High-Intensity Interval Exercise versus Focused Ultrasound on Insulin Resistance in Diabetic Female with Abdominal Obesity

Zeezy S. Eraky[1], Noha Ahmed Fouad Abd-Elrahman[2], Ahmed M. Elshinnawy[3*], Haitham M. Elmasry[4], Zeinab A. Ali[5], Mahmoud Zaki El-Readi[6], Reem Hassan Ragab[7], Heba Elmetwally Abdallah Farahat MD[8], Shymaa E. Rashed[9], Shimaa Hussien Ahmed Roshdy[10]

[1]Department of Physical Therapy for Internal Medicine and Elderly, Faculty of Physical Therapy, Modern University for Technology and Information, Cairo, Egypt. zezyeraky@gmail.com, ORCID: 0009-0002-7020-0537
[2]Department of Physical Therapy for Women's Health, Faculty of Physical Therapy, Badr University, Cairo, Egypt. Nonabird79@yahoo.com, ORCID: 0000-0002-9796-648X
[3]Department of Physical Therapy for Neuromuscular Disorders and its Surgery, Faculty of Physical Therapy, Merit University, Egypt. El_shinnawy80@hotmail.com, ORCID: 0000-0001-5678-0841
[4]Department of Basic Science, Faculty of Physical Therapy, Modern University for Technology and Information, Cairo, Egypt, haithammomenalmasry@gmail.com
[5]Department of Physical Therapy for Surgery, Faculty of Physical Therapy, Cairo University, Giza, Egypt, Department of Physical Therapy and Health Rehabilitation, College of Applied Medical Science, Jouf University, Saudi arabia, Zahamada@ju.edu.sa. https://orcid.org/0000-0002-1574-8412
[6]1_Biochemistry Department, Faculty of Medicine, Umm Al-Qura University, Makkah, Saudi Arabia 2_ Biochemistry Department Faculty of Pharmacy Alazhar University Assiut Egypt mzreadi@uqu.edu.sa https://orcid.org/0009-0007-0252-2370
[7]Lecturer of burn and surgery,Faculty of Physical Therapy, Benha National University, Egypt, drreemo1984@gmail.com
[8]Department of Radiology and Medical Imaging, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Alkharj, Saudi Arabia. Consultant Radiologist, Department of Radiology, Mansoura Specialized Hospital, Mansoura, Egypt. Heba.elmetwally@yahoo.com , h.farahat@psau.edu.sa ORCID: https://orcid.org/0009-0003-7949-0929
[9]Chemistry unit, Faculty of physical therapy, Horus university-Egypt. Department of Chemistry, Faculty of Science, Mansoura University, Mansoura, Egypt 0009-0005-9527-9810 shrashed@horus.edu.eg
[10]Department of Physical Therapy for Diseases and Surgeries of the Cardio-Respiratory system and Geriatrics. Faculty of Physical Therapy - Misr University for Science and Technology, Egypt.Shimaa.roshdy@must.edu.eg, ORCID: 0000000333343782

Abstract

Background: In women with type 2 diabetes mellitus (T2DM), abdominal obesity significantly increases insulin resistance. Focused ultrasound (FUS) decreases localized fat while high-intensity interval training (HIIT) enhances metabolic function. It's yet uncertain how effective they are metabolically.

Objective: To compare how HIIT and FUS affect insulin resistance and abdominal obesity in women with type 2 diabetes.

Methods: For 16 weeks, thirty women with T2DM and abdominal obesity were randomized to either FUS + intermittent fasting (n = 15) or HIIT plus intermittent fasting (n = 15). Glycated hemoglobin (HbA1c) and the homeostasis model assessment of insulin resistance (HOMA-IR) were the main results. Waist circumference and body mass index (BMI) were secondary outcomes. To evaluate differences both within and between groups, a mixed-design MANOVA was employed.

Results: Waist circumference and BMI were significantly lower in both groups ($p<0.05$). Only the HIIT group, however, demonstrated substantial reductions in HOMA-IR (−52.2%) and HbA1c (−27.5%) ($p<0.001$). Post-intervention comparisons showed that the HIIT group had considerably lower HbA1c and HOMA-IR values than the FUS group ($p<0.001$), whereas the FUS group had larger waist circumference reductions ($p<0.001$).

Conclusions: Despite comparable decreases in anthropometric measurements, HIIT produced greater improvements in insulin resistance and glycemic management than FUS. These results confirm that structured high-intensity exercise is the recommended non-pharmacological intervention for enhancing metabolic health in women with abdominal obesity and type 2 diabetes.

Keywords: High-Intensity Interval Training, Focused Ultrasound, Insulin Resistance, Diabetes, Abdominal Obesity, Intermittent Fasting.

Introduction

According to recent epidemiological data from the International Diabetes Federation, type 2 diabetes mellitus (T2DM) is a significant and growing global health concern that is mostly caused by the concurrent growth in obesity and sedentary lifestyles [1,2]. Insulin resistance, a key pathophysiological characteristic of type 2 diabetes, is closely associated with abdominal obesity, specifically the build-up of visceral adipose tissue [3–5]. Through a number of interconnected mechanisms, such as ectopic lipid deposition, adipokine imbalance, persistent low-grade inflammation, and disruption of insulin signaling pathways, this metabolically active fat depot contributes to insulin resistance [3,4]. Abdominal obesity, measured through waist circumference, has been clearly associated with increased cardiovascular mortality. However, there are marked differences comparing different abdominal fat depots. High adiponectin secretion in the subcutaneous abdominal layer is protective in terms of cardiovascular risk reduction, whereas visceral fat is known to secrete many insulin-resistance deleterious cytokines such as TNF, IL6, leptin, resistin or visfatin [28]. The clinical significance of fat distribution over total adiposity is highlighted by the fact that waist circumference has repeatedly been demonstrated to be a more sensitive predictor of insulin resistance and cardiometabolic risk among anthropometric markers than overall body mass index (BMI) [6].Because of these mechanisms, lifestyle therapies that target central obesity—especially organized physical activity—are essential for increasing insulin sensitivity and body composition [7, 8]. Furthermore, the usefulness of non-pharmacological approaches in improving metabolic control and treating type 2 diabetes is further supported by new models of exercise-based rehabilitation [9].

The mainstay of managing type 2 diabetic mellitus (T2DM) is still lifestyle-based therapies. Among these, high-intensity interval training (HIIT) has drawn a lot of interest because of its powerful metabolic effects and time efficiency. Even in the absence of significant weight loss, high-intensity interval training (HIIT), which consists of brief bursts of intense activity interspersed with recovery periods, has been demonstrated to improve skeletal muscle glucose uptake, stimulate mitochondrial biogenesis, improve oxidative capacity, and promote insulin sensitivity [10,11]. Improved lipid metabolism, glucose control, and general metabolic flexibility are all facilitated by these modifications. HIIT is better or at least on par with moderate-intensity continuous training (MICT) in lowering visceral adiposity, insulin resistance, and glycated hemoglobin (HbA1c) in people with type 2 diabetes and metabolic syndrome, according to data from systematic reviews and meta-analyses [12–14]. Additionally, HIIT's position as an efficient, non-pharmacological intervention in the management of type 2 diabetes may be strengthened when paired with complementary lifestyle techniques [13].

Unlike exercise-based therapies, non-invasive device-based methods like focused ultrasound (FUS) selectively disrupt adipocytes to target specific subcutaneous adipose tissue. FUS has shown effective in lowering waist circumference and regional adiposity by using high-frequency ultrasonic waves to cause mechanical and thermal damage to adipocytes [15,16].

Focused ultrasound (FUS) is the method in handling obesity, especially in destroying fat and shaping a particular part of the body. As one of the non-surgical correction method, FUS is preferred at decreasing the risk of complications due to obesity [29].

Its effects, however, seem to be mostly limited to the reduction of subcutaneous fat, and it is unclear how it affects systemic metabolic parameters, especially insulin resistance. Given that visceral fat plays a major role in the pathophysiology of insulin resistance and type 2 diabetes mellitus (T2DM), this distinction is clinically significant because decreases in subcutaneous adipose tissue may not always result in improvements in metabolic dysfunction [5,6].

There is little direct comparative data on the metabolic efficacy of FUS and high-intensity interval training (HIIT), despite their increasing use in both clinical and cosmetic settings. FUS mostly causes regional body contouring without obvious metabolic regulation, whereas HIIT provides systemic metabolic advantages through improved glucose absorption, mitochondrial activity, and insulin sensitivity. Thus, in women with type 2 diabetes and abdominal obesity, the current randomized controlled trial sought to directly assess the effects of HIIT and FUS on important metabolic and anthropometric outcomes, such as HOMA-IR, glycated hemoglobin (HbA1c), body mass index (BMI), and waist circumference.

Methods

Study Design and Ethical Approval

Over the course of four months (May–August 2024), this study was planned as a prospective, randomized controlled experiment (RCT). The study was authorized by the Ethical Committee of the Faculty of Physical Therapy at Badr University in Cairo (Approval No: IRB00014233-1) and filed on ClinicalTrials.gov (Identifier: NCT06376955). Every technique was carried out in compliance with the Declaration of Helsinki's tenets.

Prior to participation, each subject provided written informed permission. A thorough explanation of the study's goals, methods, possible dangers, and advantages was given to the participants.

Participants and Randomization

A computer-generated randomization process was utilized to randomly assign participants to either the focused ultrasound (FUS) group or the HIIT group. Opaque, sealed envelopes were used to hide allocation.

Thirty female patients with abdominal obesity and type 2 diabetes mellitus (T2DM) were divided into two equal groups (n = 15 per group):

- Group A (HIIT group): For four months, participants engaged in high-intensity interval training (HIIT) twice a week in addition to an intermittent fasting diet.
- Group B (FUS group): For four months, participants received targeted focused ultrasound (FUS) therapy twice a week in addition to the same intermittent fasting diet.

Eligibility Criteria

El-Shinnawy Physical Therapy Center was the source of the participants. Females having a diagnosis of type 2 diabetes mellitus (T2DM) and abdominal obesity were eligible to participate.

Criteria for inclusion:

- Between the ages of 25 and 35
- A BMI of 30 to 35 kg/m^2.
- A waist circumference of 88 to 100 cm

Criteria for exclusion:

- The existence of skin disorders that impact the abdomen
- A history of surgical scars or abdominal hernias in the treated area
- Cardiovascular disease
- Using drugs throughout the research period that are known to affect body weight or metabolic status
- Any medical or psychological issue that can make it difficult to participate in or stick with the intervention

Outcome Measures

Before and after the four-month intervention, all outcome measures were evaluated under uniform circumstances.

Anthropometric Measurements

- **Body weight and height:**

A computerized weight-height scale that had been calibrated was used to measure height and body weight. Weight in kilograms divided by height in meters squared (kg/m2) yields the body mass index (BMI).

$$\mathrm{BMI} = \frac{\mathrm{Weight\ (kg)}}{\mathrm{Height\ (m)}^2}$$

- **Waist circumference:**

Using a non-elastic tape, the waist circumference was measured at the midpoint between the iliac crest and lower ribs (nearest 0.1 cm) [17].

Biochemical Assessments

- **Homeostasis Model Assessment of Insulin Resistance (HOMA-IR):**

The homeostasis model assessment (HOMA-IR), which was computed from fasting plasma glucose and fasting insulin levels using the following formula, was used to measure insulin resistance.

$$\mathrm{HOMA-IR} = \frac{\mathrm{Fasting\ insulin\ (\backslash muU/L)} \times \mathrm{Fasting\ glucose\ (mmol/L)}}{22.5}$$

- **Glycated hemoglobin (HbA1c):**

To measure glycated hemoglobin (HbA1c), which represents average blood glucose levels over the previous two to three months, venous blood samples were drawn under standardized laboratory settings. According to standardized clinical recommendations, HbA1c was stated as a percentage (%).

Intervention Protocol

Group A: High-Intensity Interval Training (HIIT)

For four months, participants used a motorized treadmill (Biodex RTM 500, Biodex Medical Systems, USA) for twice-weekly supervised HIIT sessions.

Included in each 30-minute session were:

- Walking at 50% of your maximum heart rate (HRmax) for ten minutes is a warm-up.
- The ten-minute interval phase:
  - 60 seconds of high-intensity running at 85–90% HRmax
  - Walking actively for 60 seconds at 60–70% HRmax
  - Ten rounds of repetition
- Cool-down (10 minutes): Reduce intensity gradually to baseline levels

To guarantee adherence to the intended intensity, heart rate was continually measured [18].

Group B: Focused Ultrasound (FUS) Therapy

For four months, participants underwent twice-weekly non-invasive focused ultrasound therapy using a Balance Dual Cavitation and Radiofrequency System (Model CS-1000, Prime Medical Co., Korea). The duration of each treatment was forty minutes, twenty minutes for each side of the abdomen.

Throughout the intervention phase, participants were advised to maintain a daily hydration level of 1.5–2.0 liters [19].

Sample size calculation

G*Power version 3.1.9 (Heinrich-Heine-University, Düsseldorf, Germany) was used to calculate the sample size for this investigation. F tests for MANOVA were used in the computation, taking interactions and special effects into account. Type I error (α) = 0.05, power (1-β error probability) = 0.80, effect size f^2 (V) = 0.375986323, and Pillai's V = 0.5464972 were the parameters that were employed. For a two-group comparison of five key outcome variables—BMI, waist circumference, abdominal fold, HbA1c, and HOMA-IR—this led to a total sample size of 27 people. The minimum sample size was changed to 30 patients, with 15 patients in each group, to account for a 10% dropout rate.

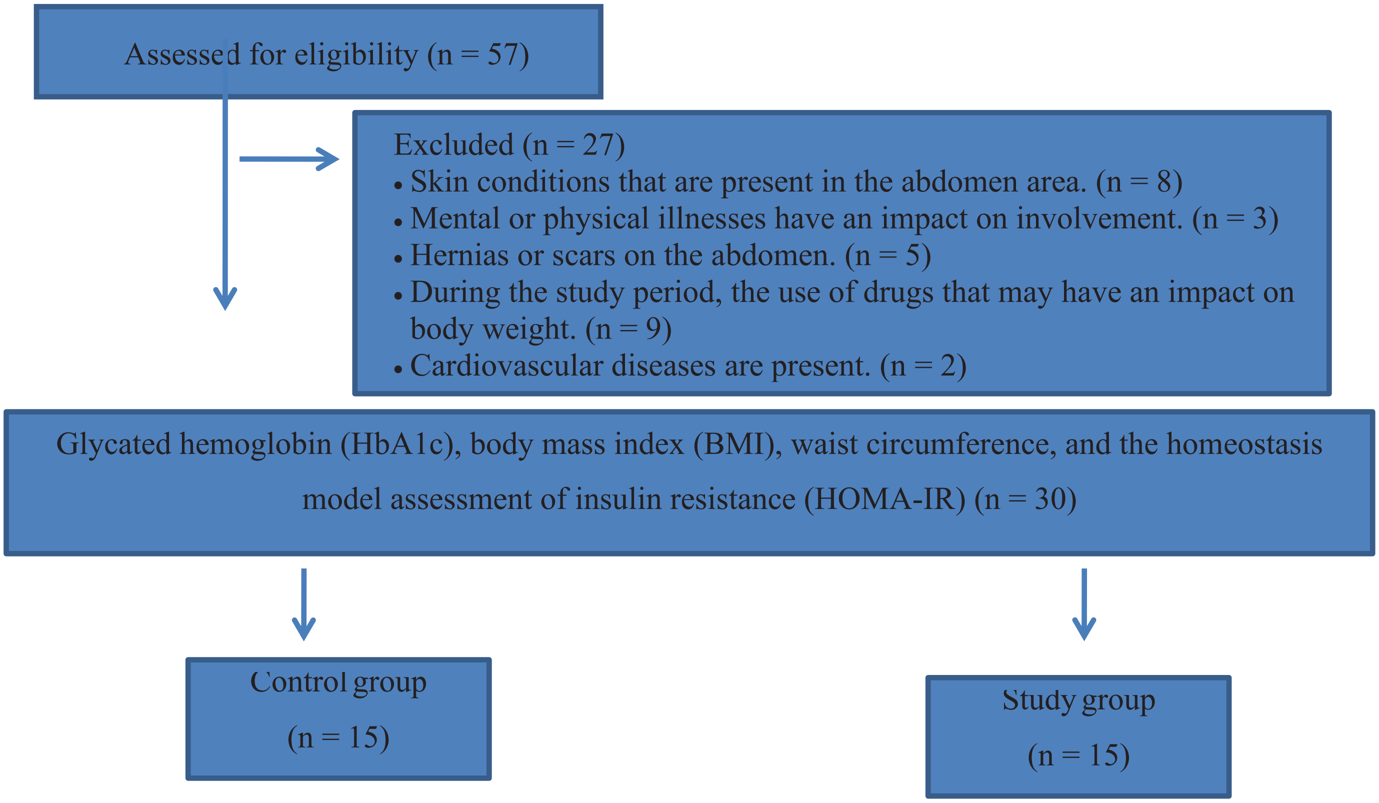

Fig 1: Flow chart

Statistical Analysis

The homogeneity of variance and normality of the data were checked. After eliminating outliers found using box and whisker plots, the Shapiro-Wilk test was used to determine whether the data were normally distributed (P>0.05). Both parametric and non-parametric analyses were possible because Levene's test showed no significant variance differences (P>0.05). Parametric analysis was carried out in light of the normal distribution.

SPSS version 25 for Windows (SPSS, Inc., Chicago, IL) was used for statistical analysis. Age, weight, height, BMI, waist circumference, abdominal fold, HbA1c, and HOMA-IR are among the quantitative data for female individuals with diabetes that are displayed as mean and standard deviation. For the primary dependent outcome variables, a mixed-design 2 x 2 MANOVA was employed, with the tested group (Group A vs. Group B) as the first independent variable and the measuring period (pre-treatment vs. post-treatment) as the second independent variable. For variables with significant F values from the MANOVA, pairwise differences within and between groups were compared using the Bonferroni correction. At a probability level of P<0.05, every statistical analysis was significant.

Results

Participant Demographics

A total of 30 diabetic female patients with abdominal obesity and insulin resistance participated in this study, randomly distributed into two equal groups: Group A (high-intensity interval exercise with intermittent fasting diet) and Group B (focused ultrasound with intermittent fasting diet). The demographic data (Table 1) showed no significant differences between the groups in terms of age, weight, height, and BMI (P>0.05).

Table 1. Clinical general characteristics for participant females in both groups

Items	Groups (Mean ±SD)		*P*-value
	Group A (n=15)	Group B (n=15)	
Age (year)	30.53 ±2.50	30.60 ±3.24	0.950
Weight (kg)	86.07 ±4.38	85.13 ±4.17	0.554
Height (cm)	159.00 ±3.11	157.93 ±2.54	0.314
BMI (kg/m^2)	34.03 ±1.70	34.09 ±2.87	0.944

Group A: high-intensity interval exercise with diet; Group B: focused ultrasound with diet

Data are reported as mean ±standard deviation. P-value: probability value. P-value>0.05: non-significant

Statistical multiple pairwise comparison tests were conducted to evaluate changes in body mass index (BMI), waist circumference (WC), abdominal fold, hemoglobin A1c (HbA1c), and homeostasis model assessment of insulin resistance (HOMA-IR) within and between the two groups.

Within-Group Comparisons

- **BMI Reduction**:
  - Both Group A (HIIT + diet) and Group B (Focused Ultrasound + diet) showed a significant decrease in BMI at post-treatment compared to pre-treatment (P = 0.001 for both groups).
  - The percentage reduction was greater in Group A (9.14%) compared to Group B (8.92%), suggesting a superior effect of HIIT on BMI reduction.
- **Waist Circumference and Abdominal Fold**:
  - Both groups exhibited significant decreases in waist circumference and abdominal fold at post-treatment (P = 0.0001 for both groups).
  - However, Group B (Focused Ultrasound + diet) demonstrated a greater percentage reduction in waist circumference (18.93% vs. 9.41% in Group A) and abdominal fold (37.98% vs. 17.01% in Group A), indicating a superior effect of focused ultrasound on body circumference reduction.
- **Glycemic and Insulin Resistance Markers (HbA1c and HOMA-IR)**:
  - Group A (HIIT + diet) showed a significant decrease in both HbA1c (P = 0.0001) and HOMA-IR (P = 0.0001) post-treatment, demonstrating improved glycemic control and insulin sensitivity.
  - Group B (Focused Ultrasound + diet) exhibited no significant reduction in HbA1c (P = 0.634) or HOMA-IR (P = 0.845) post-treatment, suggesting a limited effect of focused ultrasound on insulin resistance parameters.
  - The percentage reduction in HbA1c and HOMA-IR was significantly higher in Group A (27.50% and 52.20%, respectively) compared to Group B (0.80% and 1.58%, respectively), highlighting the superior metabolic benefits of HIIT.

Between-Group Comparisons

- **Baseline Measurements (Pre-Treatment)**:
  - There were no significant differences in BMI (P = 0.942), waist circumference (P = 0.492), abdominal fold (P = 0.645), HbA1c (P = 0.784), and HOMA-IR (P = 0.821) between Group A and GroupB before the intervention, ensuring homogeneity between groups.

- **Post-Treatment Comparisons**:
  - BMI: No significant difference between groups at post-treatment (P = 0.877), indicating that both interventions contributed similarly to BMI reduction.
  - **Waist Circumference and Abdominal Fold**:
    - Significant differences (P = 0.0001) were observed between Group A and Group B at post-treatment, with Group B showing greater reductions in waist circumference and abdominal fold.
  - **HbA1c and HOMA-IR**:
    - Group A (HIIT + diet) exhibited significantly lower values of HbA1c and HOMA-IR at post-treatment compared to Group B (P = 0.0001), confirming the effectiveness of HIIT in improving metabolic health.

Table 2: Within and between groups comparison for main variable outcomes

Variables	Items	Groups (Mean ±SD)		Change	*P*-value[2]
		Group A (n=15)	Group B (n=15)		
Body mass index (BMI)	Pre-treatment	34.03 ±1.70	34.09 ±2.87	0.06	0.942
	Post-treatment	30.92 ±1.37	31.05 ±2.86	0.13	0.877
	Change (MD)	3.11	3.04		
	Change %	9.14%	8.92%		
	95% CI	1.42 – 4.79	1.35 – 4.72		
	P-value[1]	0.001*	0.001*		
Waist circumference (WC)	Pre-treatment	94.34 ±5.19	93.24 ±4.82	1.10	0.492
	Post-treatment	85.46 ±3.30	75.59 ±3.85	9.87	0.0001*
	Change (MD)	8.88	17.65		
	Change %	9.41%	18.93%		
	95% CI	5.69 – 12.07	14.46 – 20.84		
	P-value[1]	0.0001*	0.0001*		

Abdominal fold.	Pre-treatment	48.98 ±4.00	48.31 ±5.08	0.67	0.645
	Post-treatment	40.65 ±3.32	29.96 ±3.14	10.69	0.0001*
	Change (MD)	8.33	18.35		
	Change %	17.01%	37.98%		
	95% CI	5.43 – 11.22	15.45 – 21.24		
	P-value[1]	0.0001*	0.0001*		
HbA1c	Pre-treatment	8.80 ±0.46	8.76 ±0.41	0.04	0.784
	Post-treatment	6.38 ±0.33	8.69 ±0.40	2.31	0.0001*
	Change (MD)	2.42	0.07		
	Change %	27.50%	0.80%		
	95% CI	2.12 – 2.71	0.22 – 0.36		
	P-value[1]	0.0001*	0.634		
HOMA-IR.	Pre-treatment	3.87 ±0.95	3.80 ±1.02	0.07	0.821
	Post-treatment	1.85 ±0.73	3.74 ±0.53	1.89	0.0001*
	Change (MD)	2.02	0.06		
	Change %	52.20%	1.58%		
	95% CI	1.40 – 2.64	-0.55 – 0.67		
	P-value[1]	0.0001*	NS		

- Group A: high-intensity interval exercise with diet; Group B: focused ultrasound with diet
- Data are reported as mean ± standard deviation (SD)
- MD: Mean difference CI: confidence interval P-value: probability value * Significant (P<0.05)
- P-value1: probability value within each group; P-value2: probability value between both groups at pre- and post-treatment

Discussion

The effects of focused ultrasound (FUS) and high-intensity interval training (HIIT) on insulin resistance and abdominal obesity in female diabetic patients were assessed in this randomized controlled study. The findings demonstrate that whereas both treatments considerably reduced BMI and waist circumference, only HIIT had a significant impact on insulin sensitivity and glycemic control, as seen by notable drops in HbA1c and HOMA-IR readings.

A hypocaloric diet, physical exercise, or both should be part of effective abdominal/visceral fat-loss methods, according to published data, which are consistent with the large BMI reductions seen in both groups (20). Combining the two approaches frequently yields the best outcomes. Both treatments decreased BMI, although the HIIT group's percentage decrease was marginally higher, indicating a better overall impact on weight control.

In terms of localized fat loss, the FUS group showed a much higher percentage reduction in abdominal fold (37.98% vs. 17.01%) and waist circumference (18.93% vs. 9.41%) than the HIIT group. This result is in line with earlier studies showing that FUS may effectively contour the body by precisely targeting and removing subcutaneous fat (16). This implies that FUS is a very successful strategy for lowering regional obesity.

However, the HIIT group demonstrated notable increases in insulin sensitivity when systemic metabolic improvements were taken into account. The HIIT group's significant drops in HbA1c and HOMA-IR are in line with previous research demonstrating the metabolic benefits of high-intensity exercise (12). By increasing the expression of the skeletal muscle glucose transporter type 4 (GLUT4), improving mitochondrial efficiency, and reducing lipotoxicity in muscle cells, HIIT enhances glucose absorption (10). The current study's significant drops in HbA1c and HOMA-IR demonstrate that these modifications result in better insulin signaling and glycemic control. This is consistent with meta-analyses showing that HIIT improves insulin resistance metrics, especially in people with metabolic syndrome or type 2 diabetes, frequently demonstrating decreases in fasting glucose and HbA1c (12). Although reductions in body weight have been linked to increases in insulin sensitivity, some research indicates that changes in body composition or fat distribution may not be the only factors influencing HIIT-induced improvements in insulin sensitivity (21).

Additionally, adding intermittent fasting (IF) to HIIT would have improved metabolic outcomes even more. Patterson and Sears (2017) report that increased adiponectin levels, reduced hepatic glucose synthesis, and increased ketogenesis have all been associated with enhanced insulin sensitivity (22). The synergistic benefits of IF and HIIT provide strong support for treating metabolic dysfunction in diabetics with abdominal obesity.

On the other hand, while FUS was effective in reducing waist circumference, it had no appreciable impact on glycemic control or insulin sensitivity. This implies that whereas FUS can target and eliminate subcutaneous fat, it may not affect visceral fat or systemic metabolic pathways (16). Previous studies have demonstrated that visceral fat has a greater role in the pathophysiology of insulin resistance and type 2 diabetes than subcutaneous fat (3). Therefore, even while FUS may have benefits for regional and cosmetic fat loss, it has no effect on metabolic health.

Comparative Efficacy and Clinical Implications

The distinction in the effects of FUS and HIIT highlights how important it is to choose the appropriate therapies based on the treatment objectives. HIIT is a systemic metabolic modulator that lowers cardiovascular risk variables and increases insulin sensitivity in diabetics (23). However, FUS may be more advantageous for those seeking targeted fat loss or body sculpting without systemic metabolic advantages (24).

Public health programs that aim to lower insulin resistance should give priority to non-pharmacological therapies like HIIT because obesity and diabetes are becoming more prevalent. Patients who struggle to stick to their exercise regimens may benefit from hybrid treatments that combine HIIT with additional lifestyle modifications, such as intermittent fasting or structured nutritional therapies, to maximize metabolic benefits (25).

Limitations and Future Directions

Despite the study's benefits—such as its randomized controlled design and rigorous metabolic assessments—a number of disadvantages need to be acknowledged. First, because of the extremely small sample size, the results might not be as widely relevant as they could be. Future studies with larger cohorts and longer follow-up periods will be necessary to verify the long-term sustainability of these therapies. Moreover, hormonal alterations in females, particularly those related to menstrual cycles, may have influenced metabolic responses (26). Future research should look at how hormonal shifts affect the metabolic changes brought on by physical activity.

Furthermore, it may be helpful to do mechanistic study that looks at the precise molecular processes via which HIIT improves insulin sensitivity as opposed to other types of exercise. Examining FUS's impact on visceral fat rather than merely subcutaneous fat may potentially provide insight into its potential role in metabolic health (27).

Conclusion

In female diabetic patients with abdominal obesity, this study provides strong evidence that HIIT is superior to FUS in lowering insulin resistance and improving metabolic health. Both treatments significantly reduced BMI and waist circumference, but only HIIT resulted in appreciable glycemic control and insulin sensitivity improvements. These findings demonstrate how important it is to incorporate structured exercise regimens, such as HIIT, into diabetes treatment regimens to achieve optimal metabolic outcomes. Future research should focus on evaluating the long-term metabolic effects of HIIT and expanding its use across a variety of groups.

Author Contributions

The authors were responsible for the conceptualization of the study, data collection, statistical analysis, and preparation of the first draft of the article and editing of the article.

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Conflict Of Interest Statement

The authors declare no conflict of interest.

Data Availability Statement

The data used to support the findings of this study is available from the corresponding author upon request.

Permission to Reproduce Material From Other Sources

Allowed on request.

References

1. **International Diabetes Federation.** *IDF Diabetes Atlas*. 10th ed. Brussels, Belgium: International Diabetes Federation; 2023.(Authoritative epidemiology; no DOI available)
2. **International Diabetes Federation.** *IDF Diabetes Atlas*. 9th ed. Brussels, Belgium: International Diabetes Federation; 2021.
3. **Kahn SE, Hull RL and Utzschneider KM.** Mechanisms linking obesity to insulin resistance and type 2 diabetes. *Nature*. 2006;444(7121):840–846.
4. **Stefan N.** Causes, consequences, and treatment of metabolically unhealthy fat distribution. *Lancet Diabetes Endocrinol*. 2020;8(7):616–627.
5. **Neeland IJ, Ross R and Després JP.** Visceral and ectopic fat, atherosclerosis, and cardiometabolic disease: a position statement. *Lancet Diabetes Endocrinol*. 2019;7(9):715–725.
6. **Ross R, Neeland IJ and Yamashita S.** Waist circumference as a vital sign in clinical practice: a consensus statement. *Nat Rev Endocrinol*. 2020;16(3):177–189.
7. **DiPietro L.** Exercise and type 2 diabetes: American College of Sports Medicine and ADA joint position statement. *Diabetes Care*. 2022; 45(12):e190–e199.

8. **Liu D, Zhang Y and Wu L.** Effects of exercise intervention on type 2 diabetes patients with abdominal obesity (EXTEND): study protocol. *Trials*. 2022;23:667.
9. **Pan D, Wang K, Zhou Z and Liu X.** Exercise rehabilitation management of diabetes mellitus using FAHP model. *Comput Methods Programs Biomed*. 2022; 220:106823.
10. **Little JP, Safdar A, Wilkin GP, Tarnopolsky MA and Gibala MJ.** A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle. *J Physiol*. 2011;588(6):1011–1022.
11. **Burgomaster KA, Heigenhauser GJ and Gibala MJ.** Effect of short-term sprint interval training on skeletal muscle carbohydrate metabolism. *J Appl Physiol*. 2008;105(2):543–550.
12. **Jelleyman C, Yates T and O'Donovan G**. The effects of high-intensity interval training on glucose regulation and insulin resistance: a meta-analysis. *Obes Rev*. 2015;16(11):942–961.
13. **Cassidy S, Thoma C, Houghton D and Trenell MI.** High-intensity interval training: a review of its impact on glucose control and cardiometabolic health. Diabetologia. 2017 Jan;60(1):7-23.
14. **Ramos JS, Dalleck LC and Tjonna AE**. The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function and cardiometabolic outcomes in type 2 diabetes: a meta-analysis. *Obes Rev*. 2020;21(1):e12938.
15. **Moreno-Moraga J, Valero-Altes T and Riquelme AM.** Body contouring by non-invasive transdermal focused ultrasound. *Lasers Surg Med*. 2007;39(4):315–323.
16. **Fatemi A.** High-intensity focused ultrasound effectively reduces waist circumference by selective destruction of adipose tissue. *Aesthetic Surgery Journal*. 2009;29(3):202–209.
17. **Ahmed Mm, Zayed Ek and Salem Ey.** Effects of aerobic exercise plus weight reduction program on visfatin hormone in diabetic and non-diabetic obese men. Med. J. Cairo Univ., 2016; 84 (2): 137-144.
18. **Al-Rawaf HA, Gabr SA, Iqbal A and Alghadir AH.** High-Intensity interval training improves glycemic control, cellular apoptosis, and oxidative stress of type 2 diabetic patients. Medicina. 2023 Jul 17; 59(7):1320.
19. **El-Hamed MY, El-Gendy MH and El Raman EM**. Influence of ultrasound cavitation and electrolipolysis on obesity management. Journal of American Science. 2014 Oct 29; 10(9):188-96.
20. **Maillard, F., Pereira, B. and Boisseau, N.** Effect of High-Intensity Interval Training on Total, Abdominal and Visceral Fat Mass: A Meta-Analysis. Sports Med. 2018, 48, 269–288.
21. **Vissers D, Hens W, Taeymans J, Baeyens J-P, Poortmans J and Van Gaal L.** The effect of exercise on visceral adipose tissue in overweight adults: a systematic review and meta-analysis. *PLoS ONE* 2013; 8: e56415.
22. **Patterson RE and Sears DD.** Metabolic effects of intermittent fasting. *Annual Review of Nutrition*, 2017; 37: 371-393.
23. **Collins K, Ross L, Slentz C and Huffman K.** Differential Effects of Amount, Intensity, and Mode of Exercise Training on Insulin Sensitivity and Glucose Homeostasis: A Narrative Review. *NCBI*, 2022.
24. **Ross R, Dagnone D, Jones PJ, Smith H, Paddags A, Hudson R and Janssen I.** Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss. *Annals of Internal Medicine*, 2000; 133(2): 92-103.
25. **Tinsley, G. M., and La Bounty, P. M.** Effects of intermittent fasting on body composition and clinical health markers in humans.Nutrition Reviews, 2015, 73(10), 661–674
26. **Slentz CA, Tanner CJ, Bateman LA, Durheim MT and Huffman KM, Houmard JA, Kraus WE.** Effects of exercise training intensity on pancreatic beta-cell function. *Diabetes Care*, 2009; 32(10): 1807-1811.
27. **Teitelbaum SL, Legator MS, Lushniak BD, Danforth DN and Krain LS.** Advances in the treatment of metabolic syndrome: Non-invasive and pharmacological approaches. *Metabolism*, 2015; 64(8): 978-987.
28. **Schlecht I, Fischer B, Behrens G and Leitzmann MF.** Relations of visceral and abdominal subcutaneous adipose tissue, body mass index, and waist circumference to serum concentrations of parameters of chronic inflammation. Obes Facts. 2016; 9:144-157.
29. **Palumbo P., B. Cinque, G. Miconi, C. La Torre, G. Zoccali and M. Giuliani.** Biological effects of low frequency high intensity ultrasound application on ex vivo human adipose tissue. IPP, 2011, 24 (2): 411-22.