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• LETTER •
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Electroacupuncture reduces posterior cingulate cortex activation and functional connectivity during food cue stimulation in overweight/obese subjects

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Dear editor,

Obesity is a pervasive public health issue involving excessive adiposity or body fat, and causes metabolic diseases including insulin resistance, type 2 diabetes mellitus, high blood pressure and heart disease [1]. Among the anti-obesity interventions, electroacupuncture (EA) is regarded as the safest and most effective alternative treatment for curing obesity [2], although neurological mechanisms of acupuncture in the reduction of body mass index (BMI) are not very clear. In this study, functional magnetic resonance imaging (fMRI) and a food picture stimulation paradigm, with a generalized psychophysiological interaction (gPPI) analysis [3] are employed to determine the changes in stimuli-induced neural activation/connectivity between two groups comprising overweight/obese subjects who underwent a weight-loss EA program and Sham stimulation. We propose a hypothesis that the mechanism of acupuncture in reduction of BMI and appetite might be related to the modulation of EA on brain activation/connectivity in areas associated with cognitive regulation and self-referential processing (posterior cingulate cortex, PCC).

Forty-six overweight/obese subjects are sampled and randomly allocated to the EA ($n = 27$) or Sham ($n = 19$) groups. All the subjects complete the food-cue reactivity MRI scan at the baseline and after one course of treatment (6–8 weeks). The food picture stimulation task has 3 conditions for a randomized sequence of "high calorie (HC) food-low calorie (LC) food-neutral (NC) cues". All the subjects provide written informed consents. Participants suffering from depression/anxiety are rated using the ZUNG self-rating depressive scale (SDS) and ZUNG self-rating anxiety scale (SAS). All are required to complete the dutch-eating-behavior-questionnaire (DEBQ) and the three-factor-eating-questionnaire (TFEQ). Following the initial and final treatments, real and Sham acupuncture-induced sensations are assessed with the Massachusetts-General-Hospital (MGH) Acupuncture-Sensation-Scale (MASS) [4] that is invented at the MGH [5]. A visual analog scale (0–100) is used to assess participants' level of craving for HC and LC food after the food-cue reactivity experiment.

After the treatment, ANOVA analysis shows group × time effects on weight, BMI, waist circumference (WC), and craving for HC food ($P < 0.05$). Post-hoc tests show significant reduction

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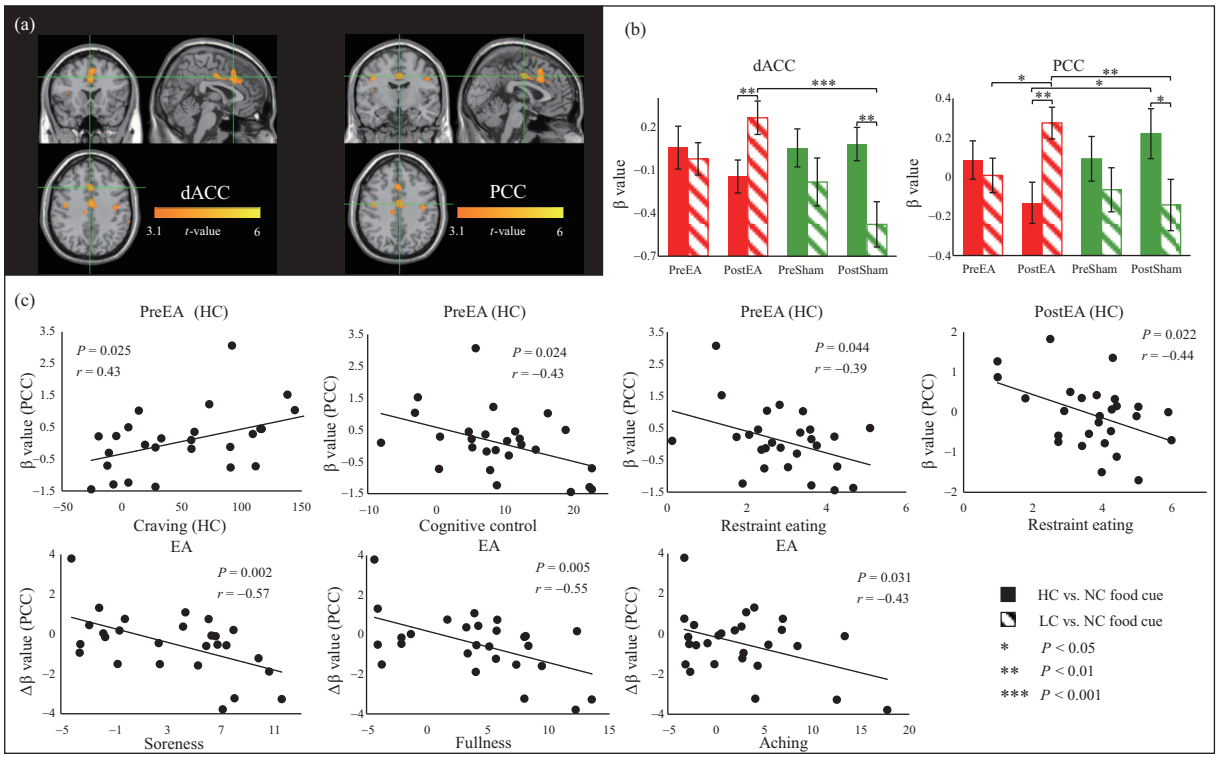

Figure 1 (Color online) Whole brain ANOVAs for brain responses to food cues. (a) Interaction effects (group × condition); (b) post-hoc tests; (c) correlation analysis.

in weight, BMI, and WC in both EA and Sham groups post-treatment ($P < 0.05$), and EA group has a larger decrease in BMI ($P < 0.001$) and percent excess-weight-loss ($P < 0.001$) than the Sham group. Group × condition effects on neural activations are in the dorsal-anterior-cingulate-cortex (dACC) and PCC (Figure 1(a)) owing to significant reduction in neural responses to HC relative to LC food stimuli in the EA group after treatment (Figure 1(b)). At baseline, PCC activation in response to HC has a positive correlation with HC food craving ($r = 0.43$, $P = 0.025$) and a negative correlation with cognitive control ($r = -0.43$, $P = 0.024$, Figure 1(c)). Additionally, changes in activation of the PCC with respect to HC relative to LC food stimuli have a negative correlation with *De*-qi sensation, including soreness ($r = -0.57$, $P = 0.002$), fullness ($r = -0.55$, $P = 0.005$) and aching ($r = -0.43$, $P = 0.031$, Figure 1(c)).

PCC is involved in self-referential processing linked with food ingestion and weight gain [6]. Kullmann et al. [7] reported increased functional connectivity in the PCC in obese individuals. A positive correlation between brain responses to HC in the PCC and craving for HC food at baseline suggested activation of the PCC may be related to heightened attention to HC food stimuli and enhanced urges to ingest food [8]. Additionally, the reduced PCC responses to HC relative to LC food stimuli and the reduced PCC-postcentral gPPI connectivity following EA treatment and negative correlations between brain activation in the PCC and restraint eating at both baseline and following EA treatment are found, suggesting the association between EA-induced changes in PCC activation/functional connectivity and improvement in eating behaviors. Notably, alterations in PCC activity in response to HC relative to LC food stimuli are associated with *De*-qi sensation. Significantly reduced neural responses to HC relative to LC food stimuli in the dACC are also observed in the EA group. These results may delineate the neural mechanism of EA in reducing BMI and appetite which might be related to the modulation of EA on brain activation/connectivity in the PCC.

Compliance and ethics The experiment is approved by the Institutional Review Board of Xi'an Traditional Chinese Medicine Hospital, and is performed according to the Declaration of Helsinki.

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Supporting information Appendixes A–C. The supporting information is available online at info.scichina.com and link.springer.com. The supporting materials are published as submitted, without typesetting or editing. The responsibility for scientific accuracy and content remains entirely with the authors.

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