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Original Article

Adding thread-embedding acupuncture to auricular acupuncture enhances short-term weight reduction in overweight and obesity: A double-blinded, randomized, sham-controlled trial

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ABSTRACT

Background: Auricular acupuncture (AA) has been widely used in overweight and obesity management due to its safety and effectiveness. The combination of other acupuncture therapies with thread-embedding acupuncture (TEA) has shown enhanced effects. However, there is a lack of evidence regarding AA plus TEA for overweight and obesity. This study was conducted to address this question.

Methods: A randomized placebo-controlled trial was conducted involving 66 overweight or obese participants, divided into two groups: 33 received AA plus TEA, and 33 received AA plus sham TEA over eight weeks. The primary outcome was body weight (BW) reduction. Secondary outcomes included changes in body mass index (BMI) and waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), food cravings questionnaire-trait-reduced (FCQ-Tr) and food craving visual analog scale (VAS) scores. Safety outcomes were adverse events (AEs).

Results: After eight weeks, BW decreased by a mean (SD) of -4.45 (1.29) kg and -2.05 (1.33) kg in the AA plus TEA and AA plus sham TEA groups, respectively (MD [95 % CI]: 2.40 [1.75; 3.05]). BMI, WC, WHR, and food craving VAS score decreased significantly more in the AA plus TEA group than in the AA plus sham TEA group. No significant differences were found in FCQ-Tr and HC between groups. Seven AEs were recorded that were mild and resolved without treatment.

Conclusion: The addition of TEA to AA is a safe and effective management of overweight and obesity. Further studies should incorporate dietary and lifestyle modifications and follow-up after the intervention to assess long-term effectiveness.

Trial registration: The study protocol had been registered on ClinicalTrials.gov (NCT06091761).

1. Introduction

According to the World Health Organization (WHO), the prevalence of obesity is one in every eight individuals in 2022. This trend is rapidly escalating, estimating a doubling since 1990 for adults and a quadrupling for adolescents. In 2022, the rates of obesity and overweight among adults were 43 % and 16 % respectively, corresponding to approximately 2.5 billion and 890 million individuals.[1] If this trend remains unchecked, it is projected that by 2025, there will be 2.7 billion overweight adults and over 1 billion obese individuals.[2] The WHO Regional Office for the Western Pacific Region has proposed lower body mass index (BMI) thresholds for defining overweight and obesity in the Asia-Pacific region. According to these standards, overweight is defined as a BMI of 23–24.9 kg/m^2, while obesity is classified as a BMI of 25 kg/m^2 or higher.[3]

Overweight and obesity significantly contribute to the development of numerous chronic diseases, including cancer, diabetes, metabolic syndrome, cardiovascular diseases, mental disorders, sleep disorders, and musculoskeletal disorders, impacting the quality of life.[4-6] The primary strategy for tackling the obesity epidemic typically starts with lifestyle adjustments like diet and exercises. Nonetheless, this frequently leads to a slow decline in weight followed by subsequent regain.[7,8] While pharmaceuticals and bariatric surgery prove effective, they can be costly and may not be suitable for all, possibly resulting in complications.[2]

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In Traditional Medicine (TM), overweight and obesity are perceived as stemming from internal imbalances within the body, which include the buildup of dampness and phlegm. TM treatment methods include both herbal remedies and non-herbal approaches.[9] Numerous non-pharmacological interventions have been employed in the management of these conditions. Particularly, auricular acupuncture (AA) has been a widely used and established method for weight management, owing to its effectiveness, safety, and convenience for overweight and obese individuals.[10-12]

Recently, a novel therapy called thread-embedding acupuncture (TEA) has shown effectiveness in reducing weight, and even more so compared to classical acupuncture for simple obesity. Moreover, the treatment frequency of TEA is lower, with greater stimulation intensity, making it more conducive to clinical application.[13-15] Several studies have shown a substantial increase in treatment effectiveness when combining TEA with other acupuncture therapies including manual acupuncture, electroacupuncture, warming acupuncture, and fire needle.[16] However, there is currently only limited data available on the combination of TEA with AA.[17] This study was conducted to assess the efficacy and safety of combining TEA with AA compared with AA monotherapy for overweight and obesity.

2. Methods

2.1. Study design

This study was conducted as a randomized placebo-controlled trial, employing balanced randomization (1:1), patient-assessor blinded design, and parallel-group evaluation to assess the efficacy of weight reduction when combining TEA with AA (AA plus TEA group) compared to sham TEA combined with AA (AA plus sham TEA group) in overweight and obesity individuals. The research took place at the University Medical Center Ho Chi Minh City from October 2023 to March 2024.

The study adhered to the ethical principles outlined in the Declaration of Helsinki and the International Conference on Harmonization-Good Clinical Practice guidelines, as well as the Consolidated Standards of Reporting Trials (CONSORT) and the Standards for Reporting Interventions in Clinical Trials of Acupuncture (STRICTA) guidelines.[18] All participants had provided written informed consent before participating.

The study protocol had been registered on ClinicalTrials.gov (NCT06091761).

2.2. Participants

We recruited participants with overweight or obesity from the community through the use of social media. After meeting the inclusion and exclusion criteria, participants were invited to the University Medical Center Ho Chi Minh City to participate in the study.

Inclusion criteria comprised: (i) males and females aged 18–60 years; (ii) a diagnosis of overweight or obesity with a BMI of 23 kg/m^2 or higher, as per the guidelines of The WHO Regional Office for the Western Pacific Region;[3] (iii) waist circumference (WC) of 90 cm or higher for males, or 80 cm or higher for females.

The decision to include both BMI and WC criteria was based on their complementary insights into obesity-related risks. While BMI reflects overall adiposity, WC captures variations in fat distribution, especially visceral adiposity linked to metabolic disorders. Studies highlight WC's stronger association with metabolic abnormalities and cardiovascular risks compared to BMI alone, particularly in individuals with normal or overweight BMI but elevated WC.[19,20] Including both criteria ensures a comprehensive assessment of obesity status and metabolic risks in participants.

Exclusion criteria included: (i) secondary obesity resulting from endocrine diseases or medication; (ii) presence of severe medical conditions (e.g., cardiovascular, hepatic, renal or others) that could potentially affect treatment outcomes as per researchers' assessments; (iii) current use of weight-affecting medications, including diabetes medications, endocrine medications, and medications for neurological psychiatric disorders; (iv) pregnancy, lactation, or recent childbirth within the past 6 months; (v) severe mental and neurological conditions that may impact treatment compliance; (vi) alcohol or substance addiction; (vii) history of hypersensitivity reactions to any form of acupuncture with needles or to polydioxanone (PDO); (viii) existing injuries or lesions at the acupoints under investigation in this study; (ix) concurrent participation in other clinical trials or utilization of other weight reduction therapies.

2.3. Randomization and blinding

Eligible participants were randomly assigned in a 1:1 ratio into either the AA plus TEA group or the AA plus sham TEA group. Block randomization with a block size of six was prepared using SAS software version 9.4. The randomization codes were concealed using opaque sealed envelopes with ordered numbers before allocation. Eligible patients were allocated to receive either AA plus TEA or AA plus sham TEA according to the sequential order of recruitment.

Investigators, outcome assessors, and data analysts were blinded to the treatment group allocation. They each had distinct roles in this study. Investigators were responsible for designing the protocol, overseeing the study's execution, and monitoring its progress. Outcome assessors evaluated the study outcomes, while data analysts analyzed the collected data. Despite the use of a sham TEA in this trial, it is unlikely that the investigators could be fully blinded due to the characteristics of the sham device. However, they could ensure impartiality by concealing themselves from the allocation process. Participants were unaware of their random allocation to receive either TEA or sham TEA. The physician, responsible for administering TEA and sham TEA procedures, was aware of the group assignments, knowing which participants received TEA and which received sham TEA. However, the physician remained uninvolved in the evaluation of outcomes and subsequent data analysis.

2.4. Interventions

All participants were not required to change their usual diet and lifestyle throughout the intervention, with no restrictions on diet and physical activity. AA was conducted weekly for eight weeks using patches, each with a square shape and a side length of 10 mm, along with sterilized needles measuring 0.25 × 1.3 mm. Five acupoints on one ear were selected, including Shen-men (TF4), Stomach (CO4), Spleen (CO13), Endocrine (CO18), and the Hunger points. The location of the acupoints was determined according to the World Federation of Acupuncture-Moxibustion Societies' standards (**Supplement 1-A**).[21] The patch with the needle will remain in place for one week, with a different ear chosen each week for its application, alternating between weeks.

In the AA plus TEA group, TEA was performed every two weeks over eight weeks, totaling four sessions, using a single PDO thread. Needles with a gauge size of 29 G, a shaft length of 38 mm, and a thread length of 50 mm, folded in half, were applied to ten acupoints, including Qihai (CV6), Shuifen (CV9), Tianshu (ST25), Shuidao (ST28), Daheng (SP15), and Siman (KI14) on both sides of the body. Additionally, needles with a gauge size of 30 G, a shaft length of 25 mm, and a thread length of 30 mm, folded in half, were used for five acupoints, including Zhongwan (CV12), Zusanli (ST36), and Pishu (BL20) on both sides of the body. The location of the acupoints was determined according to the WHO standards (**Supplement 1-B**).[22] First, the acupoints were marked using a surgical marker, and local anesthesia was administered using lidocaine 10% spray. After five minutes, the sites were disinfected with an alcoholic povidone-iodine solution, and TEA was performed. The needle was inserted perpendicularly into the acupoint to a depth of 2 to 5 cm,

depending on the body area. Subsequently, the thread was pushed into the body, and the needle was withdrawn immediately.

In the AA plus sham TEA group, sham TEA was administered in a manner similar to TEA, but with needles without threads, ensuring that no threads were left at the acupoints after the procedure (**Supplement 1-C**).

The AA and TEA procedures were each performed by a physician with corresponding experience of over 5 years.

2.5. Outcomes

The primary outcome, changes in body weight (BW) (kg), was collected by investigators in the morning after the participants' personal hygiene routine and before breakfast.

The secondary outcomes included changes in BMI (kg/m^2), changes in WC (cm) and hip circumference (HC) (cm), waist-hip ratio (WHR), food cravings questionnaire-trait-reduced (FCQ-Tr) score, food craving visual analog scale (VAS) score, and safety. WC and HC were measured similarly to BW and conducted in accordance with the protocol established by the WHO.[23] The FCQ-Tr consists of 15 items, with participants requested to express their agreement using a Likert-type scale ranging from 1 = "strongly disagree" to 5 = "strongly agree", resulting in total scores within the range of 15–75, where higher scores indicate greater food craving.[24,25] The food craving VAS score consisted of a 100 mm long line with two endpoints, ranging from "no food craving" to "greatest food craving ever experienced", with total scores ranging from 0 to 100.[26,27] Participants indicated their current level of food craving by marking their position on the scale.

The safety outcome was assessed based on adverse events (AEs) related to TEA and AA. Expected AEs for AA included pain at the insertion site, local discomfort, local skin irritation (itching and redness), local inflammation and bleeding, chondritis, dizziness, nausea, and hypersensitivity reactions.[12] For TEA, expected adverse events (AEs) included local discomfort, post-treatment elevation in body temperature, ecchymosis, local swelling, local induration, local pain, local redness, infection, abscess, pruritus, and anaphylaxis.[28,29] Additionally, any unexpected AEs associated with these procedures were also documented and monitored.

All outcomes were monitored weekly over the 8-week intervention period, except for AEs, which were monitored and recorded as needed.

2.6. Sample size calculation

The sample size was determined to detect treatment effect differences with a type-1 error of 0.01 and a type-2 error of 0.2, based on the primary outcome. According to previous research, AA reduced the mean BW by approximately 2.5 kg over 8–12 weeks, while TEA reduced it by around 1.7 kg over an average treatment period of eight weeks.[30-32] Combining AA and TEA was expected to reduce the mean BW by at least 4.2 kg. With the predicted standard deviation (SD) being half the mean, the required sample size was 25 in each group. A sample size of 33 in each group was required to account for a dropout rate of 25 %.

2.7. Statistical analysis

All efficacy analyses were conducted using an intention-to-treat (ITT) dataset. All outcomes except AEs were presented as mean and standard deviation (SD), and compared between the two groups using the Student's *t*-test. The rates of AEs were presented as frequencies and percentages, and compared between the two groups using the Fisher's exact test. The comparison between groups for binary outcomes was expressed by risk ratio (RR) and 95 % confidence interval (CI), while for numeric outcomes, it was expressed by mean difference (MD) and 95 % CI after eight weeks of treatments. The analyses were performed using the statistical software R version 4.3.3, with a significance level set at 0.05.

3. Results

From October 2023 to March 2024, among the 78 screened participants, 12 were considered ineligible for randomization. Subsequently, 66 participants were randomized into the AA plus TEA (33 participants) and AA plus sham TEA groups (33 participants). One participant from the AA plus sham TEA group dropped out (**Supplement 2**).

3.1. Sample characteristics

The baseline demographic and clinical characteristics of the randomized participants are presented in Table 1. The majority of participants were female, with an average age of 25, predominantly engaged in mental labor. The average BW was around 77 kg, with BMI of 28.2 and 29.1 in the AA plus TEA and AA plus sham TEA groups respectively. The majority were classified as obesity. Overall, the baseline characteristics were evenly distributed between the two groups.

3.2. Primary outcome

BW consistently decreased in both groups throughout the intervention period. Despite a non-significant difference between both groups after eight weeks (**Supplement 3**), a significantly greater weight reduction was observed in the AA plus TEA group compared to the AA plus sham TEA group as early as one week into the intervention (Fig. 1). After eight weeks, compared to baseline, BW had decreased by mean (SD) of −4.45 (1.29) and −2.05 (1.33) in the AA plus TEA and AA plus sham TEA groups, respectively (MD [95 % CI] was 2.40 [1.75; 3.05]) (Table 2).

3.3. Secondary outcomes

BMI and WC also demonstrated continuous reductions. Although WC in the AA plus TEA group was non-significantly lower compared to the AA plus sham TEA group after eight weeks (**Supplement 3**), significantly greater reductions in both were observed in the AA plus TEA group (Fig. 2**-A, B**). After eight weeks, the MD (95 % CI) in BMI and WC reduction between the AA plus TEA and AA plus sham TEA groups were 0.85 (0.61; 1.09) and 3.97 (3.14; 4.80), respectively (Table 2).

HC showed a transient, slightly better reduction in the AA plus TEA group at one week post-intervention, but remained largely unchanged in both groups overall (Fig. 2**-C,** Table 2). Therefore, WHR exhibited a significantly greater reduction in the AA plus TEA group after five weeks into the treatment (MD [95 % CI] was 0.04 [0.02; 0.07] at the endpoint) (Fig. 2**-D,** Table 2).

FCQ-Tr and food craving VAS scores decreased continuously throughout the intervention period in both groups. However, only the food craving VAS score showed a significant difference between the two groups, with a better reduction observed in the AA plus TEA group (MD [95 % CI] was 21.6 [14.1; 29.2] at the endpoint) (Fig. 2**-E, F,** Table 2).

A total of seven AEs were recorded. Among these, one case experienced ecchymosis following TEA at the Siman acupoint, resolved after two weeks. The remaining six cases experienced skin irritation at AA acupoints, resolved after the adhesive tape was removed. All reported AEs were mild, resolved spontaneously without the need for treatment, and there were no lasting sequelae (Table 2).

3.4. Subgroup analysis

Following subgroup analysis according to the BMI classification, similar results were observed in the obesity class 1 subgroup after eight weeks of treatment. Meanwhile, in the obesity class 2 subgroup, a non-significant difference in WHR was noted between the two groups. In the overweight subgroup, a significantly better BMI reduction in the AA plus TEA group was observed, although with small sample sizes, 5 and 2 respectively in the AA plus TEA and AA plus sham TEA groups (**Supplement 4**).

Table 1
Sample characteristics.

Characteristics	AA plus TEA (n = 33)	AA plus sham TEA (n = 33)
Sex, female	18 (54.5 %)	20 (60.6 %)
Age (years)	25.9 (4.13)	25.0 (6.32)
Occupation		
- Manual labor	1 (3.0 %)	2 (6.0 %)
- Mental labor	32 (96.9 %)	31 (93.9 %)
Physical activity†	14 (42.4 %)	12 (36.3 %)
Alcohol consumption	17 (51.5 %)	14 (42.4 %)
Hobby of eating sweets	31 (93.9 %)	31 (93.9 %)
Hobby of eating fatty foods	28 (84.8 %)	27 (81.8 %)
BW (kg)	76.8 (14.5)	76.6 (10.1)
Height (m)	1.64 (0.09)	1.62 (0.10)
BMI (kg/m^2)	28.2 (3.12)	29.1 (3.10)
BMI classification‡		
- Overweight (23,0–24,9 kg/m^2)	5 (15.1 %)	2 (6.0 %)
- Obesity class 1 (25,0–29,9 kg/m^2)	19 (57.5 %)	20 (60.6 %)
- Obesity class 2 (≥ 30,0 kg/m^2)	9 (27.2 %)	11 (33.3 %)
WC (cm)	89.7 (11.8)	90.4 (10.3)
HC (cm)	96.1 (12.9)	96.6 (11.8)
WHR	0.93 (0.06)	0.93 (0.05)
FCQ-Tr score	46.0 (13.9)	44.7 (16.0)
Food craving VAS score	84.8 (8.23)	86.4 (8.97)

Summary statistics are mean (standard deviation) and n (%).

† Physical activity for at least 30 min every day and at least 5 times per week.

‡ According to the standards of The WHO Regional Office for the Western Pacific RegionAA, auricular acupuncture; BMI, body mass index; BW, body weight; FCQ-Tr, food cravings questionnaire-trait-reduced; HC, hip circumference; SD, standard deviation; TEA, thread-embedding acupuncture; VAS, visual analog scale; WC, waist circumference; WHR, waist-hip ratio.

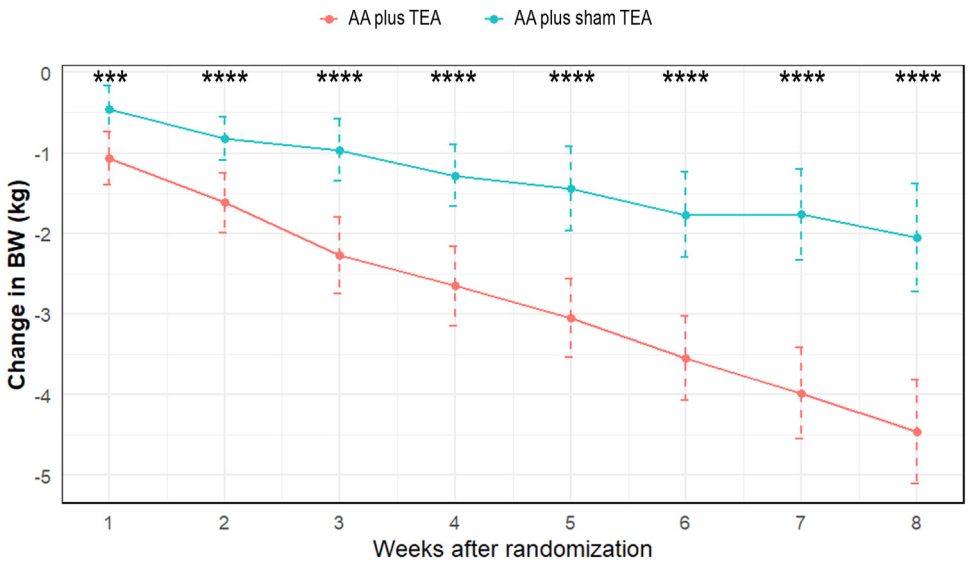

Fig. 1. Change in body weight. *** $p < 0.001$.
****$p < 0.0001$; comparison between the two groups using the Student's t-test. Points represent mean and whiskers represent standard deviation. AA, auricular acupuncture; BW, body weight; TEA, thread-embedding acupuncture.

4. Discussion

The results indicated that adding TEA to AA enhanced the efficacy of BW reduction and improved BMI in overweight or obese individuals. Other related indices including WC, WHR, and subjective perception of food craving also showed better reductions in the group receiving additional TEA. This study demonstrated a good safety profile of TEA combined with AA in overweight or obese individuals.

Current evidence suggests significant benefits of acupuncture in managing overweight and obesity, including manual acupuncture, electroacupuncture, AA, and TEA.[33,34] However, the frequent repetition of manual acupuncture and electroacupuncture is often dense, typically daily or every other day. This clinically indicates that patients often hesitate to choose them unless absolutely necessary. In contrast, AA and TEA require less frequent administration, typically once every 1–2 weeks. AA, using adhesive patches, can retain needles for a longer period, while TEA utilizes self-absorbing threads that can remain in acupoint locations for extended durations. AA and TEA have been demonstrated to be even more effective than other acupuncture methods.[14,15,31,34] Additionally, they have demonstrated safety.[12,35,36] Therefore, AA and TEA are promising approaches for managing overweight and obese individuals. One commonly observed practice is the combination of acupuncture methods with different principles of selecting acupoints to enhance treatment efficacy. TEA follows similar acupoint selection principles to

Table 2
Primary and secondary outcomes after eight weeks of treatments.

	AA plus TEA (n = 33)	AA plus sham TEA (n = 33)	MD/RR (95 % CI)	p
Change in BW (kg)	−4.45 (1.29)	−2.05 (1.33)	2.40 (1.75; 3.05)†	<0.0001
Change in BMI (kg/m^2)	−1.64 (0.43)	−0.78 (0.52)	0.85 (0.61; 1.09)†	<0.0001
Change in WC (cm)	−6.57 (2.18)	−2.60 (0.91)	3.97 (3.14; 4.80)†	<0.0001
Change in HC (cm)	−0.39 (0.24)	−0.41 (0.21)	−0.02 (−0.13; 0.09)†	0.7080
WHR	0.87 (0.05)	0.91 (0.05)	0.04 (0.01; 0.07)†	0.0015
FCQ-Tr score	26.0 (10.5)	27.4 (11.7)	1.34 (−4.17; 6.87)†	0.6279
Food craving VAS score	38.3 (10.9)	60.0 (18.3)	21.6 (14.1; 29.2)†	<0.0001
AEs	3 (9.0 %)	4 (12.1 %)	0.75 (0.18; 3.09)‡	0.6893
- Ecchymosis in TEA	1 (3.0 %)	0 (0 %)	–	0.3136
- Skin irritation in AA	2 (6.1 %)	4 (12.1 %)	0.50 (0.09; 2.54)‡	0.3918

Summary statistics are mean (standard deviation) and n (%).
*comparison between the two groups using the Fisher's exact test for AEs and the Student's t-test for the other variables.
† presented as mean difference.
‡ presented as risk ratioAA, auricular acupuncture; AE, adverse event; BMI, body mass index; BW, body weight; CI, confidence interval; FCQ-Tr, food cravings questionnaire-trait-reduced; HC, hip circumference; MD, mean difference; RR, risk ratio; TEA, thread-embedding acupuncture; VAS, visual analog scale; WC, waist circumference; WHR, waist-hip ratio.

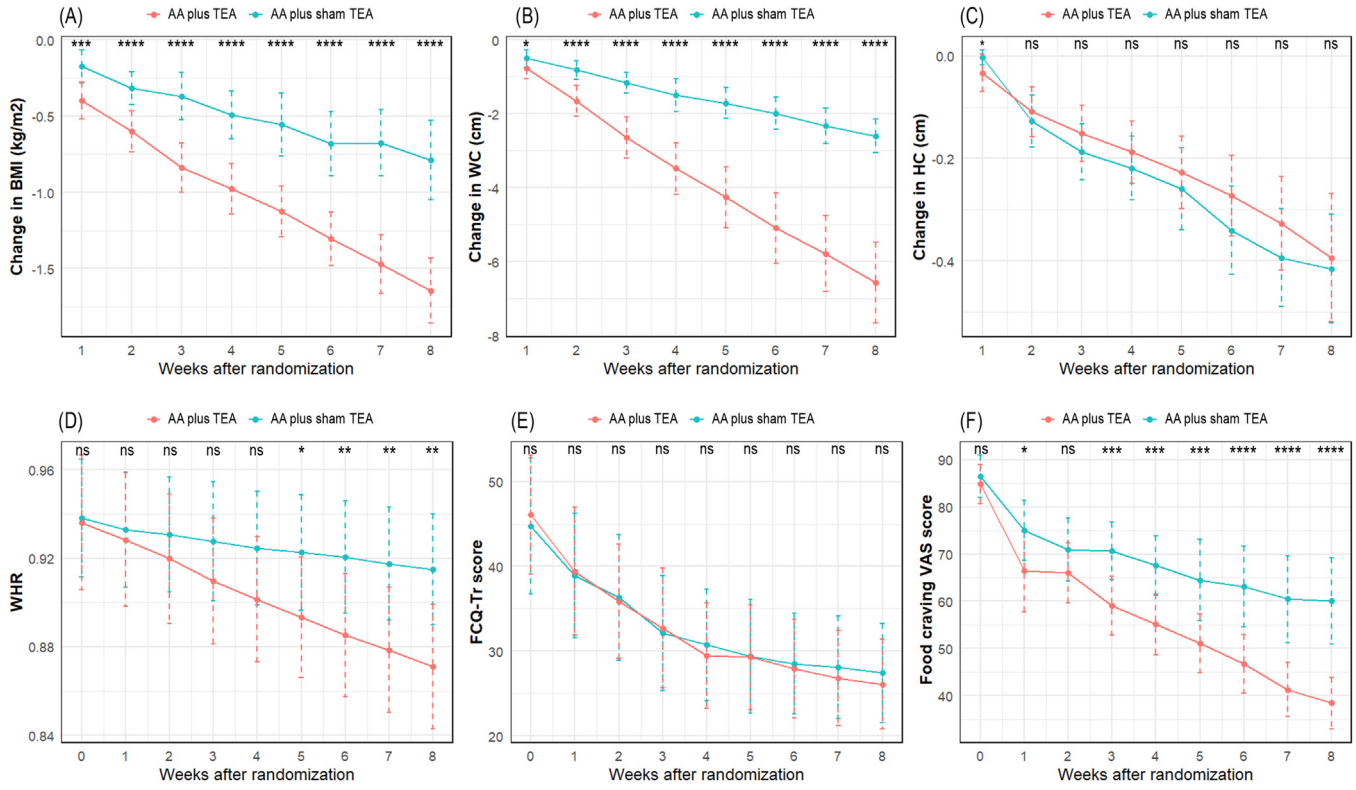

Fig. 2. Secondary outcomes.
ns, non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$; comparison between the two groups using the Student's t-test. Points represent mean and whiskers represent standard deviation. AA, auricular acupuncture; BMI, body mass index; FCQ-Tr, food cravings questionnaire-trait-reduced; HC, hip circumference; TEA, thread-embedding acupuncture; VAS, visual analog scale; WC, waist circumference; WHR, waist-hip ratio.

body acupuncture methods, while AA selects acupoints on the outer ear. An interesting aspect is that the combination of TEA and AA in managing overweight and obesity in intervention studies is still limited. The findings support AA combined with TEA, resulting in increased treatment efficacy compared to AA alone, similar to the trend observed with other acupuncture therapies combined with TEA.[16]

In TM, excess fat accumulation is often attributed to stagnation of phlegm and dampness, which are primarily linked to qi deficiency and abnormalities in the transformation processes of the Spleen and Stomach.[9,37] Therefore, for TEA in this study, acupoints were selected to tonify qi (Qihai), eliminate phlegm and dampness accumulation (Shuifen, Tianshu, Shuidao, Daheng, Siman), and enhance the function of the Spleen and Stomach (Zhongwan, Pishu, Zusanli), which is quite similar to previous studies.[14,37-39] For AA, acupoints related to the Stomach and Spleen were also chosen, along with specific points like Endocrine and Hunger points, and Shen-men was considered a common point in AA.[40,41] In Western medicine, acupuncture primarily reduces serum leptin levels, which helps control appetite cravings. Leptin communicates fat storage information to the hypothalamus, regulating the sensation of fullness. Excessive serum leptin levels can make the hypothalamus resistant to leptin signals, disrupting the feeling of fullness after meals and leading to increased calorie consumption.[42]

An interesting observation from studies using acupuncture for weight management is the lack of reports indicating participants experiencing excessive weight loss or appetite suppression leading to depletion. It is possible that studies may have ended before such occurrences or that they simply never happened. The general principle of TM treatment aims to restore balance to the human body, with acupuncture believed to have bidirectional regulatory effects, restoring homeostatic values of body systems.[43] Therefore, there is reason to believe that acupuncture can bring the body back to a normal weight and normalize appetite rather than continuously leading to depletion. However, clinical evidence supporting this notion is still lacking.

This study has several limitations. These include the applicability of the results to different age groups, as the participants in this study were predominantly young. Additionally, the study did not follow up after intervention, leaving the duration of the maintenance of effectiveness unknown. The lack of mid-term and long-term follow-up data is another limitation of this study, preventing us from assessing the sustainability of the intervention's effectiveness over an extended period. Dietary and exercise regimens that adhere more closely to scientific standards could produce more effective treatment outcomes. However, to better meet the participants' needs, their dietary and lifestyle choices were not restricted. In calculating the sample size, the study assumed a zero effect for sham TEA, potentially resulting in an overestimation of the expected mean difference and therefore underestimating the necessary number of participants.

In conclusion, the addition of TEA to AA demonstrates superiority in reducing BW, BMI, WC, WHR, food cravings, and safety in overweight and obese individuals. Further studies should integrate dietary and lifestyle modifications and include follow-up after the intervention to assess long-term effectiveness.

Declaration of competing interest

The authors have no conflict of interest to declare.

CRediT authorship contribution statement

Dieu-Thuong Thi Trinh: Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – review & editing, Supervision, Project administration. **Quoc-Viet Kieu:** Conceptualization, Methodology, Validation, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Project administration. **An Hoa Tran:** Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Minh-Man Pham Bui:** Investigation, Writing – review & editing. **Nguyen Lam Vuong:** Software, Formal analysis, Writing – review & editing, Visualization.

Data availability

The data that support the findings of this study are available from the corresponding authors, upon reasonable request.

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None.

Ethical statement

This research was reviewed and approved by the institutional review board of the University of Medicine and Pharmacy at Ho Chi Minh City (No. 700/HĐĐĐ-ĐHYD, dated July 27, 2023). Informed consent was obtained from all participants.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.imr.2024.101050.

Supplement 1.
Supplement 2.
Supplement 3.
Supplement 4.

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