Original Article

The Effect of Resistance and Aerobic Training with and Without Blood Flow Restriction and Detraining Period on Insulin Resistance in Men with Type 2 Diabetes: A Pilot Study

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ABSTRACT

Objectives: This study sought to examine the impact of resistance and aerobic exercise, with and without blood flow restriction (BFR), on insulin resistance (IR) in males diagnosed with type 2 diabetes (T2D). Furthermore, we aimed to comprehend the ramifications of a detraining period on these outcomes.

Methods: We randomly assigned a total of 30 men with T2D to four groups: resistance training with blood flow restriction (RT-BFR), resistance training without blood flow restriction (RT), aerobic training with blood flow restriction (AT-BFR), and aerobic training without blood flow restriction (AT). Training sessions occurred thrice weekly for a duration of 12 weeks, succeeded by a 6-week detraining interval.

Results: The findings of our investigation indicated that insulin levels fluctuate with physical activity. The average insulin level in RT fell, and similarly, the average insulin level in AT-BFR also decreased. The comparison of the average weight and BMI of subjects within the groups indicates that, in all groups, the average weight dropped following AT and RT. This would enhance the BMI's accuracy and appropriateness.

Conclusion: The findings from this research contribute valuable evidence to the ongoing discourse surrounding exercise and diabetes management. The study reinforces the notion that both resistance and aerobic training are effective in combating IR, particularly when complemented by BFR techniques. This study emphasizes the significance of integrating customized exercise programs, including the possibility of blood flow restriction techniques, to enhance metabolic health in persons with T2D.

Keywords: Type 2 Diabetes (T2D), Resistance Training (RT), Aerobic Training (AT), Blood Flow Restriction (BFR)

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Introduction

Type 2 diabetes (*T2D*) is a multifaceted metabolic illness marked by insulin resistance (*IR*) and has emerged as a worldwide health issue (1). Exercise is fundamental in managing *T2D*, with both aerobic training (AT) and resistance training (RT) acknowledged for their advantages in enhancing insulin sensitivity and metabolic wellness (2). Recent breakthroughs in exercise science have identified blood flow restriction (BFR) training as a potentially useful method for those with constraints that inhibit high-intensity activity (3). This article examines the impact of RT and AT, both with and without blood flow restriction (BFR), on *IR* in men with *T2D*, as well as the consequences of a detraining period (4, 5). Research indicates that both RT and AT enhance insulin sensitivity (6). RT increases muscle mass, which subsequently enhances glucose uptake by tissues (7). AT enhances cardiovascular health and facilitates fat oxidation, thereby improving glycemic control (6, 8). Research demonstrates that structured exercise interventions can markedly decrease fasting insulin levels and enhance glycemic variability in individuals with *T2D* (9).

BFR training allows individuals to engage in low-intensity strength exercises while limiting blood flow to the active muscles (10). This method has gained popularity for its capacity to induce muscle hypertrophy and strength improvements similar to traditional high-intensity training, while utilizing a lower load (11). In men with *T2D*, BFR has demonstrated potential in improving insulin sensitivity, likely attributable to its metabolic advantages and reduced risk of injury (12). Detraining, defined as the cessation of structured training, presents considerable challenges, particularly for individuals with chronic conditions such as *T2D*. Discontinuation of exercise results in swift reductions in muscle strength and cardiovascular fitness, as well as possible elevations in insulin resistance.

Research demonstrates that a period of detraining can negate the benefits acquired from exercise interventions, as indicated by the deterioration of *IR* markers (13). The magnitude of this effect varies according to the type of training previously undertaken (aerobic versus resistance) and individual factors, including baseline fitness levels. Recent findings suggest that exercise may lead to advantageous epigenetic modifications, while the discontinuation of training may reverse these alterations (14). Therefore, this pilot study aimed to investigate the effects of resistance training (RT) and aerobic training (AT), with and without blood flow restriction (BFR), on insulin resistance in men with type 2 diabetes (*T2D*). Additionally, we examined the impact of a detraining period on metabolic adaptations to determine whether the benefits of exercise are sustained after cessation. Our findings may help optimize exercise prescriptions for glycemic control in this population.

Materials and Methods

Study Design and Interventions

This quasi-experimental study involved the purposeful selection of 30 men, who were randomly assigned to one of six groups: resistance training with blood flow restriction (RT-BFR), resistance training without blood flow restriction (RT), aerobic training with blood flow restriction (AT-BFR), aerobic training without blood flow restriction (AT), and two control groups. This study included men aged 40–60 years diagnosed with *T2D* (HbA1c levels between 6.5% and 8.5%), without a history of cardiovascular diseases, contraindications for exercise, or ongoing treatment with medications that influence glucose metabolism. Exclusion criteria comprised the presence of significant comorbidities (e.g., uncontrolled hypertension, renal failure), engagement in regular exercise (≥ 2 days/week) within the past 6 months, and any severe neurological or orthopedic conditions.

Sampling occurred at the Diabetes Clinic of Bou Ali Hospital and Imam Ali Hospital in Zahedan. Initially, all procedures and methodologies for conducting the research were elucidated to the participants, and their inquiries were addressed. The participants ultimately completed the informed consent form with full agreement. Following sample selection, anthropometric measurements of the subjects were conducted using a body analysis device across two sessions in the laboratory at Sistan and Baluchestan University. Blood samples were obtained at Imam Ali Hospital in Zahedan after a 12-hour overnight fasting period. During the familiarization sessions, all participants were instructed in the proper techniques for executing resistance exercises and BFR. Forty-eight hours before starting the exercises, the participants visited the Hermas Sports Science Club, where, in familiarization with the exercise protocol, the one-repetition maximum (1RM) for two lower body exercises, including leg press and knee extension, as well as three upper body exercises, including bench press, shoulder press, and lateral pull, was determined according to the Brzeski method (15). The participants in the training group performed the exercises for a duration of 16 weeks, with the first four weeks consisting of two sessions each week and, in the following 12 weeks, three sessions each week. Each training session included 10 minutes of warm-up, the main workout (50 minutes), and 10 minutes of cool-down. The laboratory of Ali Ibn Abi Talib Hospital in Zahedan collected blood samples from the participants 48 hours after the last training session, after 12 hours of fasting, and recorded the results using statistical methods.

Resistance Training Protocol

The two lower body movements, including leg press and knee extension, and two upper body movements, including chest press and shoulder head press, were performed by the RT initially for four weeks at an intensity of 70% of 1RM with four sets of eight repetitions. During the subsequent second, third, and fourth weeks, the participants executed the exercises at intensities of 80%, 70%, and 80% of 1RM, completing four sets of 10, 10, and 12 repetitions, respectively (16, 17).

Blood Flow Restriction Training Protocol

The training group with blood flow restriction performed resistance exercises, including the two lower body movements (leg press and knee extension) and two upper body movements (chest press and shoulder head press), in four sets with repetitions of 30, 25, 20, and 15 during the first, second, third, and fourth weeks at an intensity of 20% of 1RM. The rest between each set and each station was one and three minutes, respectively (16, 17). The BFR was applied continuously to the proximal thigh and arm using a 17.5 cm wide occlusion cuff at a mean pressure of 184 ± 25 mmHg, and during rest between sets, the BFR was removed. The control group continued their normal lives during this time and had no regular training program. We consistently communicated with the participants or their families every 10 days via telephone to ascertain any alterations in their circumstances, including modifications in treatment protocols and the introduction of new medications that might influence the research outcomes, and recorded the findings.

Protocols for Aerobic Training with and without Blood Flow Restriction

Each exercise session commenced with a 10-minute warm-up and concluded with a 10-minute cool-down. Participants in the training groups engaged in aerobic treadmill running for 16 weeks, consisting of three exercise sessions per week, both with and without limb BFR. The length of aerobic activity commenced at 12 minutes at 50% of maximum heart rate in the first week and escalated to 36 minutes at an intensity of 65% of maximum heart rate over 16 weeks, both with and without BFR (Table 1) (18).

On the one hand, the participants in the group with BFR performed a similar protocol on the treadmill, starting from the first week with a workout intensity of 50% and increasing to 65% of their maximum heart rate by the 16th week. This was done using a digital BFR device produced domestically in Iran, along with two cuff rings. The proximal limb was compressed using tourniquet cuffs measuring 18×35 centimeters, suitable for adults (19), and the pressure was digitally adjusted to be between 30% and 60% of arterial occlusion pressure (AOP) on a digital monitor. A rest and activity schedule were programmed into the device, which automatically adjusted and controlled the pressure over a period of 12 to 36 minutes. The activities were conducted under the supervision of a sports specialist to avert unforeseen accidents. The participants' heart rates were continually monitored during the treadmill activity, in conjunction

Table 1. Aerobic training protocol without Blood Flow Restriction

	1st and 2nd	3rd and 4th	5th and 6th	7th and 8th	9th and 10th	11th and 12th	13th and 14th	15th and 16th
Intensity	50%	50%	55%	55%	60%	60%	65%	65%
duration (minutes)	12	18	18	24	24	30	30	36

Table 2. Aerobic training protocol with blood flow restriction.

	1st and 2nd	3rd and 4th	5th and 6th	7th and 8th	9th and 10th	11th and 12th	13th and 14th	15th and 16th
Intensity	50%	50%	55%	55%	60%	60%	65%	65%
Activity time with blood flow restriction	10	15	15	20	20	25	25	30
Pressure	30%	30%	40%	40%	50%	50%	60%	60%
Set	2	3	3	4	4	5	5	6
Active rest sets between sets with blood flow restriction (minutes)	2	3	3	4	4	5	5	6
Total training time (minutes)	12	18	18	24	24	30	30	36

with pulse oximetry. Following the conclusion of the 16-week intervention and 48 hours subsequent to the final training session, blood samples were once again procured by a professional and dispatched to the laboratory for analysis (Table 2) (19, 20).

Assessments

In our study, Body Mass Index (BMI) was assessed for anthropometric measurement. Additionally, fasting blood samples were collected at baseline, post-intervention, and during detraining for biochemical analyses (e.g., glucose, HbA_1c, insulin levels).

Statistical Analysis

Data analysis was performed utilizing SPSS Statistics version 27.0.1.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics delineated the sample. Mixed ANOVA assessed the interaction effects of training modalities, time (pre–post), and the detraining phase. Post-hoc analyses (Tukey's HSD) were conducted for multiple comparisons. A significance level was established at $p < 0.05$.

Ethical Considerations

The research was executed in accordance with ethical principles and received approval from the ethics committees of Islamic Azad University Karaj. The approval certificate can be found at https://ethics.research.ac.ir/IR.IAU.K.REC.1402.143). This study adhered to the Declaration of Helsinki ethical guidelines (The 75th WMA General Assembly, Helsinki, Finland, October 2024, https://www.wma.net/policies-post/wma-declaration-of-helsinki/). All individuals provided informed consent prior to their involvement in the study.

Results

In this study, we investigated the effects of RT and AT, both with and without BFR, on IR in men with *T2D*. This study was conducted with the aim of investigating the effect of different exercise methods and their impact

Table 3. Comparison of the average insulin levels of the studied subjects in different groups.

Mean Insulin ± SD			Groups
13.03±3.67	Pre-Test		
7.44±3.49	Post-Test	9.58±4.15	AT
8.29±3.45	After-post-test		
12.40±5.10	Pre-Test		
7.08±2.71	Post-Test	9.62±4.35	RT
9.38±3.89	After-post-test		
9.12±1.63	Pre-Test	9.13±1.51	Control AT
9.15±1.56	Post-Test		
11.07±3.08	Pre-Test		
6.96±2.11	Post-Test	8.99±3.03	AT-BFR
8.94±2.74	After-post-test		
13.92±1.50	Pre-Test		
6.19±2.25	Post-Test	9.50±3.81	RT-BFR
8.39±1.99	After-post-test		
8.19±2.91	Pre-Test	8.30±2.67	Control RT
8.42±2.74	Post-Test		

AT: aerobic training without blood flow restriction; RT: resistance training without blood flow restriction; BFR: blood flow restriction; AT-BFR: aerobic training with blood flow restriction; RT-BFR: resistance training with blood flow restriction.

on average insulin levels in subjects. Six different groups were studied: AT, RT, Control AT Group, AT-BFR, RT-BFR, and Control RT Group. The results of our study showed (Table 3) that insulin levels change with exercise, such that with AT, the average insulin level decreased from Pre-Test: 13.03 ± 3.67 to Post-Test: 7.44 ± 3.49. (In the Control AT group, the average insulin level changed from Pre-Test: 9.12 ± 1.63 to Post-Test: 9.15 ± 1.56). Also, the average insulin level in RT decreased from the baseline state of 12.40 ± 5.10 to 7.08 ± 2.71. (RT Control Group: decreased from baseline 8.19 ± 2.91 to 8.42 ± 2.74). Additionally, in AT-BFR, the average insulin level decreased from baseline 11.07 ± 3.08 to 6.96 ± 2.11, and in RT-BFR from baseline 13.92 ± 1.50 to 6.19 ± 2.25. Our results in Table 4 showed that the differences in insulin levels between AT (Pre-Test) and AT (Post-Test) groups (p = 0.013), AT (Pre-Test) and AT (After-Post-Test) (p = 0.033), AT (Pre-Test) and RT (Post-Test) (p = 0.009), AT (Post-Test) and RT (Pre-Test) (p = 0.027), and RT (Pre-Test) and RT (Post-Test) (p = 0.018) were significant. Additionally, comparison of the average weight and BMI of subjects in the groups (Table 5) shows that in all groups, the average weight decreased after AT and RT (weight loss was more pronounced in RT). This contributes to improved and more appropriate BMI. In Table 6, comparing the average level of FBS of subjects in the AT and RT groups, it was shown that FBS in the baseline state and after training changed significantly (p < 0.001) in the AT group compared to the RT group. RT, compared to AT, increased the level of FBS. In Table 7,

Table 4. *p*-value results comparing insulin levels between the studied subgroups.

Groups	AT (Pre-Test)	AT (Post-Test)	AT (After-post-test)	RT (Pre-Test)	RT (Post-Test)	RT (After-post-test)	Control AT (Pre-Test)	Control RT (Post-Test)
AT (Pre-Test)		**0.013**	**0.033**	0.769	**0.009**	0.096	0.076	0.078
AT (Post-Test)	**0.013**		0.695	**0.027**	0.867	0.372	0.439	0.430
AT (After-post-test)	**0.033**	0.695		0.063	0.577	0.613	0.700	0.689
RT (Pre-Test)	0.769	**0.027**	0.063		**0.018**	0.167	0.134	0.138
RT (Post-Test)	**0.009**	0.867	0.577	**0.018**		0.291	0.348	0.340
RT (After-post-test)	0.096	0.372	0.613	0.167	0.291		0.904	0.916
Control AT (Pre-Test)	0.076	0.439	0.700	0.134	0.348	0.904		0.987
Control RT (Post-Test)	0.078	0.430	0.689	0.138	0.340	0.916	0.987	

AT: aerobic training without blood flow restriction; RT: resistance training without blood flow restriction;

Table 5. Comparison of average weight and BMI between the studied subgroups.

Groups	Mean BMI	Mean Weight
AT (Pre-Test)	26±30	87±10.61
AT (Post-Test)	24±11	81±7.17
AT (After-post-test)	24±15	82±8.20
RT (Pre-Test)	27±32	85±9.67
RT (Post-Test)	23±23	75±9.31
RT (After-post-test)	24±14	76±11.01
Control AT (Pre-Test)	25±10	78±5.47
Control RT (Pre-Test)	24±34	72±6.21

AT: aerobic training without blood flow restriction; RT: resistance training without blood flow restriction;

Table 6. Comparison of mean FBS between AT and RT subgroups.

Before test FBS	RT	AT	*p*-value
After test FBS	287.10 ± 137.43	176.95 ± 60.51	**<0.001**
Before test FBS	260.94 ± 165.66	153.06 ± 55.98	**<0.001**

AT: aerobic training without blood flow restriction; RT: resistance training without blood flow restriction;

Table 7. Comparison of mean HbA_{1c} between AT and RT subgroups.

Groups	RT	AT	*p*-value
Before test Hb A_{1c}	7.16 ± 1.26	6.9 ± 1.11	0.627
After test Hb A_{1c}	6.87 ± 1.43	6.1 ± 1.13	0.062

comparing the average level of HbA1c in participants in the AT and RT groups revealed that HbA1c in the baseline state ($p = 0.627$) and after exercise ($p = 0.062$) increased slightly in the AT group compared to the RT group, but this change was not significant.

Discussion

The research entitled "The Effect of RT and AT with and without BFR and Detraining Period on IR in Men with *T2D*" offers significant insights into the relationship between exercise types and metabolic health in patients with *T2D*. Given that diabetes persists as a worldwide health concern, comprehending the impact of diverse training regimens on IR may facilitate the development of more effective therapies. The findings of this study underscored the differential effects of RT and AT on insulin sensitivity in men with *T2D*. RT, especially when amplified through BFR, was shown to produce favorable adaptations in insulin sensitivity, which aligns with previous research suggesting that both traditional and BFR-enhanced RT can elicit significant improvements in insulin action and reduce overall IR. This is especially significant, as muscular tension during RT facilitates not just hypertrophy but also improves glucose absorption via insulin-independent mechanisms (21, 22). Aerobic exercise also showcased its benefits in mitigating IR (23); however, the magnitude of the effect appeared to be contingent upon the intensity and duration of the aerobic intervention. Since cardiovascular health is often compromised in *T2D* patients, the implications of these findings are critical, suggesting that a combination of AT and RT may be more beneficial than either modality alone, especially in enhancing overall metabolic function. BFR training stands out in this discussion as an innovative approach that may enhance the effectiveness of traditional resistance training, particularly for populations at risk of injury or for those who are unable to perform high-load exercises (24). The combination of low-load RT-BFR may facilitate muscle hypertrophy, thus improving insulin sensitivity in a relatively safer manner. This finding aligns with the emerging body of literature supporting the use of BFR in clinical populations, as it may offer a viable alternative to high-intensity training regimens (25). The inquiry into the consequences of a detraining interval possesses considerable ramifications, especially for long-term management techniques in *T2D*. The reduction in insulin sensitivity during intervals of inactivity underscores the necessity of consistent physical activity to preserve metabolic advantages. This highlights the necessity for systematic workout programs that prioritize compliance even after initial progress is attained. The study indicates that the human body's adaptability regarding insulin sensitivity is intrinsically connected to consistent physical activity, while also demonstrating that interruptions in training might swiftly negate these adaptations. Consequently, methods designed to avert detraining—whether educational support, motivational interventions, or ongoing monitoring—may be essential in the management of *T2D*.

Conclusion

In summary, this research provides significant evidence to the continuing discussion surrounding exercise and diabetes control. The findings substantiate that both RT and AT are efficacious in addressing IR, especially when augmented by BFR strategies. The obstacles associated with detraining underscore the necessity of continuous physical activity to maintain metabolic health benefits in this demographic. Additional research is necessary to investigate the fundamental molecular mechanisms and long-term consequences of these therapies. Furthermore, it is essential to explore the convergence of genetics and exercise to refine therapies aimed at optimizing metabolic health and improving outcomes in the management of *T2D*.

Author's contribution

FF, AR and RS Methodology and Design, HM, FF, AR and RS writing the draft, HM genotyping, RS data analysis and FF clinical patient assessment, FF and AR supervision and editing.

Conflict of Interest

The authors declared that they have no conflict of interest.

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