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The effect of high-intensity interval training on inhibitory function in overweight female college students: the mediating role of body composition

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Abstract

Objective To explore the inhibitory function characteristics of overweight female college students through two studies, and on this basis, to explore the effects of high-intensity interval training (HIIT) intervention on the inhibitory function of overweight female college students, as well as to test the mediating role of body composition.

Methods Study I recruited 34 overweight female college students and 38 normal-weight female college students, using the GO/NOGO task and the Flanker task to measure the participants' response inhibition and interference inhibition. Study II randomly divided the recruited 64 overweight female college students into an experimental group (n = 32) and a control group (n = 32), with the experimental group undergoing 8 weeks of Tabata-based HIIT and the control group not engaging in any form of exercise. The body composition of the participants was measured using a bioelectrical impedance body composition analyzer made in South Korea, the GAIA KIKO. Based on the SPSS 21.0 software, statistical techniques such as independent sample t-tests, Pearson correlation analysis, and mediation effect tests were used for analysis.

Results The reaction times of overweight female college students were significantly shorter than those of normal-weight female college students under the GO stimulus, consistent conditions, and inconsistent conditions ($P < 0.05$). 8 weeks of HIIT could effectively reduce the reaction times of overweight female college students under the GO stimulus, consistent conditions, and inconsistent conditions ($P < 0.05$), and effectively improve BMI, fat-free weight, fat content, muscle content, and basal metabolic rate ($P < 0.05$). There was a significant positive correlation between fat content and reaction times under the GO stimulus, consistent conditions, and inconsistent conditions ($P < 0.05$), and a significant negative correlation between waist-hip ratio and reaction times under the GO stimulus ($P < 0.05$). In addition, the mediation effect test found that fat content had a significant mediating effect in the reaction times under the consistent conditions after HIIT intervention ($P < 0.01$).

Conclusion Overweight female college students have poorer inhibitory function, and HIIT can effectively improve their inhibitory function, with fat content playing a potential mediating role in the intervention process. It is recommended that HIIT be used as an important means to control the weight of overweight female college students and improve their inhibitory function.

Keywords High-intensity interval training, Inhibition, Overweight, Body composition, Female college students

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Introduction

Inhibition function refers to an individual's ability to suppress their own dominant responses. Depending on the content of the inhibition, inhibition function can be divided into response inhibition and interference inhibition, which respectively represent the inhibition of responses (stimulus-response mapping) and the cognitive level (control of interference in extraction and processing) [1]. Inhibition function is a core component of executive function and is also known as the narrow sense of executive function. Almost all executive processes involve inhibition control, and its external performance is mainly associated with the activation of the dorsolateral prefrontal cortex, bilateral postcentral gyrus, left middle temporal gyrus, and right superior temporal gyrus [2]. Individuals with stronger inhibition function can better control their attention, behavior, thoughts, and emotions, transcend strong internal and external inducements, and then turn to things that are more needed or more suitable; on the contrary, they are prone to be interfered by old thoughts or bad habits, resulting in more impulsive behavior [3].

Obesity and overweight are a global epidemic and the biggest threat to public health in the 21st century [4]. Not only do overweight and obesity increase the risk of individuals suffering from cardiovascular diseases such as hypertension, hyperlipidemia, and coronary heart disease [5], but they also cause cognitive decline [6] and induce neurodegenerative diseases [7]. Overweight individuals have reduced self-control over specific food responses, which are likely to lead to impulsive food consumption and diet, and over time, this will lead to a decline in the performance of inhibition function tasks [8, 9]. Although some studies has confirmed that overweight individuals have a decline in the performance of inhibition function tasks, there is a relative lack of discussion on overweight women. In addition, some studies [10, 11] have found that there are gender differences in the behavioral performance of inhibition function, and women are more affected by irrelevant information in the Flanker and Stroop tasks. Given that women are more easily influenced by spatial cue stimuli and tend to selectively pay attention to delicious food in the real world, this lower self-control over food will lead to overweight and obesity, and further cause a decline in the performance of inhibition function tasks. Based on this, this study preliminarily explores the differences in inhibition function between overweight and normal female college students and proposes the research hypothesis H1: The performance of overweight female college students in inhibition function tasks is lower than that of normal female college students.

Exercise is an important means to improve brain cognition. A large number of studies have shown that exercise has a positive intervention effect on the improvement of inhibition function in children [12], adolescents [13], the elderly [14], overweight and obese people [15], depression [16], and cognitive dysfunction [17]. In addition, according to the type of exercise intervention, aerobic exercise [12, 16], resistance exercise [18, 19], and high-intensity interval training (HIIT) [13, 20] have all shown positive intervention effects on the improvement of inhibition function. Although there is still controversy about the effects of the above types of exercise on promoting the improvement of inhibition function, such as Wang et al. [14] and Yang et al. [21] show that the intervention effect of moderate-intensity aerobic exercise and resistance exercise on inhibition function is better than that of HIIT; while Quintero et al. [22] show that the intervention effect of HIIT on cognitive inhibition in overweight men is better than progressive resistance training, but HIIT has been proven to be a feasible and effective strategy for promoting the physical and mental health of young people [23]. Because HIIT for a short time can produce physiological adaptation comparable to long-term aerobic exercise [24], it has attracted more and more attention from researchers. Although there is no direct evidence that HIIT can promote the benefits of inhibition function in overweight female college students, based on the positive benefits of HIIT intervention in children and adolescents' inhibition function [13, 25], this study proposes the research hypothesis H2: High-intensity interval training can effectively improve the inhibition function of overweight female college students.

Body composition refers to the proportion of fat tissue and non-fat tissue in the body weight. Although some studies [26, 27] also show that there is no correlation or even a positive correlation between overweight and obesity, body mass index (BMI) and the cognitive function of the participants, more studies show a negative correlation between the two. Overweight and obesity are important risk factors for causing various complications and are associated with neurocognitive dysfunction [28, 29]. A higher BMI and fat content are significantly positively correlated with executive dysfunction [30]; waist-hip ratio is significantly negatively correlated with cognitive function, while muscle content is significantly positively correlated with cognitive function [31]. In addition, study on adolescents [32] also shows that BMI is significantly negatively correlated with the performance of Flanker consistent stimuli and inconsistent stimuli tasks. Based on this, the improvement of body composition may be related to the inhibition function of overweight female college students. At the same time, HIIT can promote the improvement of body composition in overweight female college students [33], and this study proposes the research hypothesis H3: HIIT can improve the inhibition function of overweight female college students by improving their body composition.

This study carries out this research through two experiments. Firstly, it explores the characteristics of inhibition function in overweight female college students. Secondly, on this basis, it tests the effect of HIIT intervention on the inhibition function of overweight female college students and explores the mediating role of body composition. This study hopes to reveal the characteristics and laws of the inhibition function of overweight female college students through the above experiments, and provide evidence support and practical guidance for subsequent intervention practices for overweight and obese groups.

Study I: Inhibitory function of overweight female college students

Objective

The purpose of this study is to explore the characteristics of inhibitory control in overweight female college students by comparing their inhibitory function behavior with that of normal-weight counterparts, and to test the research hypothesis H1.

Methods

Participants

This study recruited participants through promotional advertisements on QQ, WeChat, and other platforms at LNNU University in September 2022. The recruitment was conducted in a 1:1 ratio of overweight to normal-weight female college students, with a total of 78 participants. Exclusion criteria for participants included: (1) Good health, no injuries to the arms or fingers; (2) No depression, anxiety, or other cognitive impairment diseases; (3) No smoking, excessive drinking, or other unhealthy lifestyles; (4) Normal vision or corrected vision, no color blindness or color weakness; (5) Non-physical education major college students, who do not participate in any systematic exercise other than two weekly physical elective courses; (6) Stable body weight in the past month, no intentional dieting; (7) BMI range for the overweight group was 24.0 to 27.9, and for the normal group was 18.5 to 23.9; (8) Adequate sleep the night before the executive function test, no tension, anxiety, or other negative emotional manifestations during the test. After screening, 6 participants were excluded, and a total of 72 participants were analyzed, including 34 overweight female college students and 38 normal-weight female college students. All students voluntarily agreed to participate in this test. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Liaoning Normal University (LL2021026).

Study design

The study employed a cross-sectional design comparing two groups to investigate the differences in inhibitory function task performance between overweight and normal-weight female college students. The outcome variables included response inhibition and conflict inhibition. The GO/NOGO task was used to measure the participants' response inhibition, and the Flanker task was used to measure their conflict inhibition.

Testing tools

1) Inhibitory function test

GO/NOGO task. Participants were required to respond quickly to GO stimuli with a specific key press and not to respond to NOGO stimuli, which is a classic paradigm for testing individual response inhibition [34]. Participants practiced under the guidance of the researcher (randomly presenting 8 GO stimuli and 2 NOGO stimuli), and after reaching an accuracy rate of 80% in the practice task, they proceeded to the formal test. During the formal experiment, a black "+" was presented in the center of the computer screen's white background to prompt participants to focus their attention. After 500ms, the stimuli "X" (GO stimulus) and "Y" (NOGO stimulus) appeared randomly, each stimulus was presented for 1000ms, and the interval between trials was 800ms. Participants were asked to respond quickly to the "X" stimulus by pressing the "space" key, while not responding to the "Y" stimulus. The formal experiment consisted of 2 blocks, each with 100 trials, with a ratio of 75% GO and 25% NOGO stimuli. The reaction time for the GO stimulus was collected, with shorter reaction times indicating better response inhibition.

Flanker task. Participants were required to identify inconsistent or consistent target stimuli presented in the center of the screen, which is a classic paradigm for testing individual conflict inhibition [35]. Participants practiced under the guidance of the researcher (randomly presenting 5 inconsistent and 5 consistent stimuli), and after reaching an accuracy rate of 80% in the practice task, they proceeded to the formal test. During the formal experiment, a black "+" was presented in the center of the computer screen's white background to prompt participants to focus their attention. After 500ms, inconsistent stimuli

(<<><< or >>><>>) or consistent stimuli (<<<<<< or >>>>>>) appeared randomly, each stimulus was presented for 1000ms, and the interval between trials was 800ms. Participants were asked to judge the direction of the middle symbol of the stimulus by pressing the "F" key for "<" and the "J" key for ">". The formal experiment included 100 trials, with 4 different stimuli each accounting for 1/4 of the total, with 50 trials for inconsistent and consistent stimuli. The reaction times for inconsistent and consistent stimuli were collected, with shorter reaction times indicating better conflict inhibition.

2) Self-compiled basic information questionnaire
Collected basic information of the participants, including age, major, history of arm and finger injuries, smoking habits (≥ 1 cigarette per day in the past 4 weeks), drinking habits (≥ 1 time per week in the past 4 weeks), participation in other exercises besides physical education classes (≥ 3 times per week, ≥ 30min each time in the past 4 weeks), normal vision or corrected vision, color blindness, color weakness, intentional dieting, sleep time the day before the test (≥ 7h), etc.

3) Self-rating Depression Scale (SDS)
Depression patients exhibit inhibitory dysfunction [36], hence it is necessary to exclude college students with potential depressive symptoms to enhance the accuracy of the test results. The SDS developed by Zung [37] was used to assess the depressive mood of college students in the past week. The scale includes 20 items, with 10 positive and negative scoring items, requiring students to select from 4 options ("none or rarely," "some of the time," "most of the time," "all of the time") according to their actual situation. The values for the 4 options are 1 to 4, and the SDS calculation method is to add the scores of each item and then multiply by 1.25. According to the Chinese norm, scores < 52 are normal, 53–62 are mildly depressed, 63–72 are moderately depressed, and ≥ 73 are severely depressed [38]. The Cronbach's α of this questionnaire is 0.91 and has been widely used for depression screening in Chinese college students [38].

4) Self-rating Anxiety Scale (SAS)
Anxiety disorder patients have inhibitory function neurological disorders [39], therefore it is necessary to exclude college students with potential anxiety symptoms to enhance the accuracy of the test results. The SAS developed by Zung [40] at Duke University was used to assess the anxiety mood of college students in the past week. The scale includes 20 items, with 15 positive and 5 negative scoring items, requiring students to select from 4 options ("rarely," "sometimes," "often," "continuously") according to their actual situation. The values for the 4 options are 1 to 4, and the SAS calculation method is to add the scores of each item and then multiply by 1.25. According to the Chinese norm, scores < 50 are normal, 51–59 are mildly anxious, 60–69 are moderately anxious, and ≥ 70 are severely anxious [40]. The Cronbach's α of this questionnaire is 0.89 and has been widely used for anxiety screening in Chinese college students [41].

5) Positive and Negative Affect Schedule (PANAS)
Negative emotions can impair self-control and inhibitory function [42], hence it is necessary to exclude participants who experience negative emotions during the testing process to enhance the accuracy of the test results. This study employs the PANAS developed by Watson et al. [43] to measure the acute emotional state of college students following executive function tests. The scale, revised by Huang et al. [44], is suitable for measuring the emotional state of the Chinese population. The consistency reliability α coefficients for positive and negative emotions are 0.85 and 0.83, respectively. PANAS consists of 20 adjectives describing different emotions and feelings, including a positive emotion factor and a negative emotion factor, with 10 adjectives each. A high positive emotion score indicates that the individual is energetic, focused, and happy; a high negative emotion score indicates that the individual feels confused and experiences painful emotions. If the participant's negative emotion score is greater than the positive emotion score, they are excluded.

6) Standing height and weight measurement
The height and weight of students were measured using a height and weight measuring instrument (model: HW-S6). The BMI index of female college students was obtained according to the formula BMI = weight (kg) / height^2 (m^2).

Test procedure

Firstly, the researcher led the participants to the Sports Psychology Laboratory of LNNU University one by one, calculated their BMI through standing height and weight measurement, and excluded participants who did not meet the BMI standard. Then, they filled out the self-compiled basic information questionnaire, SDS, and SAS. Secondly, under the guidance of the researcher, the participants underwent the inhibitory function test, including the GO/NOGO and Flanker tasks, which took about 10 minutes. The stimulus materials were compiled by the E-prime 3.0 software and presented on a Dell Inspiron 3520 (15.6-inch) laptop. After the inhibitory function test, the participants were asked to fill out the PANAS. Finally, the researcher collected the questionnaires and computer task data and paid each participant a reward of

20 yuan. The test was conducted from October 2, 2022, to October 5, 2022.

Statistical analysis

Firstly, the behavioral data collected by the E-prime 3.0 software were imported into the Excel software for data processing, extracting data including the reaction time for the GO stimulus and the reaction time for inconsistent and consistent stimuli, and excluding data with an accuracy rate lower than 50%. Secondly, the data were imported into the SPSS 21.0 software for statistical analysis. This study used the mean (M) ± standard deviation (SD) for descriptive statistical analysis. This study employed a single-sample Kolmogorov-Smirnov test combined with a P-P plot to assess the normality of the data. The results indicated that the data were approximately normally distributed; hence an independent samples t-test was used for intergroup comparison analysis of characteristic information and inhibitory function task performance between overweight and normal-weight female college students. When conducting the independent samples t-test, Levene's test was utilized to assess the homogeneity of variances; if the variances were equal, the analysis was conducted assuming equal variances, and if the variances were not equal, the analysis was conducted without assuming equal variances. Finally, the statistical results were visualized using GraphPad Prism 8 software. The level of significance for this study was defined as $\alpha = 0.05$.

Results

Basic information of participants

The age, SDS, and SAS scores of overweight and normal female college students show no significant differences ($P > 0.05$), while the BMI of overweight female college students is significantly higher than that of normal female college students ($P < 0.01$). The basic information of the two groups is detailed in Table 1.

Differences in inhibitory function between overweight and normal college women

The inter-group comparison analysis results of the inhibitory function between overweight and normal college women (Fig. 1) show that overweight college women have significantly longer reaction times to GO stimuli and to consistent and inconsistent condition stimuli than normal college women ($P < 0.05$). Therefore, overweight college women exhibit poorer response inhibition and interference inhibition functions compared to normal college women.

Table 1 Basic information of participants

Group	Overweight ($n = 34$) *M ± SD*	Normal ($n = 38$)	*P*
Age	22.09 ± 1.72	21.94 ± 1.91	> 0.05
BMI	26.41 ± 1.10	23.46 ± 1.07	< 0.01
SDS	49.80 ± 9.84	49.00 ± 11.21	> 0.05
SAS	43.88 ± 10.86	43.28 ± 11.92	> 0.05

Discussion

The results of this study show that overweight college women have lower response inhibition and conflict control functions, which is similar to the results of previous studies [45, 46]. In addition, Guerrier et al. [47] and Jasinska et al. [48] found that individuals with higher inhibitory functions can suppress the craving for high-calorie foods, reduce emotional eating, and are conducive to weight control, which further supports the results of this study from the opposite perspective. Overweight can lead to weakened activity in brain areas related to inhibition and enhanced activity in reward-related brain areas [3], which may be the internal neurophysiological mechanism for the lower inhibitory function of overweight college women. Batterink et al. [49], based on the GO/NO GO task, found that overweight individuals tend to exhibit impulsive behavior with higher error rates, and further fMRI showed that overweight individuals have reduced activation in prefrontal inhibitory control-related brain areas such as the superior frontal gyrus, middle frontal gyrus, ventrolateral prefrontal cortex, medial prefrontal cortex, and orbital frontal cortex, while there is enhanced activation in reward-related brain areas such as the insula, and its activation is significantly positively correlated with BMI. The above brain area reorganization may be due to the neural circuit of overweight individuals being more inclined to seek food rewards rather than inhibiting food impulses, which leads to a cycle that results in weaker functions of the prefrontal cortex and other inhibitory-related brain areas, reducing the individual's inhibitory function [3, 50]. Given the characteristic of lower inhibitory function in overweight college women, how to improve their inhibitory function through exercise and thus improve body composition and control weight has become the focus of the next studies.

Study II: The effect of HIIT on the inhibitory function of overweight female college students

Objective

To explore the effect of HIIT intervention on the inhibitory function of overweight female college students, and to further examine the mediating role of body composition indicators in the exercise intervention of inhibitory function, testing the research hypotheses H2 and H3.

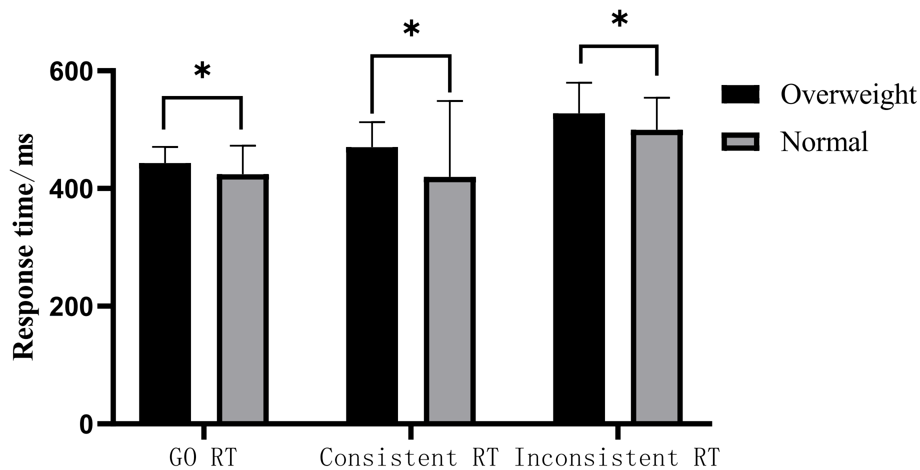

Fig. 1 Inter-group comparison analysis results of inhibitory function between overweight and normal college women

Methods

Participants

This study recruited 71 participants through promotional advertisements on QQ, WeChat, and other platforms at LNNU University from September to October 2022. Participants were screened based on the following exclusion criteria: (1) Healthy, no injuries to the arms or fingers; (2) No depression, anxiety, or other diseases that impair cognitive functions; (3) No smoking, excessive drinking, or other unhealthy lifestyles; (4) Normal vision or corrected vision, no color blindness or weakness; (5) Non-physical education college students, who do not participate in other systematic exercises besides two weekly physical elective courses; (6) Stable weight in the past month, no intentional dieting; (7) BMI values ranging from 24.0 to 27.9; (8) Adequate sleep the day before the executive function test, no nervousness, anxiety, or other negative emotional manifestations during the test. After screening, 7 participants were excluded, and a total of 64 participants were included in the experiment. All students voluntarily agreed to participate in this test. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Liaoning Normal University (LL2021026).

Study design

This study employs a randomized controlled trial for research. This study used a two-group parallel randomized controlled trial. Participants were randomly assigned to the experimental group ($n=32$) and the control group ($n=32$) using an online random number generator (http://www.99cankao.com/numbers/random-number-generator.php). The experimental group underwent HIIT intervention, while the control group did not receive any form of exercise intervention. Allocation concealment was conducted using sequentially numbered, opaque, and sealed envelopes; a single-blind strategy was used for intervention, with both the experimental and control groups unaware of the purpose of the study. The GO/NOGO task was used to measure the participants' response inhibition, and the Flanker task was used to measure conflict inhibition.

Testing tools

The GO/NO GO task and the Flanker task were used to test the students' response inhibition and interference inhibition, with specific test methods detailed in Study I; self-compiled basic information questionnaires, SDS, SAS, and PANAS were used to collect information on participants' basic information, depression, anxiety, and emotional state during the executive function test, as detailed in Study I. In addition, a GAIA KIKO bioelectrical impedance body composition analyzer made in South Korea was used to measure the participants' body composition. The test was conducted in a fasting state in the morning, requiring participants to remove shoes and socks, wear non-metallic light clothing for standing tests, and remove any items such as mobile phones and glasses. The researcher wiped the instrument with alcohol and then measured the participants, asking them to stand barefoot on the machine's sensor, hold the handle electrodes with both hands, press the button with their thumbs, naturally hang their arms at their sides, look straight ahead, and maintain a quiet upright posture. The measurement was taken when the prompt "Start Measurement" was given, and the test ended when the prompt sounded. The test indicators included BMI, fat-free weight, fat content, body fat percentage, muscle content, waist-hip ratio, and basal metabolic rate.

Experimental procedure

Firstly, the test procedures before and after the experiment were similar to those in Study I, except that body composition data collection was performed before the executive function test. The overall test order was the basic information questionnaire, SDS, SAS, body composition test, inhibitory function test, and PANAS.

The HIIT method used in this study was Tabata training. Although HIIT aids in weight loss, its high-intensity nature may increase the risk of exercise-related injuries, especially for beginners or individuals with poor physical fitness. Therefore, the experimental group underwent pre-adaptation exercises in the first week, focusing primarily on understanding safety knowledge, physical fitness assessment, and learning Tabata movements. From the second week, the researcher led the experimental group in an 8-week training program, three times a week, each session lasting 30 minutes. Each training session included a 5-minute standardized warm-up, 20 minutes of Tabata training, and a 5-minute cool-down stretch. Each training consisted of 3 sets, with each set consisting of 8 exercises (jumping jacks, kickbacks, knee drops, underarm claps, mountain climbers, squat jumps, high knees, and sidekicks), with 20 seconds of full-effort exercise and 10 seconds of rest for 4 minutes per set, that is, 4 minutes × 3 sets, with 4 minutes of active rest between sets. The experimental group's heart rate was maintained between 85% and 95% of HRmax, and a Polar watch from Finland was used for monitoring. In addition, professional supervision personnel were present during each training session to prevent sports injuries and other emergency incidents.

Statistical analysis

Firstly, the behavioral data collected by E-prime 3.0 software were imported into Excel for data processing, extracting data including GO stimulus response time, as well as response times for inconsistent and consistent stimuli, and excluding data with accuracy rates below 50%. Secondly, the data were imported into SPSS 21.0 software for statistical analysis. The study used the mean ± standard deviation ($M \pm SD$) for descriptive statistics. This study employed a single-sample Kolmogorov-Smirnov test combined with a P-P plot to assess the normality of the data. The results indicated that the data were approximately normally distributed; hence an independent samples t-test was used for intergroup comparison analysis. When conducting the independent samples t-test, Levene's test was utilized to assess the homogeneity of variances; if the variances were equal, the analysis was conducted assuming equal variances, and if the variances were not equal, the analysis was conducted without assuming equal variances. Pearson correlation analysis was used to explore the relationship between body composition and inhibitory function task performance. In addition, with inhibitory function task performance as the dependent variable and participation in high-intensity interval training as the independent variable, Amos 23.0 software was used to explore the mediating role of body composition. Finally, GraphPad Prism 8 software was used for visual presentation of the statistical results. The level of significance for this study was defined as $\alpha = 0.05$.

Results

Basic information of participants

There were no significant differences in age, SDS, and SAS scores between the experimental group and the control group ($P > 0.05$). Additionally, there were no significant differences in reaction times under GO stimulus, consistent conditions, and inconsistent conditions ($P > 0.05$). Furthermore, there were no significant differences in BMI and body composition indicators ($P > 0.05$). The basic information of the participants is detailed in Table 2.

The effect of HIIT on inhibitory function

The results of the intergroup comparison analysis of inhibitory function after the experiment (Fig. 2) show that the GO response time, consistent and inconsistent condition response times of the experimental group were significantly shorter than those of the control group ($P < 0.05$). Therefore, HIIT has a positive effect on the response inhibition and interference inhibition of overweight female college students.

The effect of HIIT on body composition

The results of the intergroup comparison analysis of body composition after the experiment (Table 3) show

Table 2 Basic information of participants

Group	Experimental ($n = 34$) $M \pm SD$	Control ($n = 38$)	P
Age	21.53 ± 1.71	21.53 ± 1.67	> 0.05
SDS	48.51 ± 6.84	48.03 ± 10.20	> 0.05
SAS	43.93 ± 8.79	43.14 ± 9.56	> 0.05
GO RT	437.25 ± 32.62	460.25 ± 16.36	> 0.05
Consistent RT	470.28 ± 43.19	466.92 ± 44.45	> 0.05
Inconsistent RT	516.10 ± 40.11	509.26 ± 40.37	> 0.05
BMI	27.11 ± 2.61	27.38 ± 3.68	> 0.05
Fat-free weight	42.63 ± 3.52	42.73 ± 3.68	> 0.05
Fat content	29.66 ± 6.92	26.29 ± 3.47	> 0.05
Body fat percentage	33.19 ± 3.12	32.46 ± 4.55	> 0.05
Muscle content	42.89 ± 4.82	42.56 ± 4.00	> 0.05
Waist-hip ratio	0.82 ± 0.06	0.81 ± 0.06	> 0.05
Basal metabolic rate	1359.16 ± 102.63	1251.22 ± 100.70	> 0.05

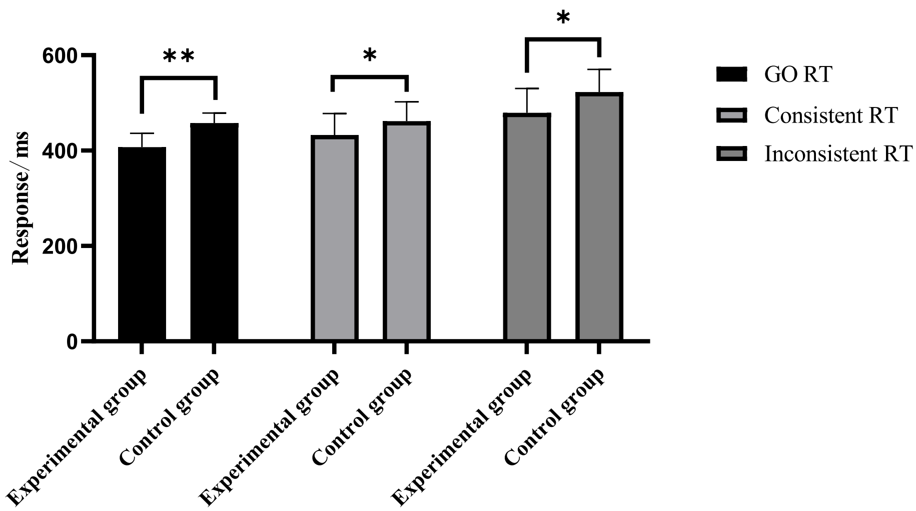

Fig. 2 Intergroup comparison analysis results of inhibitory function after the experiment

Table 3 Intergroup comparison analysis results of body composition after the experiment

Group	Experimental($n=30$) $M \pm SD$	Control($n=30$)	t	P
BMI	23.31 ± 2.49	24.51 ± 1.06	−2.424	0.020
Fat-free weight	49.92 ± 5.02	45.93 ± 6.75	2.633	0.011
Fat content	18.78 ± 3.74	20.98 ± 2.97	−2.563	0.013
Body fat percentage	28.71 ± 1.03	28.12 ± 1.44	1.799	0.078
Muscle content	45.55 ± 4.69	42.28 ± 6.20	2.341	0.023
Waist-hip ratio	0.79 ± 0.02	0.77 ± 0.03	1.792	0.078
Basal metabolic rate	1349.91 ± 63.60	1305.10 ± 84.34	2.356	0.022

that the experimental group had significantly lower BMI and fat content than the control group ($P < 0.05$), but significantly higher fat-free weight, muscle content, and basal metabolic rate ($P < 0.05$). In addition, there was no statistically significant difference between the experimental and control groups in body fat percentage and waist-hip ratio ($P > 0.05$). In summary, high-intensity interval training has a positive effect on improving the body composition of overweight female college students.

Correlation between body composition and inhibitory function

The correlation analysis results between body composition and inhibitory function (Table 4) show that fat content has a significant ($P < 0.05$) positive correlation with GO response time ($r = 0.383$), consistent condition response time ($r = 0.392$), and inconsistent condition response time ($r = 0.329$), meaning the higher the fat content, the longer the inhibitory function response time; waist-hip ratio has a significant negative correlation with GO response time ($r = -0.271$, $P < 0.05$), meaning the larger the waist-hip ratio, the shorter the response time for response inhibition. In addition, BMI, fat-free weight, body fat percentage, muscle content, and basal metabolic rate are not significantly correlated with GO response time, consistent condition response time, and inconsistent condition response time ($P > 0.05$).

Test of mediating role of body composition

Given that BMI, fat-free weight, body fat percentage, muscle content, and basal metabolic rate are not significantly correlated with GO response time, consistent condition response time, and inconsistent condition response time, these indicators are unlikely to play a potential mediating role in the intervention of high-intensity interval training on the inhibitory function of overweight female college students. In addition, given that the effect of high-intensity interval training on waist-hip ratio is not significant, its mediating role is also not significant. However,

Table 4 Correlation analysis results between body composition and inhibitory function

Variables	GO RT	Consistent RT	Inconsistent RT
BMI	0.102	−0.036	0.036
Fat-free weight	−0.051	−0.020	0.041
Fat content	0.383**	0.392**	0.329*
Body fat percentage	−0.116	−0.031	0.079
Muscle content	−0.023	−0.006	0.053
Waist-hip ratio	−0.271*	−0.160	−0.056
Basal metabolic rate	−0.003	0.006	0.063

Notes: *$P<0.05$; **$P<0.01$

Table 5 Test results of path coefficients

Path	*β*	*SE*	*CR*	*P*
HIIT → Fat content	2.205	0.850	2.595	0.009
Fat content → GO RT	1.704	0.975	1.747	0.081
Fat content → Consistent RT	4.096	1.624	2.522	0.012
Fat content → Inconsistent RT	3.362	1.934	1.738	0.082
HIIT → GO RT	46.469	6.788	6.846	< 0.001
HIIT → Consistent RT	19.553	11.301	1.730	0.084
HIIT → Inconsistent RT	36.061	13.459	2.679	0.007

high-intensity interval training has a positive effect on fat content, and there is a significant positive correlation between fat content and GO response time, consistent condition response time, and inconsistent condition response time, so fat content has potential mediating effects. The model summary shows: $\chi^2=89.110$, $df=3$, $\chi^2/df=29.703$, CFI = 0.416, RMSEA = 0.068, TLI = 1.920, $P<0.01$, so the model fit is acceptable. The test results of the path coefficients show that the direct effect of high-intensity interval training on fat content is significant ($\beta=2.205$, $P=0.009$); the direct effects of high-intensity interval training on GO response time ($\beta=46.469$) and inconsistent condition response time ($\beta=36.061$) are significant ($P<0.01$), while the direct effect on consistent condition response time is not significant ($P>0.05$); the direct effect of fat content on consistent condition response time is significant ($\beta=4.096$, $P=0.012$), while the direct effects on GO response time and inconsistent condition response time are not significant ($P>0.05$). Specifically, according to the mediating role diagram of body composition (Fig. 3), fat content plays a potential mediating role in the intervention of high-intensity interval training on the consistent condition response time of overweight female college students. The results of the path analysis are detailed in Table 5.

Discussion

HIIT intervention has a positive effect on the body composition and inhibitory function of overweight female college students, and fat content plays a potential mediating role in the intervention.

Firstly, HIIT can effectively control the weight of overweight individuals, reduce body fat percentage, improve BMI, and effectively increase the basal metabolic rate, which has been supported by many studies [51, 52]. HIIT raises the heart rate to a higher level through high-intensity exercise in a short period, thereby increasing the consumption of heat and oxygen during and for several hours after exercise, and accelerating the body's metabolism [53]. HIIT can increase the oxidation of fat, improve insulin sensitivity, and reduce cortisol levels, which are conducive to reducing body fat ratio and improving body composition [54]. In addition, HIIT promotes muscle growth by increasing muscle protein synthesis, and therefore the increase in muscle mass helps to raise the basal metabolic rate [55].

Secondly, HIIT can effectively improve the inhibitory function of overweight female college students, and this research result is similar to previous studies on other groups [56]. According to the perspective of the neuroendocrine model, HIIT can promote the concentration of dopamine and norepinephrine in the brain, thereby activating the individual's reticular structure, increasing physiological arousal, and promoting cognitive performance [57, 58]. In addition, HIIT regulates the peripheral serum concentration of brain-derived neurotropic factor (BDNF) and vascular endothelial growth factor (VEGF), improves oxidative stress and cortisol secretion in the body, and enhances brain lactate levels, thereby enhancing cognitive performance through the enhancement of mitochondrial adaptation capacity [59, 60]. At the macro level of the brain system, HIIT also enhances the metabolic activity of the parietal and frontal brain regions, and improves the brain's plasticity by increasing the concentration of markers in the hippocampal region [61].

Finally, this study found that body fat content played a mediating role in the improvement of interference inhibition by HIIT exercise, a result that supports the research hypothesis H3. This indicates that HIIT can burn a large number of calories in a short period of time, improve the physiological function of the participants, and thereby change its effect on the brain, achieving the effect of brain health [62]. HIIT increases the body's metabolic demands and energy expenditure through high-intensity exercise, leading to the oxidation and reduction of fat [53]. This physiological change may have a positive effect on cognitive

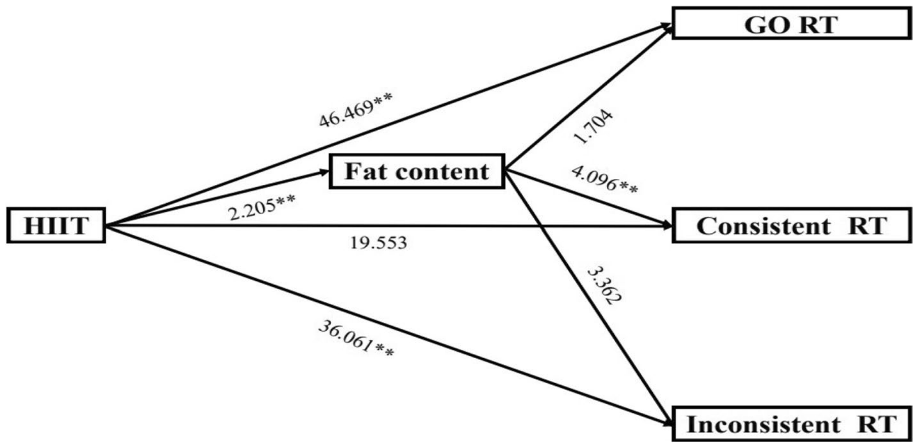

Fig. 3 Diagram of the mediating role of body composition

functions of the brain by affecting neuroendocrine pathways [62]. In summary, HIIT, as an exercise method with high time efficiency and easy implementation, can serve as an effective means to improve body composition and cognitive functions.

However, this study still has the following shortcomings. First, this study only conducted behavioral research on participants and did not deeply analyze the mechanisms of inhibitory function in overweight female college students from the perspectives of electrophysiology or brain imaging. It did not explore the specific changes in brain areas related to inhibitory function, so future research can attempt to explain the impact of physical exercise on inhibitory function from a deeper level. Second, the experimental order in this study was fixed, with the GO/NOGO task always performed before the Flanker task, which might have caused participants to have a certain degree of practice proficiency effect. It is recommended that subsequent studies randomize the order of tasks to reduce the proficiency level. Finally, this study only confirmed the effectiveness of HIIT intervention on the inhibitory function of overweight female college students, but did not discuss the dose-effect relationship. Further research is expected to improve this aspect.

Conclusion

This study explored the characteristics of inhibitory function in overweight female college students and further investigated the effects of HIIT intervention on inhibitory function. It was found that compared with normal female college students, overweight female college students had poorer response inhibition and interference inhibition functions. However, after 8 weeks of HIIT with Tabata as the carrier, the behavioral performance of the Go/Nogo and Flanker tasks, which are related to response inhibition and interference inhibition, improved in overweight female college students. Additionally, this study discovered the mediating role of body fat content in HIIT intervention for interference inhibition. Through this research, it can be confirmed that HIIT is an effective exercise method for improving body composition and inhibitory function in overweight female college students, providing a scientific basis for the application of HIIT in the health management of overweight female college students.

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Authors' contributions
Zili Zuo wrote the manuscript. Peng Shi and Jianming Zhang conceived and designed the study. Ziyun Zhang, and Yan Li discussed the results and revised the first draft. All authors approved the final version of the manuscript.

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Data availability
The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Liaoning Normal University (LL2021026). All participants have signed informed consent forms.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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