

A randomised controlled trial on the effect of ultrasound cavitation on insulin resistance, abdominal skinfold thickness, and waist-to-hip ratio in women with central obesity

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Abstract

Introduction. This study aimed to evaluate the effects of ultrasound cavitation on insulin resistance, waist-to-hip ratio (WHR), and abdominal skinfold thickness in women with central obesity.

Methods. A total of 52 women aged 25–40 years with the mean age of 32.9 ± 4.2 years with central obesity were randomly assigned to either an experimental group (ultrasound cavitation, aerobic exercise, and a low-calorie diet) or a control group (aerobic exercise and a low-calorie diet). Randomisation was computer-generated; outcome assessors were blinded. The intervention occurred twice weekly for 6 weeks. Outcomes were assessed pre- and post-treatment. Insulin resistance was measured using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), abdominal skinfold thickness with Lange callipers, and WHR with a non-elastic tape. Normality was confirmed via the Shapiro–Wilk test, and homoscedasticity was verified. Parametric tests including paired *t*-tests and multivariate analysis of variance (MANOVA) were applied, with Bonferroni correction used for multiple comparisons.

Results. The experimental group showed reductions of 23% in HOMA-IR (mean change: -0.64 ± 0.2), 7% in abdominal skinfold thickness (2.4 ± 0.5 mm), and 8% in waist-to-hip ratio (7.5 ± 1.2). In contrast, the control group demonstrated smaller reductions of 5% (0.13 ± 0.2), 0.5% (0.16 ± 0.1 mm), and 0.7% (0.63 ± 0.2), respectively. Between-group differences in all three obesity markers were statistically significant ($p < 0.05$), favouring the experimental group.

Conclusions. Ultrasound cavitation, combined with exercise and dietary interventions, significantly improves insulin resistance and central obesity markers. This finding supports its use as a non-invasive metabolic intervention.

Key words: central obesity, ultrasound cavitation, insulin resistance, waist-to-hip ratio, skinfold thickness

Introduction

Obesity is a growing global health concern, with its prevalence steadily rising due to factors such as sedentary lifestyles, unhealthy diets, and urbanization [1]. Obesity rates vary widely across regions: prevalence is projected to reach 20–50% in Africa by 2025, exceeds 23% in Europe, afflicts over 30% of adults in the Americas, and is rapidly increasing in parts of Asia, particularly in urban areas, with some countries reporting prevalence rates of 10–25%. These global patterns highlight the need for effective and region-specific obesity interventions [2].

Obesity is commonly classified using the body mass index (BMI), where individuals with a BMI of 25.0 – 29.9 kg/m² are considered overweight and those with BMI ≥ 30.0 kg/m² are classified as obese. However, BMI does not distinguish between muscle and fat mass or indicate fat distribution. Central obesity, a more specific phenotype, refers to excessive fat accumulation in the abdominal region and is commonly assessed using waist circumference or waist-to-hip ratio. It is associated with higher cardiometabolic risks compared to general obesity [3].

Central obesity is particularly concerning because visceral fat, stored within the abdominal cavity, has a greater impact on metabolic health than subcutaneous fat. Research has highlighted the potential role of alterations in the gut micro-

biome in obesity and related metabolic dysfunction [4]. Traditional assessment methods, like body mass index (BMI), have however limitations in diagnosing central obesity, leading to a greater reliance on waist circumference as a risk indicator. Recent evidence suggests that waist circumference is to be a more useful predictor of mortality than BMI in obese patients admitted to the intensive care unit (ICU) [5]. Factors contributing to the increasing prevalence of abdominal obesity include physical inactivity, high-energy diets, and lifestyle changes associated with urbanisation and modern transportation [6].

Metabolic disorders, such as type 2 diabetes, insulin resistance, and polycystic ovary syndrome (PCOS), are strongly associated with central obesity. Insulin resistance plays a key role in the development of type 2 diabetes and substantially increases cardiovascular risk [7]. Previous findings have suggested that metabolic dysfunctions, including metabolic syndrome and insulin resistance, are associated with impairments in cognitive function and brain structure, further highlighting their widespread consequences [8]. However, whether temporary or chronic, insulin resistance can often be managed through lifestyle modifications and medical interventions [9].

Ultrasound-based non-invasive lipolysis devices use ultrasound energy to target subcutaneous adipose tissue and promote localised fat reduction through mechanical and other energy-induced effects on adipose tissue [10]. Compared

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with traditional liposuction, non-invasive body-contouring modalities, such as focused ultrasound, are associated with fewer complications, lesser pain, and minimal recovery time. Clinical studies have reported reductions in localised subcutaneous fat and improvements in body contour following ultrasound-based body-contouring treatments [11].

Several other non-invasive lipolytic techniques are available, including radiofrequency (RF), cryolipolysis, and other energy-based modalities. RF uses thermal energy to heat the dermis and subcutaneous tissue, stimulating collagen remodelling and adipocyte apoptosis, whereas cryolipolysis reduces fat by controlled cooling-induced adipocyte death. These techniques have demonstrated variable efficacy, and their mechanisms of action differ substantially from ultrasound-based fat reduction [10].

Despite the increasing clinical use of these techniques, few comparative studies have examined their effects on metabolic health, including insulin resistance. Moreover, ultrasound cavitation's impact on metabolic markers, like HOMA-IR, abdominal skinfold thickness, and waist-to-hip ratio, especially when combined with exercise and dietary interventions, remains underexplored. This study addresses this gap by evaluating the efficacy of ultrasound cavitation within a structured lifestyle intervention framework and comparing its outcomes with findings from alternative fat-reduction methods [12].

Therefore, this randomised controlled trial aimed to evaluate the effects of ultrasound cavitation on insulin resistance, waist-to-hip ratio (WHR), and abdominal skinfold thickness in women with central obesity.

Subjects and methods

Study type and design

This study was a randomised controlled trial (RCT) designed to investigate the effect of ultrasound cavitation on insulin resistance, waist-to-hip ratio, and abdominal skinfold thickness in women with central obesity. The intervention period lasted 6 weeks, and participants were randomly allocated to two equal groups in a parallel-group design. The study was conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) 2010 guidelines.

Sample size calculation

The sample size was determined using G*Power software (version 3.1) based on data from a preliminary pilot study. With an assumed effect size of 0.8, a significance level (α) of 0.05, and a statistical power ($1-\beta$) of 0.80, a minimum of 26 participants *per* group (total $n = 52$) was required to detect significant between-group differences.

Eligibility criteria and study groups

A total of 52 women aged 25 to 40 years, diagnosed with central obesity (BMI between 30 and 35 kg/m²), were recruited and randomly assigned into two equal groups using computer-generated randomisation. Inclusion criteria were a waist circumference between 88 and 102 cm, HbA1c levels within the prediabetic range (5.7%–6.4%), and a sedentary lifestyle (defined as < 150 min of moderate physical activity *per* week). Exclusion criteria included a diagnosis of diabetes mellitus, current pregnancy, metabolic or endocrine disorders, or a history of bariatric surgery. A CONSORT flow diagram was prepared to illustrate participant enrolment, allocation, and follow-up throughout the study (Figure 1).

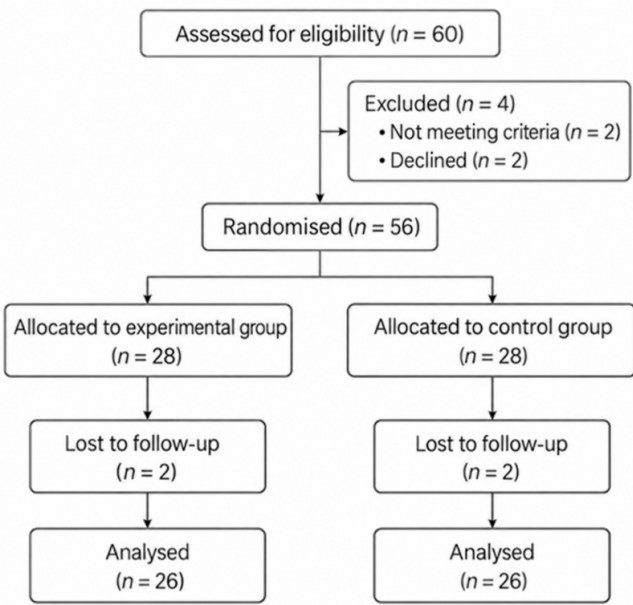


Figure 1. CONSORT flow diagram

Demographic and baseline characteristics

Baseline demographic and clinical characteristics, including age, weight, height, body mass index (BMI), and HbA1c level, were assessed for all participants before the intervention. These characteristics were recorded to describe the study population and assess baseline comparability between the experimental and control groups.

Interventions

Participants in the experimental group followed a program with ultrasound cavitation, aerobic exercise, and a low-calorie diet. This low-frequency ultrasound is designed specifically for lipolytic purposes and differs from conventional therapeutic ultrasound (typically 1–3 MHz), which is used for deep tissue heating and musculoskeletal rehabilitation. Cavitation uses mechanical pressure waves rather than thermal effects to disrupt adipocyte membranes and promote localised fat breakdown. Ultrasound cavitation was administered using the Laser Cavitation Fat System LS650 device (Guangzhou Beautylife Electronic Technology Co., Ltd., Guangzhou, China), which operates at a therapeutic frequency of 40 kHz and a power output of 45 watts. The LS650 device used in this study does not emit laser energy; its mechanism of action is purely mechanical. A 3-cm circular applicator probe was used to apply treatment over both the upper and lower abdominal regions using circular, overlapping strokes for 30 min. A conductive gel was applied to ensure proper acoustic coupling, and participants remained in the supine position during each session. These sessions were conducted twice weekly for six weeks (12 sessions in total). The dosage and session duration were selected based on the treatment protocol used in the present study and previous literature data on non-invasive body-contouring interventions [12].

In addition to cavitation, participants followed a structured aerobic exercise regimen consisting of 30-minute moderate-intensity treadmill walking sessions conducted twice a week under physiotherapist supervision. They also adhered to a low-calorie diet of 1500 kcal/day, consisting of 45% carbohydrates, 35% protein, and 20% fat. The control group followed exactly the same aerobic exercise program and dietary protocol as the experimental group but did not receive ultrasound cavitation treatment.

Outcomes

Insulin resistance was assessed using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), a validated and widely utilised method for estimating insulin sensitivity and β -cell function, particularly in large epidemiological studies. Abdominal skinfold thickness was measured using Lange skinfold callipers, which have demonstrated excellent intra-rater reliability (intraclass correlation coefficient > 0.90) and strong validity when compared to dual-energy X-ray absorptiometry (DEXA) for evaluating subcutaneous fat. Waist-to-hip ratio (WHR) was measured using a non-elastic tape and is considered a reliable and valid anthropometric indicator of central obesity and associated metabolic risk.

Additionally, all anthropometric assessments were conducted by a licensed physiotherapist who was blinded to group allocation to ensure measurement objectivity and minimise assessor bias.

Statistical analysis

All data were analysed using the Statistical Package for the Social Sciences (SPSS, version 29, IBM Corp., Armonk, NY, USA). Descriptive statistics were reported as mean $\pm$ standard deviation (SD) for continuous variables. The Shapiro–Wilk test was used to assess the normality of data distribution, while Levene’s test evaluated the homogeneity of variances across groups.

For inferential analysis, paired t -tests were used to examine within-group changes before and after the intervention. A two-way mixed-model multivariate analysis of variance (MANOVA) was employed to analyse the interaction between group (experimental vs. control) and time (pre- vs. post-intervention) across the dependent variables: HOMA-IR, abdominal skinfold thickness, and waist-to-hip ratio. When significant MANOVA results were observed, follow-up univariate ANOVAs were conducted for each variable. Partial eta squared (η^2) was reported to indicate effect sizes. Bonferroni-adjusted post-hoc tests were applied when appropriate to identify between-group differences. Statistical significance was set at $p \leq 0.05$ for all analyses.

Results

Demographics and clinical characteristics

Fifty-two women with central obesity were included in the study and equally divided into two groups: experimental group followed a program with ultrasound cavitation, aerobic exercises, and a low-calorie diet, while control group followed aerobic exercises and a low-calorie diet only. Both groups

were similar in baseline characteristics, including age, weight, height, BMI, and HbA1c, with no statistically significant differences observed ($p > 0.05$) (Table 1).

Overall effect of intervention

Multivariate analysis of variance (MANOVA) revealed significant effects of treatment, time, and their interaction ($p < 0.001$). Post-treatment improvements were significantly more pronounced in the experimental group across all measured outcomes (Table 2).

Levene’s test demonstrated no significant violations of variance homogeneity for the primary outcome measures ($p > 0.05$), supporting the use of MANOVA and t -tests.

Table 2. MANOVA table for the effect of treatment on the measured outcomes

Source of variation	F-value	p-value	η^2
Interaction effect (treatment $\times$ time)	298.9	$< 0.001^*$	0.95
Effect of time	483.7	$< 0.001^*$	0.97
Effect of treatment	11.7	$< 0.001^*$	0.42

* statistically significant at $p < 0.05$

HOMA-IR

Following the 6-week intervention, the experimental group demonstrated a significant reduction in HOMA-IR values by 23%, decreasing from $2.74 \pm (0.1)$ to $2.10 \pm (0.2)$ ($p < 0.001$). In contrast, the control group showed a modest 5% reduction, from $2.73 \pm (0.2)$ to $2.60 \pm (0.2)$ ($p < 0.001$). Between-group comparisons (Table 3) after the intervention revealed a statistically significant difference in favour of the experimental group ($p < 0.001$), indicating that ultrasound cavitation had an additional effect beyond diet and exercise alone.

Effect of intervention on abdominal skinfold thickness

Participants in the experimental group experienced a 7% reduction in abdominal skinfold thickness (Table 3), which decreased from 33.73 ± 6.1 mm to 31.33 ± 5.9 mm ($p < 0.001$). The control group showed only a 0.5% reduction, from 35.3 ± 5.1 mm to 35.11 ± 5.1 mm ($p = 0.023$). The post-treatment difference between groups was statistically significant ($p = 0.016$), again favouring the experimental group.

Effect of intervention on waist-to-hip ratio (WHR)

The WHR in the experimental group decreased by 8% (from 97.92 ± 4.7 to 90.42 ± 3.0 ; $p < 0.001$), while the control group saw a minimal reduction of 0.7% (from 95.65 ± 4.4 to 95.02 ± 4.3 ; $p = 0.038$). A statistically significant between-group difference was observed post-intervention, favouring the experimental group ($p < 0.001$, Table 3).

Discussion

This study investigated the effect of ultrasound cavitation on insulin resistance, abdominal skinfold thickness, and waist-to-hip ratio (WHR) in women with abdominal obesity. The findings revealed significant improvements in all measured outcomes, particularly in the experimental group, supporting the role of ultrasound cavitation as an effective complementary treatment alongside aerobic exercise and dietary modification.

Table 1. Baseline characteristics of participants

Demographic data	Experimental group ($n = 26$) mean $\pm$ SD	Control group ($n = 26$) mean $\pm$ SD	t-value	p-value
Age (years)	32.4 ± 4.2	33.4 ± 4.2	−0.8	0.416
Weight (kg)	82.0 ± 8.0	82.3 ± 7.7	−0.2	0.873
Height (cm)	158.4 ± 6.2	158.3 ± 6.3	0.0	0.965
BMI (kg/m ²)	32.6 ± 1.8	32.8 ± 1.5	−0.5	0.633
HbA1c (%)	6.1 ± 0.2	6.1 ± 0.2	−0.1	0.892

BMI – body mass index, HbA1c – glycated haemoglobin

Table 3. Within-group and between-group comparisons

Measured variables	Experimental group (<i>n</i> = 26)	Control group (<i>n</i> = 26)	<i>MD</i> (95% <i>CI</i>)	<i>F</i> -value	<i>p</i> -value	η ²
HOMA-IR						
pre-treatment (mean ± <i>SD</i>)	2.7 ± 0.1	2.7 ± 0.2	0.01 (−0.07, 0.09)	0.1	0.778	0.002
post-treatment (mean ± <i>SD</i>)	2.1 ± 0.2	2.6 ± 0.2	−0.5 (−0.6, −0.4)	97.7	< 0.001*	0.66
<i>MD</i> (95% <i>CI</i>)	0.7 (0.6,0.7)	0.1 (0.09, 0.17)				
% of change	23%	5%				
<i>p</i> -value	< 0.001*	0.001*				
Abdominal skinfold thickness (mm)						
pre-treatment (mean ± <i>SD</i>)	33.7 ± 6.1	35.3 ± 5.1	−1.5 (−4.7, 1.6)	1.0	0.326	0.019
post-treatment (mean ± <i>SD</i>)	31.3 ± 5.9	35.1 ± 5.1	−3.79 (−6.8, −0.7)	6.2	0.016*	0.11
<i>MD</i> (95% <i>CI</i>)	2.4 (2.26, 2.54)	0.2 (0.02, 0.3)				
% of change	7%	0.5%				
<i>p</i> -value	< 0.001*	0.023*				
Waist-to-hip ratio						
pre-treatment (mean ± <i>SD</i>)	97.9 ± 4.6	95.7 ± 4.4	2.27 (−0.25, 4.77)	3.3	0.076	0.6
post-treatment (mean ± <i>SD</i>)	90.4 ± 3.0	95.0 ± 4.3	−4.6 (−6.65, −2.55)	20.4	< 0.001*	0.29
<i>MD</i> (95% <i>CI</i>)	7.5 (6.9, 8.1)	0.6 (0.04, −0.03)				
% of change	8%	0.7%				
<i>p</i> -value	0.001*	0.038*				

HOMA-IR – Homeostatic Model Assessment of Insulin Resistance
Pre- and post-treatment differences within each group were assessed using paired *t*-tests (*p*-value).
Between-group comparisons were analysed using mixed MANOVA.
* Differences were considered statistically significant at *p* < 0.05.

Comparison of literature data

Effect of intervention on insulin resistance

The observed improvement in insulin sensitivity among participants receiving ultrasound cavitation is consistent with the broader evidence that reductions in central adiposity achieved through lifestyle modification and adjunct non-invasive body-contouring procedures can favourably influence metabolic risk profiles. Clinical and experimental studies of non-invasive body-contouring technologies have reported reductions in localised subcutaneous fat, although the magnitude and consistency of outcomes vary across studies and depend on the modality and treatment parameters. This variability underscores the importance of considering ultrasound cavitation as an adjunct to a structured lifestyle intervention rather than as a stand-alone approach for metabolic health [13].

Beyond glucose metabolism, reductions in central adiposity have important implications for cardiometabolic health, as measures of abdominal adiposity are associated with cardiometabolic and type 2 diabetes risk [14]. These observations suggest that interventions capable of reducing central adiposity, particularly when combined with lifestyle modification, may have potential benefits beyond cosmetic outcomes [14].

Effect of intervention on abdominal skinfold

Several reports have indicated that non-invasive body-contouring modalities, including ultrasound-based devices, can

reduce localised subcutaneous fat and skinfold thickness, particularly when applied in multiple sessions and combined with lifestyle advice on diet and physical activity. Systematic and narrative reviews of these technologies describe modest but measurable reductions in regional fat thickness on imaging or calliper measurements but also emphasise substantial variability in individual response and study quality, underscoring the importance of protocol standardisation and appropriate patient selection when interpreting outcomes [13].

Effect of intervention on waist-to-hip ratio (WHR)

Reductions in WHR observed in this study are consistent with the well-established association between central adiposity, cardiometabolic risk, and the clinical relevance of abdominal adiposity measures [3].

Clinical and epidemiological data indicate that waist-based measures of central adiposity are more closely related to cardiometabolic risk than BMI alone, supporting the clinical relevance of the WHR changes observed in the present trial [3].

Beyond statistical significance, the magnitude of the improvements observed in this study also supports their potential clinical importance. A 23% reduction in HOMA-IR represents a substantial improvement in insulin sensitivity among women with central obesity, while the 7% reduction in abdominal skinfold thickness and the 8% decrease in WHR indicate meaningful reductions in central adiposity, a key driver of cardiometabolic risk.

These findings suggest that ultrasound cavitation, when integrated with aerobic exercise and dietary control, may offer

a practical, non-invasive strategy for improving both metabolic health and body composition, rather than providing purely aesthetic benefit [13].

Physiological mechanisms underlying metabolic improvements in central obesity

Polak-Szczybyło and Tabarkiewicz [15] highlight how poor dietary habits and sedentary lifestyle contribute to chronic low-grade inflammation in obese individuals, manifested by elevated levels of pro-inflammatory cytokines, such as IL6, IFN γ , and TNF α , which are known to impair insulin signalling pathways. This inflammatory state is closely linked to insulin resistance, one of the primary outcomes addressed in our study. Additionally, Ortiz-Alvarez *et al.* [16] emphasise the relationship between physical activity and gut microbiota, showing that higher physical activity levels are associated with differences in faecal microbiota diversity and composition, which can be improved through regular physical activity. These findings align with our approach, where aerobic exercise and dietary control accompany ultrasound cavitation to promote systemic metabolic improvements. Finally, Albajy and Mihailescu [17] underscore that comprehensive management of type 2 diabetes should address both metabolic dysfunction and inflammatory status – an integrated strategy reflected in our multimodal intervention for central obesity.

Adverse effects of ultrasound cavitation

Non-invasive body-contouring technologies have generally demonstrated favourable safety profiles, although adverse effects may vary according to the modality and treatment parameters. Radiofrequency-based treatments can induce thermal effects in adipose tissue [18], while cryolipolysis has been reported to be generally well tolerated with high patient satisfaction [19]. In the present study, ultrasound cavitation was well tolerated, and no adverse events were observed during the intervention period. Nevertheless, further studies with appropriate biochemical monitoring are needed to fully evaluate the metabolic safety of ultrasound cavitation.

Comparative efficacy of ultrasound cavitation and other modalities

In the context of non-invasive body contouring, ultrasound cavitation demonstrates several advantages when compared to other lipolytic techniques. Unlike radiofrequency, which relies on thermal energy to induce effects in subcutaneous adipose tissue [18], ultrasound cavitation uses mechanical energy to disrupt fat cell membranes, potentially leading to more direct and localised fat reduction. Cryolipolysis, on the other hand, reduces subcutaneous fat through controlled cooling and adipocyte apoptosis and may be associated with treatment-related discomfort [20].

Electro-lipolysis, though minimally invasive, has shown inconsistent results unless combined with diet or exercise. Importantly, experimental evidence suggests that low-frequency ultrasound may exert metabolic effects, including improvements in insulin resistance [21]. In the present study, ultrasound cavitation was integrated with lifestyle interventions and evaluated for its effects on metabolic and anthropometric outcomes, including insulin resistance and WHR. Study results suggest that cavitation may offer not only aesthetic improvements but also potential metabolic benefits when used as an adjunct to lifestyle interventions.

Cryolipolysis, another widely used non-invasive fat reduction technique, has been shown to reduce subcutaneous fat through controlled cooling and adipocyte apoptosis. For example, Krueger *et al.* [20] reported significant reductions in abdominal circumference and skinfold thickness after cryolipolysis treatment, though improvements in metabolic parameters, such as insulin resistance, were not consistently observed. In contrast, the present study found that ultrasound cavitation not only reduced abdominal skinfold thickness and waist-to-hip ratio but also improved insulin resistance, as indicated by the reduction in HOMA-IR.

Moreover, unlike cryolipolysis, which may cause treatment-site discomfort or other treatment-related adverse effects [19], ultrasound cavitation was well tolerated by participants in the present study, with no adverse events observed during the intervention period. These findings suggest that cavitation may offer a broader therapeutic benefit when integrated with lifestyle interventions.

The lipolytic effects of ultrasound may lead to changes in adipocyte structure, followed by the clearance of cellular debris through inflammatory and phagocytic processes [12].

Treatment protocols vary according to the device parameters and treatment area, with repeated sessions commonly used to achieve progressive fat reduction [10]. In the present study, treatment sessions were scheduled twice weekly according to the study protocol.

Compared to other non-invasive body contouring modalities, ultrasound cavitation represents an energy-based approach for localised fat reduction. Unlike cryolipolysis, which targets adipose tissue through controlled cooling and may be associated with treatment-related discomfort or transient sensory changes [20], ultrasound cavitation uses acoustic energy to produce mechanical effects within adipose tissue [12]. Radiofrequency (RF) treatments primarily rely on thermal energy to affect subcutaneous adipose tissue and surrounding structures [18]. Ultrasound cavitation may, therefore, provide a non-invasive option for localised fat reduction, although treatment outcomes depend on the device, treatment parameters, and patient characteristics [10].

Limitations

This study has several limitations that should be acknowledged. First, the relatively short duration of the intervention (6 weeks) limits the ability to assess the long-term sustainability of the observed effects. Second, the sample size, although statistically justified, was modest and limited to a specific demographic group (women aged 25–40 years with central obesity), which may affect the generalisability of findings to other populations. Third, the study did not include any follow-up assessments beyond the post-intervention period, which precludes evaluation of whether the improvements in insulin resistance and body composition were maintained over time. Future research should aim to incorporate longer follow-up periods to determine the persistence of treatment outcomes and explore long-term metabolic and behavioural adherence.

Clinical implications and future directions

The findings of this study suggest that ultrasound cavitation is an effective and safe adjunctive therapy for reducing abdominal obesity while improving metabolic health. This has important implications for clinical practice, as it offers a non-invasive alternative for individuals who are unable or unwilling to undergo surgical procedures.

Future research should aim to include larger sample sizes and longer follow-up periods to validate these findings. Additionally, studies exploring the molecular mechanisms of ultrasound cavitation and its impact on systemic inflammation and hormonal regulation would provide deeper insights into its therapeutic potential.

Conclusions

This study highlights the efficacy of ultrasound cavitation, combined with aerobic exercise and diet, in significantly improving insulin resistance, abdominal fat, and waist-to-hip ratio in women with central obesity. Experimental group showed superior results compared to the control group, with greater reductions in HOMA-IR, skinfold thickness, and WHR. These findings support ultrasound cavitation as a non-invasive, synergistic intervention for managing central obesity. Further research is, however, recommended to assess its long-term impact and applicability.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Faculty of Physical Therapy, Cairo University, Egypt (approval No.: P.T. REC/012/005421). The study protocol was prospectively registered with ClinicalTrials.gov (registration No.: NCT06729203, registered January 3, 2024).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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