HOMA IR insulin resistance (F3, 40 = 8.20, P < 0.001). The LSD post hoc test revealed this difference was between the control group and the high intensity (P = 0.001), low intensity (P > 0.001), and moderate intensity (P > 0.001). There was no significance difference between the three training (P > 0.3).

The mean of HbA1C was measured in the three training groups and the control group in the pre-test and post-test, and the results are shown in Figure 5. One-way ANOVA on gain scores showed that there is a significant difference in HbA1C between these four groups (F3, 40 = 4.32, P < 0.001). The LSD post hoc test revealed that this difference was between the control group and the high intensity (p = 0.008), low intensity (p = 0.004), and moderate intensity (p = 0.004) in HbA1C level. There was no significant difference between the three training groups (p > 0.7).

By calculating the effect size of these exercises on the serum factors of diabetes (Table 2), it was shown that the effect sizes of the exercises on the factors are different. Low intensity training had the greatest effect on insulin (ES = 1.11), insulin resistance (ES = 1.39) and HbA1C (ES = 2.05), while glucose (ES = 1.09) and adiponectin (ES = 0.38) were affected more by high intensity.

Discussion

Based on the results, it could be said that the 12-week exercise protocols by the experimental groups, compared to the no-exercise that is the control group, caused significant changes in the blood sugar of men with type 2 diabetes in the direction of reduction has been found that this is due to the positive effect of all three protocols on the blood sugar levels of the patients. These results are consistent with some previous studies such as Yousefipour et al. 2013 (Yousefipoor et al., 2014), Broumand et al. 2023 (boroomand et al., 2023), which reported the effect of resistance, aerobic or combined exercises on blood sugar reduction. Egar et al., 2013, investigated two types of moderate intensity and low intensity resistance training in diabetic patients, and they found both methods to be effective (Egger et al., 2013). Resistance training can lead to favorable changes in hormones that regulate glucose metabolism. For example, it can reduce levels of and increase levels of hormones like adiponectin, which improves insulin sensitivity. Resistance training also can help reduce visceral fat, which is associated with insulin resistance and higher blood glucose levels.

Saremi et al reported that resistance exercise also has advantages in controlling blood glucose and insulin action in type 2 diabetes. In a well-controlled study, it was observed that performing 3 sessions of resistance exercise per week for 3 months in elderly men with type 2 diabetes caused a 5% increase in insulin action, a decrease of 6.1 percent of blood glucose and significant reduction of visceral fat (Saremi, 2011). In another study, researchers found that after 10 weeks of aerobic and resistance training (3 sessions per week), the blood glucose of diabetic subjects decreased significantly. Of course, the decrease of hemoglobin A1c in resistance training group was more (Bweir et al., 2009).

Therefore, this claim, based on the obtained results, shows that all three-exercise groups caused a decrease in insulin in the blood of men with type 2 diabetes, which was significant in the low intensity group and the moderate intensity group, and was significantly different from the control group, but the decrease in the high intensity group was not significant, so it can be said that the 12-week exercise protocol by the experimental group, compared to the control group, caused significant changes in the blood insulin of men with type 2 diabetes in order to reduce the two groups of low intensity and moderate intensity group. The same results have been reported in previous studies (Attarzadeh Hosseini et al., 2015; Bweir et al., 2009; Egger et al., 2013; Saremi, 2011).

According to the results, although all three-exercise groups caused a significant increase in blood adiponectin levels of men with type 2 diabetes, no significant difference was found between the three exercise groups. The same results were reported in other study (Parsian et al., 2022). On the other hand, another study showed that eight weeks of resistance training improves insulin sensitivity in men with type 2 diabetes, but these exercises have no significant effect on body weight and adiponectin (Boudou et al., 2003). In the present study, only the moderate intensity group had a significant difference with the control group, and the low intensity and high intensity groups did not have a significant difference with the control group in the post-test.

Regarding the immediate effects of resistance training on blood glucose and adiponectin levels in type 2 diabetics, there is less evidence compared to aerobic training. In people with prediabetes conditions (glucose level 100 to 125 mg/dL), resistance exercise leads to a decrease in fasting blood glucose up to 24 hours later. Of course, a greater decrease has been observed in response to resistance training with high volume (several sets versus one set per session) and intensity (Black et al., 2010). In general, it has been shown in diabetic individuals that resistance training leads to the improvement of insulin sensitivity by increasing the expression of GLUT-4, glycogen synthesis, adiponectin and decreasing TNF-α. In contrast with aerobic exercise, higher intensities (3 sets of resistance exercise of 8 to 10 repetitions with 75 to 85 percent of 1RM) can be tolerated by people with diabetes and have many advantages for these people (Saremi, 2011).

In term of insulin resistance, the results showed that although all three training groups significantly reduced HOMA IR insulin resistance in men with type 2 diabetes, no significant difference was found between the three training groups. Recent meta-analysis review showed resistance training had a significant effect on HOMA IR (Boyer et al., 2023). Resistance training increases the GLUT-4 expression. The reduction of glycogen synthase, adiponectin and TNF-α leads to the improvement of insulin sensitivity. Pereira et al. (2019) report that in rat models, a short-term training protocol improved hepatic insulin sensitivity, causing a decrease in hepatic glucose production and reducing liver inflammation through increased Akt-phosphorylation and decreased TNF-α activity respectively. Resistance training, similar to aerobic training improves the liver's ability to respond to insulin and suppress endogenous glucose production (Pereira et al., 2019).

Resistance training enhances the sensitivity of muscle cells to insulin, allowing for more efficient glucose uptake. This occurs through the upregulation of insulin signaling pathways, including the PI3K/Akt pathway, which promotes the translocation of glucose transporter type 4 (GLUT4) to the cell membrane. Studies have shown that resistance training improves insulin sensitivity in both healthy individuals and those with type 2 diabetes (T2D). For example, a study by Holten et al. (2004) demonstrated that 6 weeks of resistance training increased insulin-stimulated glucose uptake in skeletal muscle by 48% in individuals with T2D. According to the results obtained, which show that all three exercise groups caused a significant decrease in glycosylated hemoglobin HbA1C in men with type 2 diabetes, but considering that no significant difference was found between the three exercise groups, the implementation of all three exercise protocols by the experimental group has caused significant changes in the reduction of HbA1C in men with type 2 diabetes. These results were consistent with some previous studies, Zanuso et al. 2010 (Zanuso et al., 2010). Recent meta-analysis review showed the effects of high and medium-low intensity resistance training on T2DM patients were different in terms of HOMA-IR, only medium-low intensity resistance training resulted in a decrease in HOMA-IR (Fan et al., 2023). Also, another recent review has shown that high-intensity resistance training has a greater effect on HbA1C than low-intensity resistance training (Fan et al., 2023; Jansson et al., 2022).

Due to the fact that no difference was found between the three groups, it shows that all three training methods were effective, but it is possible to determine which one is more effective by using the effect size calculation. Effect sizes are a critical component of statistical analysis, as they provide a measure of the magnitude of a phenomenon or the strength of a relationship between varia-bles, independent of sample size. Unlike p-values, which only indicate whether an effect exists, effect sizes quantify how large or meaningful that effect is. Therefore, the results of calculating the effect size showed that the low intensity protocol had the greatest effect on insulin factors (1.11), insulin resistance (1.39) and HbA1C (2.05), while glucose (1.22) and adiponectin (-0.49) have changed the most with high intensity. Past studies also differed for the size of the effect of resistance training; Hansen et al. reported that resistance training had an effect on glucose absorption by muscles, while low intensity resistance had a greater effect on increasing insulin sensitivity (Hansen et al., 2012). The effect size of the current study looks large compared to other studies. Recent mete analysis review study (Liu et al., 2019) on HbA1c showed both intensive and low-moderate resistance have effect on A1c (-0.45; 95% CI, -0.65, -0.25). One study (Shenoy et al., 2009) at that review report (-1.82; 95% CI, -2.57, -1.07).

In terms of fasting glucose, a resent review study (Qadir et al., 2021) confirmed effect of resistance training in total was (-1.48; 95% CI, -3.0, 0.04), and some studies on that review report (-1,88; 95% CI, -2.46, -1.30), and another one (-3,31; 95% CI, -3.78, -2.84). The causality could be the most subject of these two studies were male and former studies reported differential responses after the resistance training with males improving and females worsening. Of course further supports the need for research in females specifically and careful examinations of sex-based differences in exercise physiology, muscle metabolism and glycemic control in order to optimize the prevention and management of type 2 diabetes in females (Surdi, 2023). The high effect size of the present study could probably be due to the appropriate volume and optimal intensity of the protocols, and male subjects.

There were limitations in this study that could be useful for researchers to pay attention to in future studies, such as paying attention to the severity of the disease, drug interactions, as well as the gender of the patients and diet. This study did not examine this method, and it is suggested that this method be compared at different severities and between the two genders.

Conclusion

The results showed that all three types of strength training at different intensities had an effect on sugar, insulin, insulin resistance, HbA1C, and adiponectin. Based on the results of the research, it is recommended to clinicians that type 2 diabetic patients use high intensity resistance exercises to reduce serum glucose levels and increase serum adiponectin levels, and also use low intensity resistance exercises with the provided protocol to reduce serum insulin levels. In addition, in order to reduce insulin resistance and reduce HbA1C, resistance exercises with the provided protocol should be used.

What is already known on this subject?

The all type of weight training as intervention have effect on sugar profile.

What this study adds?

Although the three types of weight training did not differ significantly, the effect sizes between the three types of training differed by more than 0.5.

Organ Cross-Talk Tips:
• Adiponectin is a key molecule in organ crosstalk that affects insulin signaling. Resistance training can influence adiponectin levels, thereby impacting insulin resistance and glucose metabolism.

Acknowledgements

In the end, we are grateful to the diabetes association and diabetes center of Yazd province and all the diabetic patients of Yazd city who participated in this study.

Funding

The funding for this research was provided by the author

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All subjects completed the PAR-Q questionnaire and medical evaluation, then a written consent form was received to participate in the program, and after signing the consent form and the PAR-Q being negative, they were introduced to the laboratory. This study has the code of ethics from the Ethics Committee of Shahid-Sadoughi University of Medical Sciences, Yazd, (IR.SSU.REC.1396.103).

Informed consent Participants signed an informed consent form prior to participation in the study.

Author contributions

Conceptualization: S.A, M.M.; Methodology: S.A., H.A.; Software: H.A.; Validation: R.Sh. Formal analysis: S.A.; Investigation: M.M., H.A.; Resources: R.Sh., H.A.; Data curation: R.Sh., H.A.; Writing - original draft: S.A.; Writing – review & editing: H.A.; Visualization: H.A.; Supervision: S.A. Project administration: H.A.; Funding acquisition: S.A.

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