Effect of resistance training on insulin resistance without clinical manifestations of type 2 diabetes in Jordanian men

Efecto del entrenamiento de resistencia sobre la resistencia a la insulina sin manifestaciones clínicas de diabetes tipo 2 en hombres jordanos

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Abstract

Introduction: Resistance training has been associated with improved insulin sensitivity in individuals with type 2 diabetes, but its role in non-diabetic overweight individuals remains unclear.

This study aimed to evaluate whether progressive resistance training reduces insulin resistance in overweight men at high risk of developing type 2 diabetes. We hypothesized that such training would significantly improve insulin sensitivity markers.

Methods: Thirteen overweight male individuals (aged 30-50 years, BMI > 25 kg/m2, HOMA-IR > 1.9 mg/kg and HbA1c < 5.8%) participated in an 8-week supervised resistance training program (3 sessions/week). Strength was measured using no more than one repetition of each exercise. Pre- and post-training assessments included Bioelectrical impedance analysis, fasting blood insulin (FBI), fasting blood glucose (FBG), total cholesterol, HbA1c and HOMA-IR.

Results: A significant gain in muscle mass (pre: 35.21 ± 3.18 kg *vs.* post: 36.12 ± 2.91 kg, $p< 0.001$) and a decrease in fat mass (pre: 30.93 ± 1.88 kg vs. post: 30.17 ± 1.82 kg, $p<0.001$) were observed. Rates of insulin resistance decreased significantly as insulin sensitivity improved with decreased FBI (pre: 12.16 ± 1.88 *vs.* post: 11.64 ± 1.52 µUI/mL, $p< 0.05$), while FBG remained unchanged. HbA1c levels dropped from 5.37 ± 0.31% to 5.10 ± 0.34% ($p < 0.001$). HOMA-IR scores improved significantly (pre: 2.77 ± 0.50 vs. post: 2.57 ± 0.42, $p < 0.001$).

Conclusion: In overweight Jordanian men at risk of developing type 2 diabetes, a resistance exercise program administered 3 times per week for 8 weeks can significantly improve insulin resistance.

Keywords

Resistance exercise; HOMA-IR; overweight; insulin sensitivity; blood glucose.

Resumen

Introducción: El entrenamiento de resistencia se ha asociado con una mejor sensibilidad a la insulina en personas con diabetes tipo 2, pero su papel en personas con sobrepeso no diabéticas sigue siendo incierto.

El objetivo de este estudio era evaluar si el entrenamiento de resistencia progresivo reduce la resistencia a la insulina en hombres con sobrepeso y alto riesgo de desarrollar diabetes tipo 2. Planteamos la hipótesis de que dicho entrenamiento mejoraría significativamente los marcadores de sensibilidad a la insulina.

Métodos: trece hombres con sobrepeso (de 30 a 50 años, IMC > 25 kg/m^2, HOMA-IR > 1,9 mg/kg y HbA1c < 5,8 %) participaron en un programa de entrenamiento de resistencia supervisado de 8 semanas (3 sesiones por semana). La fuerza se midió utilizando el máximo de una repetición de cada ejercicio. Las evaluaciones previas y posteriores al entrenamiento incluyeron análisis de impedancia bioeléctrica, niveles de insulina en ayunas (FBI), glucemia en ayunas (FBG), colesterol total, HbA1c y HOMA-IR.

Resultados: se observó un aumento significativo de la masa muscular (pre: 35,21 ± 3,18 kg vs. post: 36,12 ± 2,91 kg, $p < 0{,}001$) y una disminución de la masa grasa (pre: 30,93 ± 1,88 kg vs. post: 30,17 ± 1,82 kg, $p < 0{,}001$). Las tasas de resistencia a la insulina disminuyeron significativamente a medida que mejoraba la sensibilidad a la insulina, con una disminución de la FBI (pre: 12,16 ± 1,88 µIU/mL vs. post: 11,64 ± 1,52 µIU/mL, $p < 0{,}05$), mientras que la glucosa en ayunas (GA) no se alteró. Los niveles de HbA1c disminuyeron del 5,37 ± 0,31 % al 5,10 ± 0,34 % ($p < 0{,}001$). Las puntuaciones HOMA-IR mejoraron significativamente (2,77 ± 0,50 frente a 2,57 ± 0,42, $p < 0{,}001$).

Conclusión: en hombres jordanos con sobrepeso y riesgo de desarrollar diabetes tipo 2, un programa de ejercicios de resistencia administrado tres veces por semana durante ocho semanas puede mejorar significativamente la resistencia a la insulina.

Palabras clave

Ejercicio de resistencia; HOMA-IR; sobrepeso; sensibilidad a la insulina; glucemia.

Introduction

Insulin resistance (IR) is a known threat to type 2 diabetes (T2D), cardiovascular disease, and other metabolic disorders (Mlinar et al., 2007). People who are overweight are more likely to have IR which increases their susceptibility to T2D (Reaven, 2005). This common metabolic disease is characterized by impaired insulin signaling, which lowers peripheral tissues' absorption of glucose and causes hyperglycemia (Hawley et al., 2014). However, it is important to understand that not every individual who is overweight would have T2D, whereas obesity increases the risk of IR and disease (Wondmkun, 2020). This can be because obesity may be a complex disorder that's affected by numerous factors, including environment, genetics, lifestyle, wellness, nutrition, and common well-being. The hazard of acquiring T2D is altogether impacted by these factors (Wu et al., 2014).

The adipose tissue is considered the main component of obesity, which has a role in the development of T2D. Adipose tissue secretes Adipokines which disrupt insulin signaling and aggravate IR (Guilherme et al., 2008). Moreover, low-grade chronic inflammation created by obesity frequently aggravates IR. Insulin sensitivity is hampered by inflammation caused by the release of pro-inflammatory chemicals from adipose tissue, such as chemokines and cytokines (Makki et al., 2013). Moreover, leptin resistance is a result of the hormone leptin's dysregulation, which affects appetite control. According to Merz & Thumond, (2020) this dysregulation results in reduced insulin action, altered insulin signaling, and decreased cell absorption of glucose. Furthermore, because too much fatty acid has a negative impact on cells and tissues, excessive fat accumulation can interfere with insulin signaling pathways and reduce insulin sensitivity (Park & Seo, 2020; Sears & Perry, 2015).

Physical activity is known to enhance mitochondrial energetics, which in turn may reduce IR (Cefis et al., 2025). Maintaining a healthy body weight, regular exercises, and a well-balanced diet plan are considered effective ways to treat obesity related to IR and diabetes (American Diabetes Association, 2020; Bramante et al., 2017; Venkatasamy et al., 2013). Regular exercises and physical activity contribute and help to reduce body fat, especially visceral fat, which is linked to metabolic dysfunction and IR (Church et al., 2010), thus, preventing T2D, by improving IR (Hawley et al., 2014; Strasser & Pesta, 2013). Exercise efficiently reduces IR and improves overall metabolic health by increasing insulin sensitivity, encouraging healthy body composition, and lowering inflammation (Church et al., 2010; Pedersen & Saltin, 2015). Moreover, by reducing pro-inflammatory markers and raising anti-inflammatory markers, exercise can regulate systemic inflammation, and its role in IR (Pedersen & Saltin, 2015). Resistance exercise duration, intensity, and frequency are crucial factors to optimize its impact on IR (Hawley et al., 2014).

Aerobic exercises such as brisk walking, running, and others have been shown to improve insulin sensitivity and glucose regulation by inducing increased glucose uptake by skeletal muscles and activating insulin pathways (Hawley et al., 2014). On the other hand, many studies have proven the benefits of resistance exercise on insulin sensitivity and body composition in T2D patients (Cannata et al., 2020; Plotnikoff et al., 2010; Syeda et al., 2023). Resistance exercises are effective for increasing muscle development and strength because they involve contracting muscles against external resistance, such as weights or resistance bands (Pedersen & Saltin, 2015). Including a range of resistance and aerobic workouts based on personal interests and skills could enhance adherence and overall fitness. However, little research has been done on the benefits of resistance training (RT) among Jordanians in particular, especially for those who are at risk of T2D.

Although the effectiveness of RT in people with T2D has been demonstrated, its role in non-diabetic individuals with IR remains understudied. Furthermore, few studies have examined the specific impact of RT on IR in overweight or obese men (Boyer et al., 2023). We hypothesize that a structured RT program would lead to significant improvements in insulin sensitivity, as measured by the HOMA-IR score, as well as favorable changes in body composition. The aim of this study is to evaluate the effects of such a program on IR and body composition in overweight Jordanian men without clinical manifestations of T2D.

Method

Participants

Thirteen men aged 34 to 59 years lived in Amman, Jordan, were included in this study. The participants' characteristics are presented in Supplementary 1. The inclusion criteria for participants in the protocol were: a body mass index (BMI) > 25 kg/m2 and the level of IR (HOMA-IR) > 1.9. The study did not include participants with T2D clinical symptoms who had a glycated hemoglobin (cumulative glucose) (HbA1c) level > 5.8 %, engagement in regular RT, or presence of any condition contraindicating exercise. The procedures were approved by the Scientific Research Ethics Committee of Al-Ahliyya Amman University (FES-18G-249). The purpose of the study was explained to the participants and, after their consent, the necessary instructions were given.

Protocol design

Training program

For 8 weeks, participants underwent RT, with 3 sessions per week lasting 45 to 60 minutes/session. Exercises were performed at 65–80% of one-repetition maximum, consisting of 2–3 sets of 8–12 repetitions each. The program was designed to ensure progressive intensity and supervised by a health practitioner and a qualified trainer. Participants maintained their usual lifestyle throughout the 8-weeks of the research period. No control group was included. To avoid a potential interaction or cumulative effect between the training program and hypoglycemic medications, participants were advised to avoid taking their medications during the protocol period or to announce their intake in this case in order to adapt to the exercise load (Holman, 2007). Additionally, throughout of the protocol, participants were asked to refrain from any other high-intensity physical activity or training program.

Training progress

A 1RM (one repetition maximum) isometric torque test, which targets specific muscles, was used to assess each participant's maximum strength.

For a warm-up, the participants used a treadmill to walk for 5 minutes, flexibility exercises for 8 minutes, followed by 10 minutes of weight training at low loads. Low weights were used during the first two weeks to teach the participants proper technique.

The RT program included 10 full-body workouts that took 45 to 60 minutes to complete. Exercises including leg flexion and extension, calf raises, lat pulldowns, shoulder presses, chest presses, triceps extensions, bicep curls, and abdominal crunches were among them. Four flexibility exercises were included after a 5-minute vibration exercise session to help with muscle recovery.

The 8-week training program was divided into 3 parts: 1) during the first 2 weeks, participants carried out 2 sets of eight repetitions at a level of effort equal to 65% of their 1RM; 2) from weeks 3 to 6 participants carried out 2 sets of 12 repetitions at 70% of their 1RM; and 3) finally, in weeks 7-8, the participants finished 3 sets of 10 repetitions at a level of effort that was 80% of their 1RM.

Parameters assessment

Body composition and IR were assessed before and after application of the RT program. Bioelectrical impedance analysis (InBody Technology, model 370S) was used to assess the body composition including body weight (BW in kg), body fat mass (BFM in kg), and skeletal muscle mass (SMM in kg). However, the HOMA-IR homeostatic model assessment was used to assess IR for each participant. At the beginning and end of the protocol, morning fasting blood samples were collected from each participant. In order to monitor blood glucose within 48 hours to measure fasting blood glucose (FBG in mg/dL), a Blood Glucose Meter was used. Fasting blood insulin level (FBI in μUI/mL), glycated hemoglobin (HbA1c in %) and total cholesterol (TC in mg/dL) were analyzed before and after the protocol period.

Statistical analysis

All statistical analyses were performed using R software (3.4.0) (R Foundation for Statistical Computing, Vienna, Austria). Results are presented as mean ± standard deviation. Fluctuations in body composition, IR and physiological parameters between pre- and post-training measurements were compared between the intervention using ANOVA tests, as only one group was included. When a significant value was obtained, we performed a post-hoc test with Bonferroni correction (emmeans package). No power analysis was conducted due to sample constraints, which is acknowledged as a limitation. The test was considered significant if $p < 0.05$.

Results

A group of 13 adult men aged 46.84 ± 7.45 years agreed to participate in this study. Anthropometric parameters (body weight, BMI, fat mass, muscle mass) were compared before and after a RT protocol. After 8 weeks of RT, there was a statistically significant increase in SMM (pre: 35.21 ± 3.18 kg; post: 36.12 ± 2.91 kg; $p < 0.001$) and a decrease in BFM (pre: 30.93 ± 1.88 kg; post: 30.17 ± 1.82 kg; $p < 0.001$). However, body weight and BMI revealed no significant changes after the training period ($p > 0.05$). (Table 1)

One of the main criteria of the protocol is that participants must not change their eating habits. However, the values recorded for insulin and glucose show a decrease in the concentration of FBI (pre: 12.16 ± 1.88 µUI/mL; post: 11.64 ± 1.52 µUI/mL; $p < 0.05$), on the other hand, the level of FBG was not affected by the 8-week RT ($p > 0.05$). (Table 1)

The average cumulative sugar of the participants was affected by the 8-week RT, a significant decrease in HbAIc was observed between pre- and post-protocol (respectively; 5.37 ± 0.31 vs. 5.10 ± 0.34 %, p< 0.001). However, using the HOMA-IR homeostatic model to assess each participant's IR showed a significant decrease in IR after 8 weeks of RT (pre: 2.77 ± 0.50 vs post: 2.57 ± 0.42 , p<0.001). (Table 1)

Regarding TC, the average concentration of the participants was not affected by the period of RT followed by the different participants during the 8 weeks of the protocol (p> 0.05). (Table 1)

Table 1. Test results for Paired t-test between pre- and post-protocol variables for sample

Variables	Pre- protocol	Post- protocol
BW (kg)	98.56 ± 6.25	98.78 ± 6.23
BMI (kg.m^{-2})	30.92 ± 1.49	30.98 ± 1.49
BFM (kg)	30.93 ± 1.88	30.17 ± 1.82 ***
SMM (kg)	35.21 ± 3.18	36.12 ± 2.91***
FBI (µUI/mL)	12.16 ± 1.88	11.64 ± 1.52*
FBG (mg/dL)	5.12 ± 0.38	4.98 ± 0.32
HbA1c (%)	5.37 ± 0.31	5.10 ± 0.34 ***
HOMA-IR	2.77 ± 0.50	2.57 ± 0.42 ***
TC (mg/dL)	212.78 ± 30.58	219.03 ± 19.54

Data are presented as mean ± SD. BW: Body weight; BMI : Body mass index; BFM: Body fat mass; SMM: Skeletal muscle mass; FBI: Fasting blood insulin; FBG: Fasting blood glucose; HbA1c: glycated hemoglobin; HOMA-IR: insulin resistance; TC: Total Cholesterol. The effect of the protocol on the different parameters was analyzed using the t test between pre-protocol and post-protocol. *: p<0.05; ***: p<0.001

Discussion

The current study examined the effects of 8-weeks of RT on fluctuations in IR and other blood parameters in people with high levels of IR but without clinical manifestations of T2D. The results show that 8 weeks of RT may have beneficial effects on IR and skeletal muscle mass.

Effects on Body Composition

Despite no significant changes in overall body weight or BMI, a significant increase in SMM and decrease in BFM were observed, this could be related to the 8 weeks training duration which may not be sufficient for a change in body size (Lopez et al., 2022). However, these results align with previous findings (Cannata et al., 2020; Murlasits et al., 2012; Westcott, 2012) and suggest that body composition can improve without altering total body weight. The American College of Sports Medicine (2015) indicated that body composition can be improved through RT by enhance the muscle to fat ratio. In contrast, Warner et al.,(2010) found that resistance exercise improved metabolic health, although it did not directly address weight changes. Additionally, resistance exercise has been shown to improve the body's ability to burn fat and calories. Resistance exercises can often help reduce body fat, which in turn can help reduce body weight (Cox, 2017).

Furthermore, several studies have been demonstrated that increasing and developing muscle mass through RT can significantly enhance IR and insulin sensitivity (Deschenes & Kraemer, 2002; Lewis et al., 2025; Prado et al., 2012; van der Heijden et al., 2010) These studies have examined the relationship between insulin sensitivity and resting energy expenditure in terms of muscle mass, and concluded that greater muscle mass is associated with improved insulin sensitivity and elevated resting energy expenditure. Muscle tissue is considered very important for glucose absorption and metabolism and is also an essential location for insulin-mediated glucose disposal (Otto Buczkowska & Dworzecki, 2003).

Ross et al.,(2015) demonstrated that RT can improve IR by reducing visceral fat and improving fat distribution. Abdominal or visceral fat is more metabolically active and linked to high levels of inflammation and IR (Vincent et al., 2016). Vincent et al.,(2016) showed that 16 weeks of RT in obese elderly subjects significantly reduced their visceral fat and reduced IR. Additionally, resistance exercise may enhance insulin sensitivity by increasing fat oxidation and particularly intramuscular fat content (Goodpaster et al., 2000).

Increased Insulin Sensitivity

The results of this study show the existence of a significant variation in fasting blood insulin levels between the pre- and post-protocol. The reduction in fasting blood insulin levels and HOMA-IR scores reflects an improvement in insulin sensitivity. These results are consistent with prior research (Gordon et al., 2009; Katz, 2019; Ratajczak et al., 2024; Ryan et al., 2001), indicating that RT enhances metabolic function. However, studies have shown that RT for 8 to 12 weeks would not affect the rate of insulin in the blood (Moradi F, 2015; Nazari et al., 2016). In contrast, Church et al. (2010) showed that this reduction of IR is not conditioned solely by RT but by the combination of 2 types of exercises: resistance and aerobic. Interestingly, the decrease in IR observed in the present study could be due to the protocol applied with a progressive training load over a duration of 8 weeks (Gordon et al., 2009). Although the study observed improvements in insulin sensitivity as measured by HOMA-IR, it did not evaluate potential changes in inflammatory markers, such as C-reactive protein (CRP) or interleukin-6 (IL-6), which are known to be associated with IR. Future research could incorporate these biomarkers to provide a more comprehensive understanding of the physiological adaptations to RT.

Although fasting glucose levels remained unchanged, the significant reduction in HbA1c suggests improved glycemic regulation over time. However, both short- and long-term RT has been shown to improve HbA1c levels in people with T2D (Ghalavand et al., 2014; Jansson et al., 2022; Nazari et al., 2016). However, studies have demonstrated that the reduction in HbA1c induced by endurance training is lower than that induced by aerobic training (Church et al., 2010; Yardley et al., 2013). Additionally, Yalcin et al.,(2017) demonstrated that people with high levels of IR are more likely to develop T2D. Yalcin's results could explain a potential link between improvement in IR and reduction in HbA1c in this study. Combining these findings with the stable glucose levels in this study, performing RT may represent an alternative strategy to prevent the acute drop in blood glucose observed during aerobic training (Yardley et al., 2013) while maintaining more favorable glucose levels after exercise. There was, however, a trend toward more frequent, albeit mild, nocturnal hypoglycemia after resistance exercise sessions, which warranted further investigation (Yardley et al., 2013). However, this study did not monitor for hypoglycemic events.

Link to Cardiovascular Risk

Although this study found no effect of RT on blood cholesterol levels, it reported an absolute reduction in HbA1c of 0.27%. According to the literature, even a modest reduction in HbA1c is associated with a lower risk of cardiovascular and microvascular complications (Church et al., 2010; Selvin et al., 2004; Zhang et al., 2012). However, it would be difficult to extrapolate from these results: although the magnitude of HbA1c reduction in our study was statistically significant, it cannot definitively predict cardiovascular outcomes without supporting longitudinal data.

Strengths and limitations

The strength of the study lies in its use of a RT program involving a progressive increase in load. However, a major limitation is the lack of control over participants from outside the field of training science. Our ability to identify changes in caloric intake and diet composition was limited by the absence of a dietary changes and food frequency survey before, during and after the protocol. Although the population was somewhat heterogeneous in terms of age, good adherence to the training protocol was achieved, as was a low dropout rate, with consistent results across participants (Supplementary 1). Another limitation is our reliance on a single experimental group of a small number of participants, rather than including a control group. This restricts our ability to attribute the observed changes solely to the RT intervention, as external factors such as lifestyle changes, stress, or unmonitored physical activity could have influenced the results. Future research should employ randomized controlled designs, larger sample sizes and longitudinal follow-up to evaluate the sustainability and clinical significance of improvements. Additional biomarkers of inflammation and insulin signaling would strengthen the physiological interpretation.

Conclusions

This study demonstrates that an 8-week progressive RT program improved insulin sensitivity and body composition in overweight Jordanian men without type 2 diabetes. A significant decrease in HbA1c levels confirms the potential of RT to enhance metabolic health.

However, due to the small sample size, these results should be interpreted with caution. These results contribute to the growing body of evidence suggesting that RT may be an effective, non-pharmacological approach to reducing the risk of diabetes. Further controlled studies are needed to confirm these effects and explore their long-term impact.

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