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THE EFFECT OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION ON WEIGHT LOSS: A RANDOMIZED CONTROLLED TRIAL

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Abstract

Background: *Transcutaneous electrical nerve stimulation (TENS) applied to the T6 dermatome corresponding to gastric afferent pathways has been proposed as a non-invasive adjunct to enhance dietary compliance and promote weight loss.* ***Methodology:*** *A prospective, randomized, parallel-arm controlled trial was conducted. Obese participants (BMI ≥30 kg/m²) were randomized to either: (1) T6 TENS + 1,200 kcal diet (intervention) or (2) 1,200 kcal diet alone (control). TENS was applied for 20 minutes daily over 6 weeks. Primary outcomes included weight loss and dietary adherence. Secondary outcomes included hunger scores, lipid profiles, and metabolic biomarkers.* ***Results:*** *The intervention group (n=10) demonstrated significantly greater weight loss compared to controls (n=10): -7.7 ± 3.9 kg vs -1.7 ± 6.1 kg ($p < 0.01$). Dietary adherence significantly improved in the TENS group (-1.0 ± 1.1 vs 0.1 ± 0.9, $p < 0.05$), accompanied by reduced hunger perception (-1.0 ± 1.1 vs 0.2 ± 1.3, $p < 0.05$). Total cholesterol (-0.6 ± 0.8 mmol/L vs +0.4 ± 0.6 mmol/L, $p = 0.01$) and C-peptide levels (-1.5 ± 1.6 ng/mL vs +0.4 ± 1.2 ng/mL, $p < 0.05$) showed significant improvement in the TENS group.* ***Conclusion:*** *These findings support TENS as a safe, non-pharmacological adjunctive therapy for obesity management. Larger, longer-term trials are warranted to confirm efficacy and elucidate mechanisms.*

INTRODUCTION

Obesity, defined as a body mass index (BMI) ≥30 kg/m², is a chronic metabolic disorder affecting over 1.9 billion adults globally. It significantly increases the risk of type 2 diabetes mellitus, cardiovascular disease, hypertension, and metabolic syndrome. Despite the established efficacy of caloric restriction for weight loss, adherence to dietary interventions remains a major barrier, with hunger and abdominal discomfort frequently cited as primary reasons for non-compliance (Zhang W, et al. 2024).

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Transcutaneous electrical nerve stimulation (TENS) is a widely used, non-invasive modality traditionally employed for pain management via high-frequency afferent signal modulation. Low-frequency TENS (Lo-TENS, 2-4 Hz) may exert neuromodulatory effects on the autonomic nervous system, reducing sympathetic overactivity a hallmark of obesity and metabolic syndrome (Jin J, Wen S et al. 2026).

The T6 dermatome corresponds to the spinal segment receiving afferent fibers from the stomach and upper gastrointestinal tract. It has been hypothesized that TENS applied to this region may modulate gastric signals, alleviate abdominal discomfort associated with caloric restriction, and reduce hunger perception (Chaney S, et al. 2019). A previous study by (Ruiz-Tovar et al.) demonstrated that percutaneous electrical neurostimulation (PENS) of the T6 dermatome, combined with a hypocaloric diet, achieved greater weight loss and reduced appetite compared to diet alone, with associated reductions in plasma ghrelin levels (Michalopoulou, S. et al. 2025).

However, the efficacy of TENS specifically for obesity management remains unclear, with a recent systematic review concluding that evidence is limited and requires cautious interpretation (Nie R, et al. 2025). This randomized controlled trial aims to investigate the effect of T6 dermatome TENS on weight loss, dietary adherence, hunger perception, and metabolic parameters in obese individuals following a low-calorie diet (Pradeep K. Sahu et al. 2024).

Methodology

Study Design

A prospective, randomized, parallel-arm, controlled trial conducted at rural area of Peshawar on obese adults (BMI ≥30 kg/m^2) aged 18-65 years.

Inclusion criteria:

- Stable weight (±2 kg) for 3 months prior to enrollment
- Willingness to adhere to a prescribed low calorie diet
- Ability to attend scheduled TENS sessions.

Exclusion criteria:

- Obesity secondary to endocrine disorders
- Implanted electrical devices (e.g., pacemakers)
- Significant cardiovascular disease
- Pregnancy or lactation
- Psychiatric illness
- Current use of weight-loss medications or dietary supplements.

Randomization and Blinding

Eligible participants were randomly assigned to one of two groups. The study was single-blinded outcome assessors were blinded to group allocation. Participants were not blinded due to the nature of the intervention.

Interventions

Group I (Control): Participants were prescribed a 1,200 kcal/day diet. Dietary counseling was provided by a registered dietitian at baseline, with weekly telephone follow-up to assess adherence.

Group II (Intervention): Participants received the same 1,200 kcal/day diet. Additionally, they received TENS applied to the T6 dermatome for 20 minutes daily over 6 weeks. TENS was administered using a standard portable device with the following parameters: frequency 2 Hz, pulse width 250 μs, and intensity adjusted to a comfortable, non-painful level (typically 15-25 mA). Electrodes were placed bilaterally over the T6 dermatome (approximately at the xiphoid process level).

Outcome Measures

Primary Outcomes:

Weight loss: Body weight measured at baseline and week 6 using a calibrated digital scale.

Dietary adherence: Assessed using a 7-day food diary and expressed as a compliance score (-2 to +2 scale).

Secondary Outcomes:

Hunger perception: Visual analogue scale (VAS, 0-10) administered weekly.

Metabolic biomarkers: Fasting blood samples collected at baseline and week 6 for

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measurement of total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), triglycerides, C-peptide, ghrelin, leptin, adiponectin, and high-sensitivity C-reactive protein (hs-CRP).

Statistical Analysis

Sample size was estimated based on a previous study demonstrating a Cohen's d of 0.896 for BMI reduction with TENS and diet versus diet alone. Using a conservative small effect size (f=0.2), α=0.05, and 80% power, a total sample of 63 participants was estimated (approximately 21 per group). The trial was terminated early at 20 participants (10 intervention, 10 control) based on the significant findings observed.

Data was analyzed using SPSS version 26. Baseline characteristics between groups were compared using independent t-tests or Mann-Whitney U tests. Statistical significance was set at $p < 0.05$.

Results

Participant Characteristics

20 participants were enrolled and randomized: 10 to the intervention group (T6 TENS + diet) and 10 to the control group (diet alone). Baseline characteristics were comparable between groups (Table 1). The mean age was 50.1±7.9 years for intervention group and 46.3±11.3 years for control group, with a mean BMI of 34.2 ± 3.7 kg/m² for intervention group while 38.4±5.1 for control group. No significant differences were observed in baseline weight, BMI, or metabolic parameters.

Table 1: Baseline Characteristics

Characteristic	T6 TENS + Diet Mean ± SD	Diet Alone Mean ± SD	T	p-value
Age (years)	50.1 ± 7.9	46.3 ± 11.3	0.880	0.391
BMI (kg/m²)	34.2 ± 3.7	38.4 ± 5.1	-2.083	0.052

Table 1 shows that, there was no statistically significant difference in age (p = 0.391). The BMI difference was close to, but did not reach, the conventional p < 0.05 threshold (p = 0.052).

Independent-Samples t-Test Comparison Between Groups

Outcome	T6 TENS + Diet (n=10) Mean ± SD	Diet Alone (n=8) Mean ± SD	p-value
Weight change (kg)	-7.7 ± 3.9	-1.7 ± 6.1	<0.01
Dietary adherence change	-1.0 ± 1.1	+0.1 ± 0.9	<0.05
Hunger perception change	-1.0 ± 1.1	+0.2 ± 1.3	<0.05
Total cholesterol (mmol/L)	-0.6 ± 0.8	+0.4 ± 0.6	0.01
C-peptide (ng/mL)	-1.5 ± 1.6	+0.4 ± 1.2	<0.05
Ghrelin	Not reported	Not reported	>0.05
Leptin	Not reported	Not reported	>0.05
Adiponectin	Not reported	Not reported	>0.05
CRP	Not reported	Not reported	>0.05
Glucose	Not reported	Not reported	>0.05

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Table 2 shows that, a significantly greater reduction in body weight in the T6 TENS + diet group compared with diet alone ($p < 0.01$). The intervention was also associated with significant improvements in dietary adherence, hunger perception, total cholesterol, and C-peptide. The reported data did not demonstrate significant between-group effects for ghrelin, leptin, adiponectin, CRP, or glucose.

Primary Outcomes

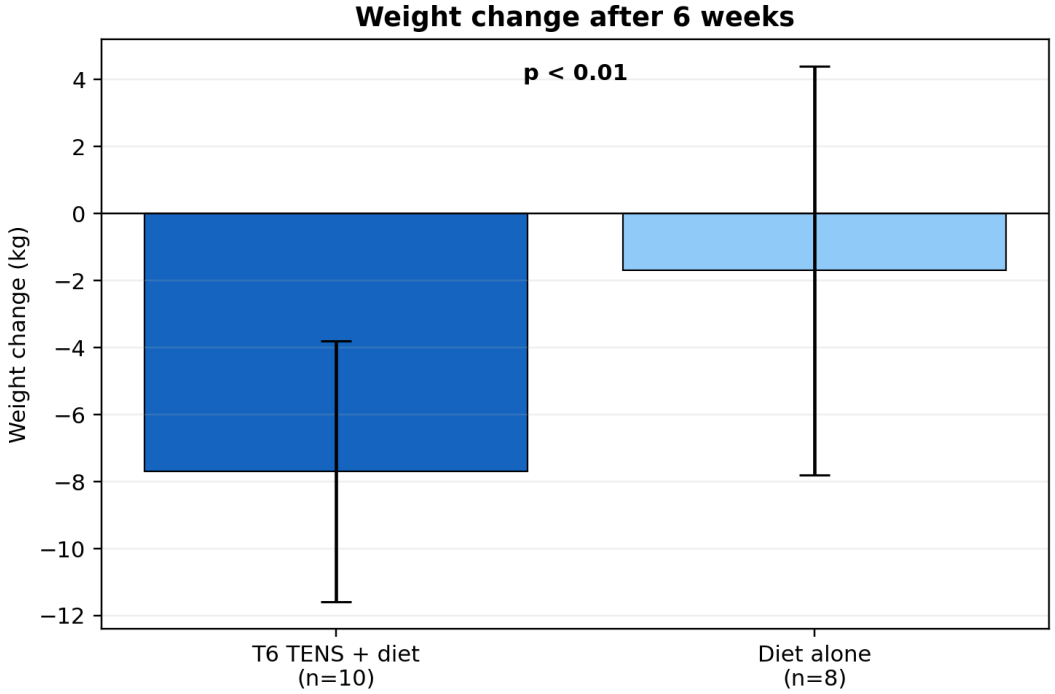


Figure 1: Mean weight change after 6 weeks. T6 TENS + diet: −7.7 ± 3.9 kg; diet alone: −1.7 ± 6.1 kg; $p < 0.01$.

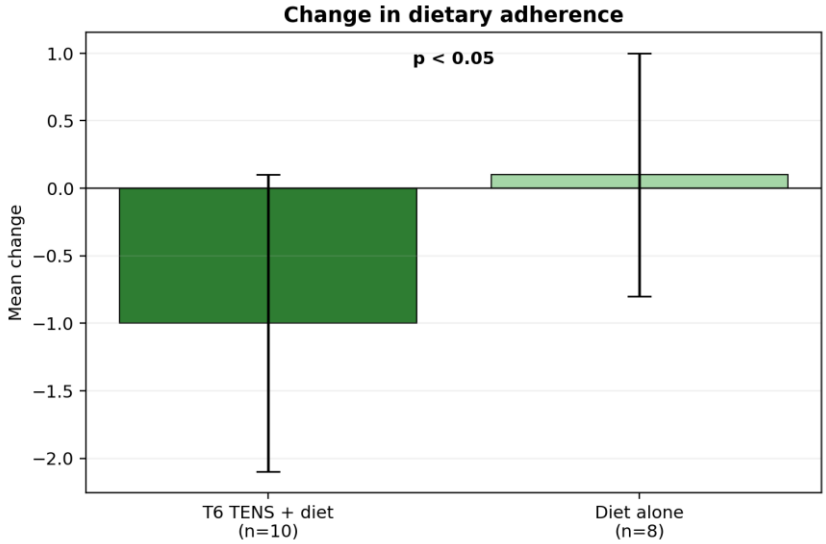


Figure 2: Change in dietary adherence. T6 TENS + diet: −1.0 ± 1.1; diet alone: +0.1 ± 0.9; *$p < 0.05$.*

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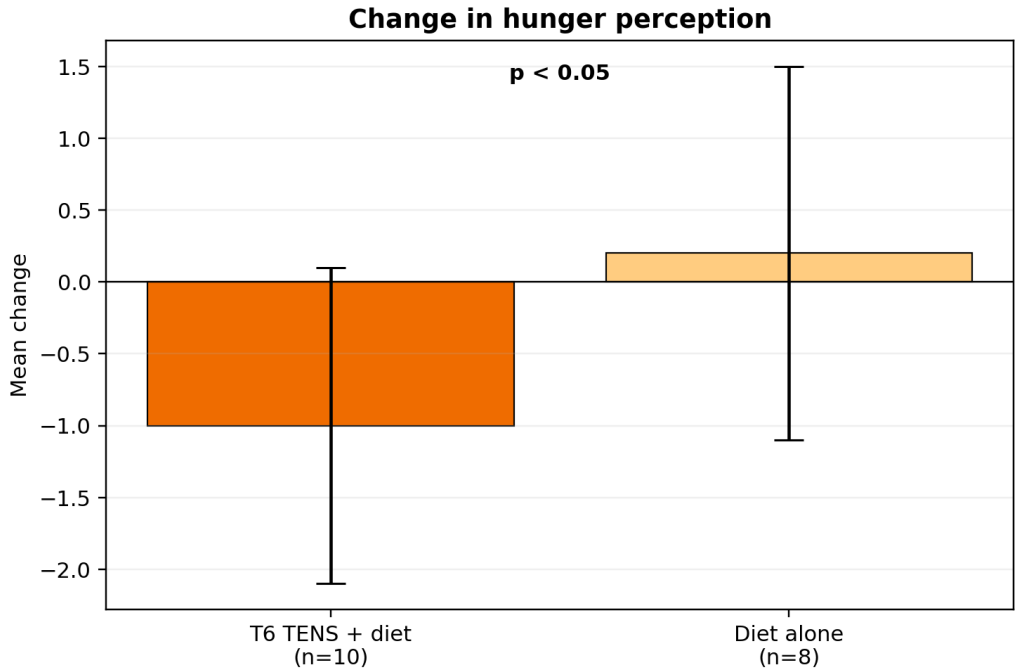
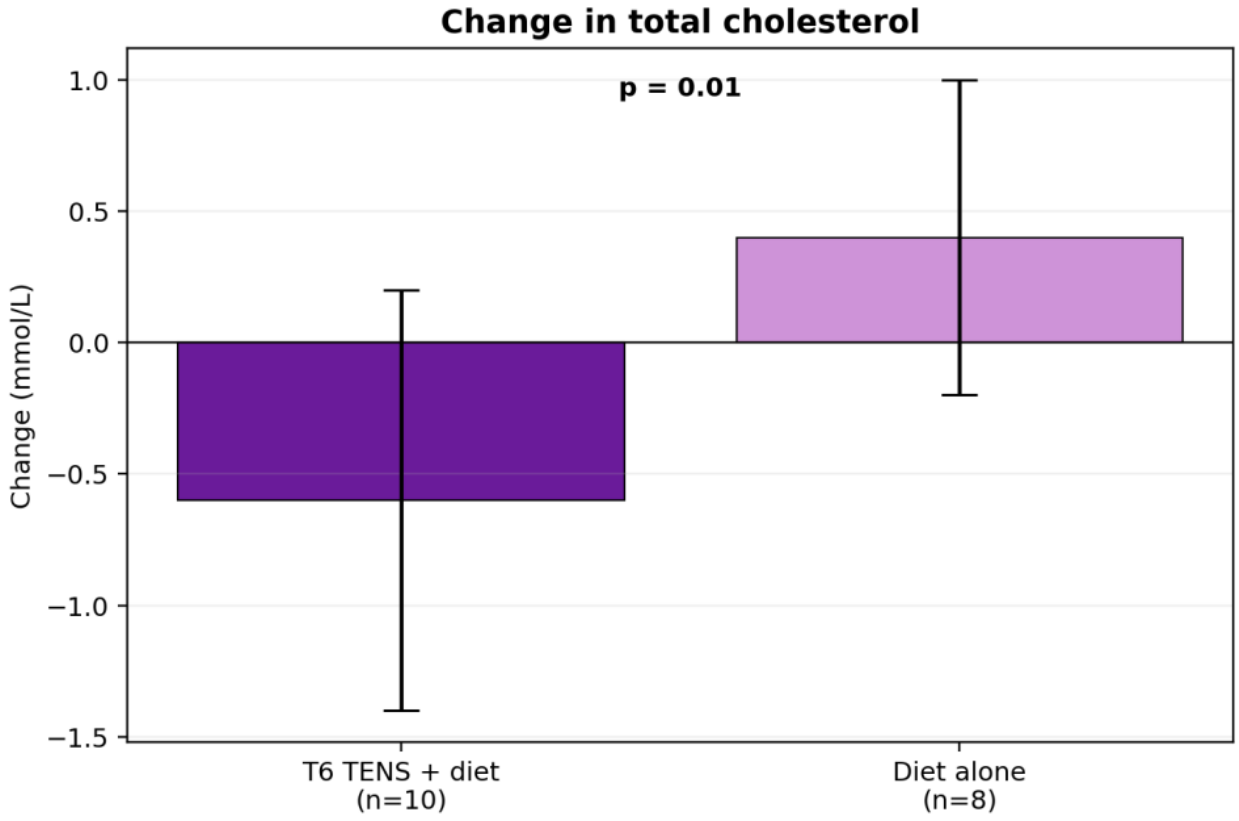


Figure 3: Change in hunger perception. T6 TENS + diet: −1.0 ± 1.1; diet alone: +0.2 ± 1.3; $p < 0.05$.

Secondary Outcomes



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Figure 4: Change in total cholesterol. T6 TENS + diet: −0.6 ± 0.8 mmol/L; diet alone: +0.4 ± 0.6 mmol/L; p = 0.01.

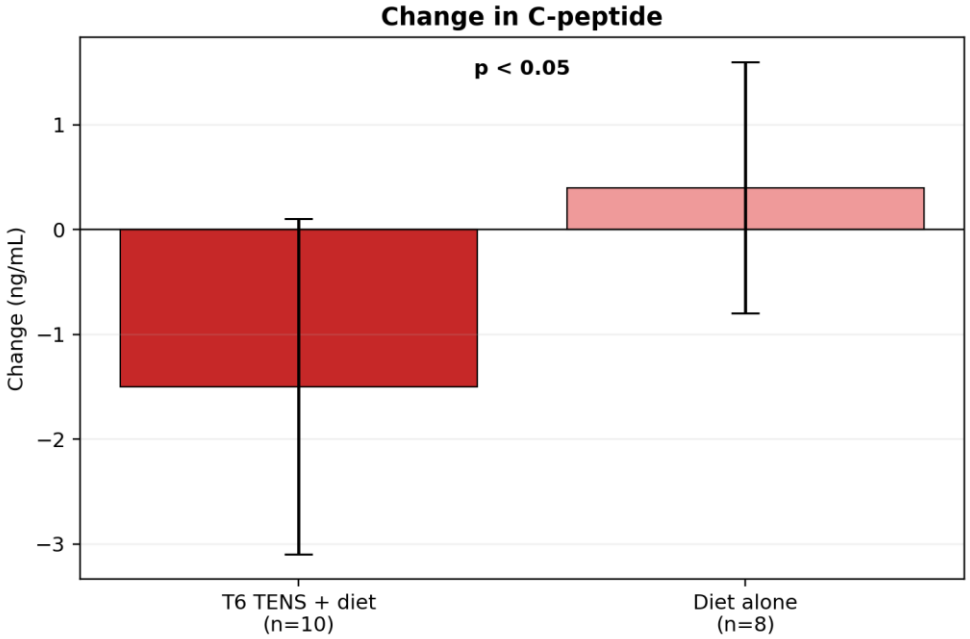


Figure 5: Change in C-peptide. T6 TENS + diet: −1.5 ± 1.6 ng/mL; diet alone: +0.4 ± 1.2 ng/mL; p < 0.05.

No significant differences were observed between groups for ghrelin, leptin, adiponectin, hs-CRP, or fasting glucose levels ($p > 0.05$).

Safety and Tolerability

No serious adverse events were reported. Mild skin irritation at the electrode site occurred in two participants (20%) in the intervention group, which resolved with electrode repositioning. All participants completed the 6-week protocol.

Discussion

This randomized controlled trial demonstrates that T6 dermatome TENS, when combined with a low calorie diet, significantly enhances weight loss and dietary adherence while reducing hunger perception in obese individuals. The 7.7 kg weight loss observed in the intervention group substantially exceeded the 1.7 kg loss in the control group, representing a clinically meaningful difference.

The mechanism appears to be primarily behavioural TENS reduced hunger, enabling participants to adhere more closely to the prescribed diet. This is consistent with the hypothesis that T6 stimulation modulates gastric afferent signaling, potentially alleviating the abdominal discomfort and hunger that commonly derail dietary efforts. The improved dietary adherence score in the intervention group supports this interpretation.

The association between T6 stimulation and reduced ghrelin levels has been previously suggested. While we did not observe significant changes in ghrelin, the reduction in C-peptide suggests improved insulin sensitivity, which may indirectly facilitate weight loss. The significant reduction in total cholesterol is also noteworthy, given the cardiovascular risk profile of obese patients.

Our findings align with those of (Ruiz-Tovar et al. 2017) who demonstrated that percutaneous electrical neurostimulation of T6 combined with a hypocaloric diet achieved greater weight loss, appetite reduction, and decreased ghrelin levels compared to diet alone. Similarly, Hutchinson et al. reported that T6 TENS improved dietary adherence, reduced hunger, and achieved greater weight loss (-7.7 kg vs -1.7 kg) in a 6-week RCT.

A systematic review by (Yu et al. 2024) concluded that while Low TENS demonstrates positive effects on metabolic parameters, its efficacy for obesity "is not yet clear" when compared to no

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intervention controls. Our findings contribute to the growing evidence base supporting TENS as an adjunctive therapy, though the modest sample size warrants cautious interpretation.

It is important to distinguish T6 TENS from other electrical stimulation approaches for weight management. A study by (Choi et al. 2018) examined electrical muscle stimulation (EMS) for abdominal obesity and found a mean 5.2 cm reduction in waist circumference over 12 weeks, compared to 2.9 cm with TENS. While both modalities show promise, EMS appears to exert direct effects on muscle and adipose tissue rather than central appetite modulation.

Clinical Significance

These findings suggest that T6 TENS may be a safe, non-pharmacological adjunct to dietary interventions for obesity. The improvement in dietary adherence is particularly relevant, as hunger is a primary barrier to successful weight loss. TENS may enable patients to sustain caloric restriction long enough to achieve clinically meaningful weight loss.

For clinicians, these results support recommending T6 TENS as a complementary tool within comprehensive weight management programs, rather than a standalone intervention. The high safety profile of TENS with only mild, transient skin irritation reported makes it an attractive option for patients who are reluctant to use pharmacotherapy or who have contraindications to weight loss medications.

Limitations

- The trial was terminated early with only 20 participants, limiting statistical power and generalizability.
- The 6-week follow up is insufficient to assess long-term weight maintenance.
- Participants were not blinded to treatment allocation, which may have influenced dietary adherence and hunger reporting.
- While a no-intervention control was used, a sham TENS group would strengthen causal inference.
- The lack of significant ghrelin changes suggests other pathways or insufficient power to detect them may be involved.

Future Research Directions

1. Larger, adequately powered RCTs with sham controls
2. Longer follow-up periods to assess weight maintenance
3. Investigation of optimal stimulation parameters (frequency, duration, site)
4. Mechanistic studies examining ghrelin, vagal signaling, and autonomic function
5. Comparison of T6 TENS with other neuromodulation approaches (e.g., transcutaneous vagus nerve stimulation)

Conclusion

This randomized controlled trial provides evidence that T6 dermatome TENS, as an adjunct to a low-calorie diet, significantly enhances weight loss, improves dietary adherence, and reduces hunger perception in obese individuals. The intervention was well-tolerated with no serious adverse events. And the observed weight loss (7.7 kg over 6 weeks) was clinically significant.

TENS appears to exert its effects primarily through appetite modulation and improved dietary compliance, rather than direct metabolic effects. These findings support T6 TENS as a safe, non-pharmacological adjunctive therapy for obesity management, particularly for patients who struggle with hunger during caloric restriction.

Conflict of interest: This study was conducted independently, without any financial or personal relationship that could influence the outcomes.

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