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Additional health education and nutrition management cause more weight loss than concurrent training in overweight young females

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ABSTRACT

Objective: This study aimed to compare the effect of concurrent training and the addition of health education and nutrition management on body composition and health-related outcomes.

Methods: Twenty-four healthy overweight females (20.42 ± 1.02 years, body mass index [BMI] 25.83 ± 3.63 kg•m^{-2}) were assigned to a concurrent training group (Exe, $n = 12$) or a concurrent training and health education group (Exe + Edu, $n = 12$). Both groups completed 8 weeks of concurrent training (6 days/week), whereas the Exe + Edu participants received additional health education and controlled daily energy intake within the basal metabolic rate. Body composition, serum glucose, lipids and related hormones were measured before and after intervention.

Results: After intervention, the Exe group lost 2.47 kg (±2.46) of body mass, 2.44 kg (±1.71) of total fat mass (FM), corresponding to a body fat percentage (BF%) of 2.25%. Losses of body mass, total FM and BF% in the Exe + Edu group were −5.19 ± 1.87 kg, −4.42 ± 1.83 kg and −4.33 ± 2.39%, respectively. The Exe + Edu participants had significantly greater reductions of body mass, total FM, and trunk and leg FM relative to the Exe participants ($p < 0.05$). Serum glucose, lipids, insulin and progesterone levels were improved in both groups without group difference.

Conclusion: Concurrent training is an effective short-term training strategy for reducing FM and improving fasting glucose, blood lipids and related hormones. Furthermore, the combination of additional health education can achieve greater effects on weight loss and the reduction of total and regional FM, which may be a better obesity treatment method.

1. Introduction

Overweight and obesity are associated with a variety of chronic diseases such as cardiovascular disease, diabetes, musculoskeletal disorders and some cancers, as well as psychosocial and economic difficulties [1]. Excess body fat is a complex problem resulting from the interaction of non-modifiable factors (genetic and socioeconomic, such as age, gender, ethnic group and socioeconomic status) and modifiable factors (behavioural and environmental, such as physical activity, dietary habit and lifestyle) [2]. Obesity treatment therefore should be focused more on reversing the modifiable behaviours, such as physical activity and dietary patterns, as well as health and nutrition knowledge [3].

Regular physical activity is an important strategy to treat obesity and the associated comorbidities [4]. An ideal weight loss programme should selectively deplete adipose tissue (especially visceral and abdominal fat) while maintaining skeletal muscle tissue. Chronic aerobic training is traditionally considered the most suitable form of weight loss training, which promotes negative energy balance and lipid substrate oxidation, thereby reducing body fat and improving lipid and glucose metabolism [5]. Nonetheless, muscle-strengthening exercises such as resistance training seem to be more sufficient in terms of increasing muscle mass, strength and aerobic fitness [6,7]. Therefore, recent position statements recommend the utilization of combined

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resistance and aerobic training to achieve more health benefits [4]. Incorporating both endurance and resistance training into an exercise regime is termed "concurrent training" [8]. Many randomized controlled trials and meta-analysis studies have reported that concurrent training can significantly reduce body mass and visceral adiposity, and improve metabolic profiles while increasing lean mass (LM) [7,9–11]. Adipose tissue stored in distinct body parts has different effects on metabolic health, and the accumulation of fat depots in the abdominal area is a well-known vital factor involved in the aetiology of type 2 diabetes and cardiovascular disease [12,13]. However, many previous studies used skinfold thickness [6,10] or the bioelectrical impedance method [14,15] to measure body composition, making it difficult to accurately evaluate the efficacy of concurrent training on body fat distribution. Therefore, it is necessary to use a more sophisticated technique of body composition measurement, such as dual-energy X-ray absorptiometry (DEXA), to elucidate the effects of concurrent training on body fat distribution in obese populations.

Health education, defined as any combination of learning experiences aimed at promoting voluntary actions conducive to health [16], is a direct pathway to improve health knowledge that enables people to make sensible decisions and change behaviours relating to their personal health [17]. The health education topics can be varied, from nutrition to injury prevention, from healthy lifestyle to physical activities, etc. [5]. Moreover, energy deficits leading to weight loss have been revealed to promote a situation where the matching of energy intake to lowered energy consumption is accompanied by adaptations that are conducive to compensatory behaviour, namely, increasing energy intake or decreasing the energy consumption of the physical activity [18]. These adaptations are likely to lead to lower-than-expected weight loss or even weight relapse. Therefore, for multi-strategy lifestyle interventions, the addition of knowledge about health and nutrition is necessary to avoid energy compensatory behaviour and achieve ideal weight loss [19–22]. Many studies have shown that health and/or nutrition education programmes improve participants' health knowledge and behaviours: for example, reduced consumption of sweets, soft drinks, high-fat products and processed meats, increased lean meat and poultry intake and increased amounts of physical activity [19,20]. The modifications in eating habits and sedentary behaviour further reduced body weight and cardiovascular risk [19–21]. These findings suggest that health education not only can increase health and nutrition knowledge about obesity but also can trigger beneficial behavioural changes, such as better eating patterns and more time for physical activity, which may further lead to weight loss. Therefore, it is of interest to examine whether concurrent training combined with health education would result in better improvements in obese-related health outcomes.

Collectively, the objective of this study was to examine the effects of concurrent training on body composition and cardiometabolic health-related variables in obese young females and to evaluate whether such training, combined with health education, would induce additional benefits in these variables. It was hypothesized that the addition of health education to concurrent training would further improve obesity-related outcomes.

2. Methods

2.1. Participants

The study protocol was conducted according to the Declaration of Helsinki and approved by the Research Ethics Committee of Beijing Sport University (RC Ref. no. 2018018H). Prior to recruiting, a power analysis was performed to estimate sample size using G*Power (Version 3.1). With an assumed power of 0.80, an alpha level of 0.05 and a moderate effect size based on the outcome of body mass resulting from the concurrent training [15], the results showed that a minimum sample size of 12 participants for each group was required. Considering a dropout rate of 20%, a total sample size of 30 subjects was needed.

The participants were non-sports-major females recruited from three universities in Haidian District, Beijing. The inclusion criteria were: (1) overweight or obese, defined as a body mass index (BMI) of >23 and a body fat percentage (BF%) of >30 measured using a body composition analyser (Biospace Inbody 720, South Korea) [23]; (2) healthy (without endocrine, metabolic, osteoarticular or heart disease); (3) stable body mass (variation within 5%) in the past 6 months; and (4) not participating in organized training programmes or following structured weight-loss dietary plans at the time of recruitment. Volunteers interested in this study were further asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) and a medical history questionnaire to determine whether they were healthy and able to participate in the study. Participants were screened and excluded if they had secondary obesity caused by endocrine, metabolic, genetic or central nervous system diseases, were using tobacco, e-cigarettes or alcohol, were on contraceptive pills, weight loss or nutritional supplements, were taking prescribed drugs of any kind that would affect body composition or the endocrine system or were currently under medical treatment for any reason. Of the 89 participants screened, 29 female college students (18–25 years old) with simple obesity were eligible and were randomly assigned to either a concurrent training group (Exe, $n = 14$) or a concurrent training and health education group (Exe + Edu, $n = 15$). Two participants in the Exe group and three in the Exe + Edu group dropped out for personal reasons and were excluded from data analysis (Fig. 1).

2.2. Study overview

After obtaining written informed consent from all the participants, they attended an information workshop where the procedures, requirements and all aspects of training and testing of the study were explained and demonstrated. A familiarization session was then given to explain and demonstrate how to use 3-day food questionnaires to record dietary intakes. All the study participants rehearsed the method for recording and weighing their food and beverage consumption. Prior to the formal study, two weeks of 3-day dietary records (two weekdays and one weekend day) were collected to analyse baseline energy intake and macronutrient composition levels using a nutrition analysis computer program developed by the National Institute of Sports Medicine (Version 1.0, China, Beijing).

The formal study consisted of pre-intervention measures (including anthropometric indexes and blood parameters), an 8-week intervention period and post-intervention measures. The pre- and post-intervention measures were carried out 48–120 h before the first intervention day and 72–96 h after the last intervention day, respectively. During the intervention, the Exe participants completed a concurrent training programme of endurance and resistance training (six sessions/week), and were instructed to maintain baseline dietary patterns and daily routines and refrain from extra physical activities. The concurrent training was expected to result in an energy consumption of ~3000 kcal/week. The Exe + Edu group underwent the same concurrent training programme at the same relative exercise intensity as the Exe participants, and they were also required to maintain daily routines and not take part in additional exercise. Furthermore, the Exe + Edu participants received additional health education and were required to manage their calorie intake within the personal basal metabolic rate (BMR), aiming to create an additional energy deficit of ~300 kcal/day to make up for the energy compensation effect of exercise-induced weight loss. The health education workshops and all dietary instructions were given by a protocol-trained, board-certified dietitian who had received professional training, passed the examination and obtained the certificate of "Public Nutritionist" issued by the Ministry of Human Resources and Social Security of China.

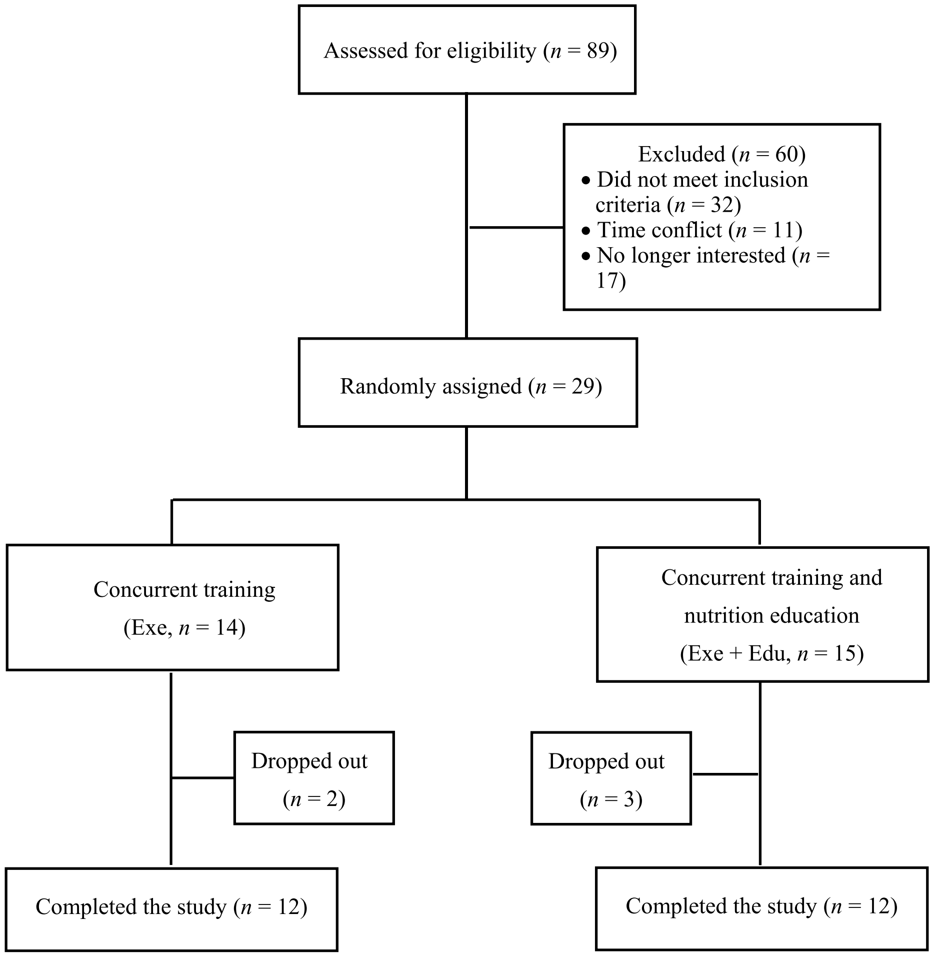

Fig. 1. Flowchart of participant screening and completion.

2.3. Concurrent training programme

Participants in both groups took the same structured concurrent training programme, consisting of a combination of aerobic and resistance exercise for 8 weeks, with six sessions/week. Training was carried out in a laboratory with controlled room temperature (22 °C) and humidity (50–60%). Each concurrent training session lasted 90 min and was divided into 15 min of initial warm-up, 40 min of aerobic exercise, 20 min of resistance exercise and 15 min of cool-down exercise. The choice of aerobic exercise frequency and intensity was based on the recommendations of the American Medical Association (AMA): at least 150–300 min of moderate-intensity or 75–150 min of vigorous-intensity aerobic exercise per week to obtain substantial health benefits [4]. The AMA also recommended that adults should engage in muscle-strengthening activities of moderate or greater intensity that involve all major muscle groups on two or more days a week [4]. Therefore, six 40-min sessions per week of moderate-intensity (70–75% of maximal heart rate: HR_{max}) aerobic exercise combined with 20 min of moderate-intensity (perceived somewhat hard to hard) multi-joint resistance exercise was used to improve the cardiometabolic health-related profiles of overweight young females.

The concurrent training began with a 15-min warm-up (5 min of joint mobility; 10 min of cardiovascular activation). The subsequent aerobic exercise included 40 min of fast walking, rope skipping and aerobics at the intensity of 70–75% HR_{max}. The 20 min of resistance exercise involved the main muscle groups of the upper body, core and lower body. Five exercises (without load) were performed: 10 repetitions of kneeling push-ups; 10 repetitions of supine mountaineering; 10 repetitions of lie prone and lift upper and lower body; 10 repetitions of squat vertical jumps; and 10 repetitions of lie supine and lift upper and lower body (Table 1). The rest duration between exercises was 60–120 s. The concurrent training ended with a 15-min cool-down exercise: 5 min of stretching and 10 min of myofascial release. Two trained research assistants, who were blinded to the participants' group allocation, led and supervised the whole training process.

The exercise intensity of the aerobic exercise aimed at 70–75% HR_{max} and was continuously monitored using a heart rate monitor (Polar F4M BLK, Finland) in all sessions. The HR_{max} for each participant was estimated as 220 - age, and the targeted range for each participant was calculated individually. The OMNI-Resistance Exercise Scale (OMNI-RES) was used to measure the perceived exertion of resistance training [24], aiming to reach 6–7 out of 10 at the completion of each

Table 1
Training protocol for the concurrent training.

	Time	Physical activities	Intensity
Warm-up	15 min	Joint mobility and cardiovascular activation	–
Aerobic exercise	40 min	Fast walking, rope skipping or aerobics	70–75% HR_{max}
Resistance exercise	20 min	10 reps of 5 exercises (kneeling push-ups; supine mountaineering; lie prone and lift upper and lower body; squat vertical jumps; and lie supine and lift upper and lower body)	6–7 out of a 10-point OMNI-RES
Cool-down	15 min	Stretching and myofascial release	–

HR_{max}: maximal of heart rate, OMNI-RES: OMNI-Resistance Exercise Scale.

exercise. Participants in both groups were instructed to keep away from extra exercise throughout the training programme. No adverse events were reported or observed throughout the study.

2.4. Health education and nutrition management

To improve participants' health knowledge, stimulate their subjective initiative to participate in weight loss and equip them with skills to develop and practice healthy behaviours, the Exe + Edu group received additional health education and implemented the method of nutrition management with the help of a dietitian. The intervention included five health education workshops provided by a protocol-trained, board-certified dietitian with more than 5 years of teaching and research experience in the nutrition field. The five workshops were organized in a theoretical–practical manner. The topics of the five workshops were aspects of general concern relating to obesity treatment, namely: "How to control the quantity and quality of food"; , "Causes and consequences of obesity"; "Healthy lifestyle"; "Dietary and nutrition management"; and "Scientific exercise methods". Each 120-min workshop consisted of 10 min reviewing the contents of the previous session and clarifying queries, followed by approximately 60 min of the content for the session. Afterwards, a 30-min practical session was arranged to demonstrate that the participants could apply the health and nutrition knowledge to their daily lives. For example, in the practical session entitled "How to control the quantity and quality of food", participants practiced how to record and weigh the consumption of food and beverages and also the calculation method for daily energy intake. The last 20 min was devoted to discussing problems encountered during practice and clarifying any doubts. The main strategies used in health education were lectures (with PowerPoint), educational films, demonstrations, education booklets and practical/discussion sessions.

To avoid the energy compensation effect observed in exercise-induced weight loss [18], participants in the Exe + Edu group were required to manage their calorie intake within their individual BMR during the 8-week intervention period. According to the average value of ~15% energy compensation reported in the literature [18], nutrition management aimed at ~300 kcal/day of energy deficits. The dietitian provided each participant with a balanced diet in which the target calorie intake was restricted to each individual's estimated BMR level. Protein, fat and carbohydrate accounted for 15–20%, 20–30% and 50–60% of the total daily energy intake. The Mifflin-St Jeor equation was used to calculate the resting energy expenditure (REE): REE = 10 × Weight (kg) + 6.25 × Height (cm) – 5 × Age (years) − 161 [25]. Then, REE multiplied by 1.53 (representing sedentary or light activity) was used to calculate participants' individual BMR. The average target energy intake was 2257.1 ± 174.3 kcal/day for the first week.

The Exe + Edu participants met with the dietitian before breakfast on the last morning of each training week to reassess their weight and recalculate their BMR. After reassessing the weight, the dietitian provided detailed personal diet adjustment guidance to each participant and helped to solve the problems encountered in the previous week.

2.5. Medical supervision

To prevent injuries and adverse medical events, participants' health status was strictly supervised, with body composition, HR, blood pressure and other physiological indicators measured by a nurse every week. Adverse medical events were recorded and participants' questions and feedbacks about the study were answered and followed up immediately through WeChat, phone calls or personal meetings. Luckily, no adverse events were reported during the intervention.

2.6. Blood sampling

Blood samples before and after intervention were collected at the same period of each participant's menstruation (avoiding the menstrual period), which was calculated according to the self-reported menstrual cycle. Participants were required to avoid strenuous activity and caffeine 48 h before blood sampling and to arrive at the laboratory in the morning (at around 7:30 a.m.) under the condition of overnight fasting (12 h). Blood samples (8 ml) were collected from the median cubital vein by a certificated nurse, who was blinded to participants' group allocation, then separated for serum and frozen at −80 °C until later analysis.

2.7. Anthropometric assessments

After blood sampling, height and weight were determined by standard methods using a stadiometer and an electronic scale (in light clothing and with no footwear) to the nearest 0.1 cm and 0.1 kg, respectively. BMI (in $kg \bullet m^{-2}$) was calculated by dividing the weight by the squared height. Then, a DEXA scanner (Norland X-46 DXA densitometer, Norland Corporation, Fort Atkinson, WS, USA) was used to measure the participants' body composition variables in a supine position. LM and fat mass (FM) from the whole body and areas of the trunk, abdomen, arms and legs were scanned and analysed using software programme (version 3.7.4/2.1.0; Norland Corporation). The instrument was calibrated daily and operated by medical staff. The abdominal region referred to the area consisting of the line between the two iliac crests, the two edges of the hip and the lateral sides of the femoral neck. The trunk region was defined as being from the lower edge of the mandible to the upper edge of the line between the iliac crests, excluding the head and upper limbs. LM and FM were calculated from the total and regional analyses of the whole-body scan.

2.8. Blood assays

Fasting glucose, serum total cholesterol (CHOL), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), apolipoprotein A (Apo A) and apolipoprotein B (Apo B) were measured using an automatic biochemical analyser (Hitachi 7170, Japan); serum concentrations of insulin, leptin and progesterone were tested by radioimmunoassay (R-911 radioimmunoassay, China).

2.9. Statistical analysis

SPSS software version 22.0 (IBM, New York, USA) was used to perform statistical analyses. The Shapiro–Wilk test was performed to confirm the normal distribution of outcome variables before conducting the main analyses. Analysis of covariance (ANCOVA) with pre-intervention values as the covariate was used to examine the group differences in the main outcomes between the two groups. Partial eta squared (η^2) was calculated to measure the effect size of the main and interaction effects; effect size was considered small when $\eta^2 < 0.06$ and large when $\eta^2 > 0.14$ [26]. Cohen's d was used to evaluate the effect size for the difference between variables, which was considered small when $d = 0.2$–0.3, medium when $d \sim 0.5$ and large when $d > 0.8$ [27]. Considering the small sample size, *a posteriori* power data of the statistical analysis were calculated using G* power to indicate the statistical power of the outcome variables (see Table 6). Data were presented as the mean and standard deviation (SD), and $p < 0.05$ with two tails was set as statistical significance.

3. Results

3.1. Participants

A total of 29 overweight but healthy female students (18–25 years old) underwent randomization, of whom 24 (82.8%) completed all the pre- and post-measurements and the entire study protocol and were included in the data analyses. At baseline, there were no differences in body composition, fasting glucose, blood lipids or hormone profiles between the two groups (Table 2, $p > 0.05$).

3.2. Dietary intakes

At baseline, the calorie intake of the Exe group was 2628.8 ± 724.9 kcal/day, with carbohydrate, fat and protein intakes accounting for 49.0 ± 13.0%, 33.0 ± 13.1% and 16.1 ± 6.8% of the energy intake, respectively. In contrast, the daily energy intake of the Exe + Edu group was 2556.9 ± 524.6 kcal/day, in which the proportion sizes of carbohydrate, fat and protein were 47.3 ± 8.8%, 35.6 ± 7.0% and 15.7 ± 2.6%, respectively. There was no group difference in the baseline dietary level (Table 3, $p > 0.05$). During the intervention, the Exe group was asked to maintain their normal diet, and the Exe + Edu group took a balanced diet and limited energy intake within the estimated individual BMR level. The BMR was estimated as 2257.1 ± 174.3 kcal/day for the first week, which was reduced to 2177.6 ± 172.0 kcal/day at the 8_{th} week along with the reduction of body weight, causing an energy deficit of approximately 300–400 kcal/day compared to the baseline dietary level (Table 3).

3.3. Changes in body composition after intervention

After intervention, marked improvements in body composition were found in both groups. The Exe group showed reduced body mass (−3.5%), BMI (−3.4%), BF% (−2.3%), total FM (−9.9%), trunk FM (−12.6%), abdominal FM (−14.8%), arm FM (−8.7%) and leg FM (−7.7%, $p < 0.05$; Table 4). However, the Exe + Edu group experienced larger decreases of 7.3% and 16.8% for body mass and total FM, respectively ($p < 0.05$; Table 4). In terms of group difference, losses of body mass (−2.47 ± 2.46 vs. −5.19 ± 1.87 kg; $\eta^2 = 0.321$), BMI (−0.9 ± 0.9 vs. −1.97 ± 0.79 kg•m^{-2}; $\eta^2 = 0.298$), BF% (−2.3% vs. −4.3%; $\eta^2 = 0.177$), total FM (−2.44 ± 1.71 vs. −4.42 ± 1.83 kg; $\eta^2 = 0.223$), trunk FM (−1.67 ± 1.21 vs. −2.77 ± 1.09 kg; $\eta^2 = 0.182$) and leg FM (−0.61 ± 0.49 vs. −1.35 ± 0.69 kg; $\eta^2 = 0.252$) were significantly greater for the Exe + Edu group relative to the Exe group ($p < 0.05$; Tables 4 and 5).

3.4. Changes in blood parameters after intervention

In addition to benefits in body composition, circulating levels of glucose, CHOL, Apo B, TG and progesterone were significantly reduced in both groups ($p < 0.05$; Table 5), whereas serum HDL-C and Apo A were significantly increased by ~20% and ~25% in the Exe and Exe + Edu groups, respectively ($p < 0.05$; Table 5). Although there was no group difference, the insulin level was significantly reduced in the Exe + Edu group (−5.3%). There was no group difference in the changes for any of the blood parameters ($p > 0.05$; Table 5).

Table 2
Participant characteristics at baseline.

	Exe ($n = 12$)	Exe + Edu ($n = 12$)	p
Age (years)	20.25 ± 0.87	20.58 ± 1.17	0.745
Height (cm)	166.50 ± 7.96	164.50 ± 6.43	0.236
Body mass (kg)	70.78 ± 12.50	71.14 ± 10.62	0.940
BMI (kg•m^{-2})	25.25 ± 2.65	26.66 ± 4.34	0.346
BF% (%)	42.53 ± 6.06	42.97 ± 5.94	0.087
Total LM (kg)	23.91 ± 5.16	26.58 ± 6.60	0.508
Total FM (kg)	33.67 ± 4.58	36.92 ± 4.30	0.212
Trunk LM (kg)	20.58 ± 3.93	19.30 ± 2.98	0.380
Trunk FM (kg)	12.52 ± 3.70	13.77 ± 3.43	0.397
Abdominal LM (kg)	10.61 ± 1.98	9.97 ± 1.28	0.359
Abdominal FM (kg)	5.60 ± 1.61	5.81 ± 1.39	0.728
Arm LM (kg)	4.25 ± 0.96	4.18 ± 0.85	0.859
Arm FM (kg)	2.45 ± 0.49	2.53 ± 0.87	0.782
Leg LM (kg)	1.75 ± 0.34	1.71 ± 0.23	0.688
Leg FM (kg)	7.77 ± 1.34	8.79 ± 2.43	0.219

Exe: concurrent training group; Exe + Edu: concurrent training and health education group; BMI: body mass index; BF%: body fat percentage; LM: lean mass; FM: fat mass.

4. Discussion

The purpose of this study was to evaluate whether an 8-week concurrent training intervention could improve body composition and obesity-related parameters in obese Chinese females and whether a combination of health education and nutrition management has additional effects on these variables. We found that the 8-week concurrent training alone induced marked reductions in body mass, BMI and total and regional FM, improved glucolipid metabolism, and decreased circulating insulin and progesterone levels. In comparison, the group with additional health education yielded more reductions in body mass, BMI, BF% and total, trunk and leg FM, indicating that health education and nutrition management can be an important supplement to concurrent training to improve body composition in obesity treatment, although no additional effects on glucolipid metabolism or related hormones were found.

Using the DEXA technique, this study showed that the 8-week concurrent training intervention reduced body mass by 2.47 kg (or −3.5%), of which 2.44 kg came from the total FM. Furthermore, the loss of total FM was mainly due to the reductions in trunk FM (−12.6%, or −1.67 kg) and abdominal FM (−14.8%, or −0.84 kg). In contrast, we did not find significant changes in LM following the concurrent training. Given that an upper body/visceral fat distribution in obesity is strongly linked with the metabolic complications of obesity [12,13], such an extent of reduction in upper body FM may transfer considerable health benefits in reducing the risk of cardiovascular disease. These findings are consistent with previous short-term concurrent training studies that reported significant reductions in body mass and FM, as well as abdominal FM or waist circumference, after 5–12 weeks of concurrent training in overweight or obese individuals [10,14,15], despite the body mass reductions in these studies varying from 0.7 to 2.72 kg. In addition to decreases in body weight and FM, some studies also observed significant increases in fat-free mass or LM in response to concurrent training [6,10,14], whereas another study reported unchanged LM after concurrent training [15]. The concurrent training in the present study failed to increase LM as well. The different results among the above-mentioned studies could be attributed mainly to discrepancies in training loads and intervention durations, which could lead to distinct metabolic, hormonal and molecular responses in participants with different initial health conditions. Nonetheless, preserving LM is also of great importance from the perspective of maintaining strength and the BMR level.

Compared to concurrent training alone, the group with additional health education and nutrition management (i.e. the Exe + Edu group) obtained greater losses in body mass (−2.47 vs. −5.19 kg; $d = 1.25$), total FM (−2.44 vs. −4.42 kg; $d = 1.13$), trunk FM (−1.67 vs. −2.77 kg; $d = 0.95$) and leg FM (−0.61 vs. −1.35 kg; $d = 1.23$). It has been reported that health and/or nutrition education improved participants' health-related knowledge, modified their health behaviours/eating habits and increased physical activity time, and that these improvements were accompanied by a decrease in body weight [19–22]. However, the greater reduction in body weight and FM observed in the Exe + Edu group is more likely the result of nutrition management, given that health education may take more time to have effects. Although improvements of health knowledge and health awareness are important for understanding and interpreting health information and making sensible decisions related to personal health, it is also important to put learned health strategies into practice. Therefore, the Exe + Edu group implemented the method of nutrition management under the guidance of a dietitian. The dietary intake of Exe + Edu participants was limited to their individual BMR level during the 8-week study period, resulting in an energy deficiency of about 300–400 kcal/day, which thus may lead to more weight loss compared to the Exe group. The results support the use of health education and nutrition management as a supplement to

Table 3
Baseline dietary intake and estimated dietary intake during the intervention.

	Exe ($n = 12$)			Exe + Edu ($n = 12$)		
	Baseline	Week1	Week 8	Baseline	Week1	Week 8
Energy intake (kcal/day)	2628.8 ± 724.9	–	–	2556.9 ± 524.6	2257.1 ± 174.3	2177.6 ± 172.0
Carbohydrate intake (%)	49.0 ± 13.0	–	–	47.3 ± 8.8	50–60%	50–60%
Fat intake (%)	33.0 ± 13.1	–	–	35.6 ± 7.0	20–30%	20–30%
Protein intake (%)	16.1 ± 6.8	–	–	15.7 ± 2.6	15–20%	15–20%

Exe: concurrent training group; Exe + Edu: concurrent training and health education group.

Table 4
Anthropometric and body composition outcomes before and after 8 weeks of intervention.

	Exe ($n = 12$)			Exe + Edu ($n = 12$)			Group effect	
	Pre	Post	p	Pre	Post	p	p	η^2
Age (years)	20.25 ± 0.87			20.58 ± 1.17				
Height (cm)	166.50 ± 7.96			164.50± 6.43				
Body mass (kg)	70.78 ± 12.50	68.32 ± 12.31**	0.005	71.14 ± 10.62	65.95 ± 9.96**	0.000	0.006	0.321
BMI (kg•m^{-2})	25.10 ± 2.65	24.20 ± 2.34**	0.005	26.66 ± 4.34	24.62 ± 4.03**	0.000	0.007	0.298
BF% (%)	33.67 ± 4.58	31.42 ± 4.40**	0.000	36.92 ± 4.30	32.58 ± 4.78**	0.000	0.045	0.177
Total LM (kg)	44.97 ± 8.38	44.52 ± 8.78	0.393	42.97 ± 5.94	44.97 ± 8.38	0.064	0.930	<0.001
Total FM (kg)	23.91 ± 5.16	21.48 ± 4.52**	0.001	26.58 ± 6.60	22.16 ± 5.72**	0.000	0.026	0.223
Trunk LM (kg)	20.58 ± 3.93	20.36 ± 3.98	0.517	19.30 ± 2.98	19.30 ± 3.12	0.993	0.668	0.090
Trunk FM (kg)	12.52 ± 3.70	10.85 ± 2.97**	0.001	13.77 ± 3.43	11.00 ± 3.13**	0.000	0.043	0.182
Abdominal LM (kg)	10.61 ± 1.98	10.26 ± 2.08	0.282	9.97 ± 1.28	9.72 ± 1.65	0.235	0.802	0.003
Abdominal FM (kg)	5.60 ± 1.61	4.75 ± 1.38**	0.000	5.81± 1.39	4.74 ± 1.35**	0.000	0.287	0.054
Arm LM (kg)	4.25 ± 0.96	4.17 ± 0.97	0.244	4.18 ± 0.85	4.11 ± 0.85	0.318	0.943	<0.001
Arm FM (kg)	2.45 ± 0.49	2.23 ± 0.47*	0.014	2.53 ± 0.87	2.25 ± 0.66**	0.006	0.629	0.011
Leg LM (kg)	17.54 ± 3.36	17.65 ± 4.03	0.701	17.06 ± 2.35	16.73 ± 2.19*	0.022	0.207	0.075
Leg FM (kg)	7.77 ± 1.34	7.16 ± 1.32**	0.001	8.79 ± 2.43	7.44 ± 1.97**	0.000	0.015	0.252

Significant difference from pre-intervention at * $p < 0.05$ and ** $p < 0.01$. Exe: concurrent training group; Exe + Edu: concurrent training and health education group; BMI: body mass index; BF%: body fat percentage; LM: lean mass; FM: fat mass.

Table 5
Blood outcomes before and after 8 weeks of intervention.

	Exe ($n = 12$)			Exe + Edu ($n = 12$)			Group effect	
	Pre	Post	p	Pre	Post	p	p	η^2
FG (mmol•l^{-1})	6.16 ± 1.28	5.09 ± 0.69*	0.011	6.08 ± 0.86	5.07 ± 0.67**	0.000	0.999	0.000
CHOL (mmol•l^{-1})	5.14 ± 1.15	4.47 ± 1.07*	0.016	4.85± 0.53	4.24 ± 0.37**	0.000	0.870	0.001
HDL-C (mmol•l^{-1})	1.11 ± 0.22	1.29 ± 0.15**	0.000	1.18 ± 0.17	1.40 ± 0.16**	0.000	0.092	0.129
LDL-C (mmol•l^{-1})	2.81 ± 0.87	2.58 ± 0.85	0.171	2.46 ± 0.40	2.24 ± 0.42	0.109	0.632	0.011
Apo A (g•l^{-1})	1.15 ± 0.20	1.42 ± 0.22**	0.000	1.08 ± 0.18	1.34 ± 0.22**	0.008	0.596	0.014
Apo B (g•l^{-1})	0.83 ± 0.10	0.74 ± 0.09**	0.000	0.83 ± 0.09	0.75 ± 0.10**	0.003	0.853	0.002
TG (mmol•l^{-1})	1.93 ± 0.54	1.41 ± 0.41**	0.009	2.28 ± 0.66	1.42 ± 0.45**	0.001	0.664	0.009
Insulin (μIU)	15.30 ± 0.84	14.26 ± 0.59**	0.000	14.76 ± 0.79	13.97 ± 0.71**	0.000	0.769	0.004
Leptin (ng•ml^{-1})	5.69 ± 0.66	5.61 ± 0.66	0.407	5.85 ± 0.67	5.82 ± 0.67	0.077	0.575	0.015
Progesterone (pg•ml^{-1})	90.08 ± 4.13	83.68 ± 3.75**	0.001	90.40 ± 8.07	82.86 ± 6.27**	0.000	0.999	0.000

Significant difference from pre-intervention at * $p < 0.05$ and ** $p < 0.01$. Exe: concurrent training group; Exe + Edu: concurrent training and health education group; FG: fasting glucose; CHOL: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; Apo A: apolipoprotein A; Apo B: apolipoprotein B; TG: triglyceride.

concurrent training for losing weight and FM.

This study also explored the effects of concurrent training combined with health education on glycolipid regulation and related hormones, finding that in both groups the glucose, CHOL, LDL-C, Apo B and TG levels decreased by 7.2–34.0%, the HDL-C and Apo A concentrations increased by 18.6–26.5%, and also that the serum insulin and progesterone levels decreased significantly. The combination of health education and nutrition management failed to trigger additional benefits on blood profiles, indicating that the improvements of glycolipid regulation and hormone levels are mainly attributed to concurrent training rather than to health education. Using different concurrent training protocols, similar beneficial effects of concurrent training on cardiovascular risk factors have previously been reported in obese adults and adolescents, such as decreased fasting glucose, CHOL, LDL-C, Apo B and TG levels and increased HDL-C and Apo A [6,11,15,28]. In contrast, short-term (12 weeks, 3 days/week) concurrent training failed to detect statistical differences on glucolipid metabolism has also been reported due to small sample size ($n = 6$ in each group) [15]. Both LDL-C and Apo B are recognized predictors for cardiovascular disease, whereas high levels of HDL-C can compensate for some of the harmful effects of LDL-C [29]. Therefore, the decrease of "bad blood lipids" and the increase of "good blood lipids", as well as better glycaemic control caused by the concurrent training, can help to reduce the risks of cardiovascular disease in obese young females. Insulin is a well-known anabolic hormone that facilitates lipogenesis and inhibits lipolysis, whereas progesterone can increase the insulin basal level and also promote fat storage [30]. Therefore, the exercise-induced reduction in circulating insulin and progesterone levels may have partly contributed to the loss of total and regional FM in the present study. However, there was no difference between the Exe and Exe + Edu groups in improving the above-mentioned indicators. The lack of differential effects of health education and nutrition management may be due to the short-term

Table 6
Change in outcomes after intervention.

	Exe (n = 12)	Exe + Edu (n = 12)	ES (d)	*A posteriori* power data
Δ Body mass (kg)	−2.47 ± 2.46	−5.19± 1.87	1.25	0.833
Δ BMI (kg•m^{-2})	−0.90 ± 0.90	−1.97 ± 0.79	1.26	0.833
Δ BF% (%)	−2.25 ± 1.48	−4.33 ± 2.39	1.05	0.691
Δ Total LM (kg)	0.44 ± 1.72	−0.44 ± 0.74	0.00	0.050
Δ Total FM (kg)	−2.44 ± 1.71	−4.42 ± 1.83	1.13	0.753
Δ Trunk LM (kg)	−0.22 ± 1.16	0.00 ± 0.94	0.21	0.078
Δ Trunk FM (kg)	−1.67 ± 1.21	−2.77 ± 1.09	0.95	0.604
Δ Abdominal LM (kg)	−0.35 ± 1.08	−0.25 ± 0.68	0.12	0.059
Δ Abdominal FM (kg)	−0.84 ± 0.49	−1.07 ± 0.47	0.48	0.203
Δ Arm LM (kg)	−0.08 ± 0.24	−0.08 ± 0.25	0.04	0.051
Δ Arm FM (kg)	−0.22 ± 0.26	−0.28 ± 0.29	0.23	0.084
Δ Leg LM (kg)	0.12 ± 1.02	−0.33 ± 0.43	0.57	0.267
Δ Leg FM (kg)	−0.61 ± 0.49	−1.35 ± 0.69	1.23	0.821
Δ FG (mmol•L^{-1})	−1.07 ± 1.20	−1.01 ± 0.61	0.06	0.052
Δ CHOL (mmol•L^{-1})	−0.67 ± 0.82	−0.61 ± 0.36	0.10	0.056
Δ HDL-C (mmol•L^{-1})	0.18 ± 0.12	0.21 ± 0.05	0.34	0.125
Δ LDL-C (mmol•l^{-1})	−0.22 ± 0.53	−0.22 ± 0.44	0.00	0.050
Δ ApoA (g•L^{-1})	0.27 ± 0.15	0.26 ± 0.28	0.03	0.051
Δ ApoB (g•L^{-1})	−0.09 ± 0.03	−0.09 ± 0.08	0.06	0.052
Δ TG (mmol•L^{-1})	−0.52 ± 0.57	−0.86 ± 0.64	0.55	0.252
Δ Insulin (μIU)	−1.04± 0.64	−0.79 ± 0.32	0.51	0.223
Δ Leptin (ng•ml^{-1})	−0.08± 0.32	−0.03 ± 0.06	0.20	0.076
Δ Progesterone (pg•ml^{-1})	−6.40± 4.80	−7.54 ± 3.14	0.28	0.101

Exe: concurrent training group; Exe + Edu: concurrent training and health education group; ES: effect size; BMI: body mass index; BF%: body fat percentage; LM: lean mass; FM: fat mass; FG: fasting glucose; CHOL: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; Apo A: apolipoprotein A; Apo B: apolipoprotein B; TG: triglyceride.

follow-up. As the change from cognition to behaviour requires time and practice to develop and play a role in real life, health education may take longer to show its effect. Therefore, future studies of similar design may obtain more information about changes in behaviour and cardiovascular risk indicators through multiple follow-up tests after intervention (e.g. retest the outcome variables after 2 months or more).

Data are lacking regarding regional morphological changes among obese Chinese females after exercise training. This study employed DEXA to assess changes in whole body and regional (i.e. trunk, abdominal, arms and legs) FM and LM, which provided more accurate evidence for the influence of concurrent training, as well as health and nutrition education on distributions of body fat and fat-free mass. However, this study also has several limitations. Firstly, although participants were required to maintain their daily routines and not to take extra exercise, the Exe group also being required to keep a normal diet during the intervention, these potential confounding factors were not strictly monitored and recorded in this pilot study, which may affect the interpretation of the results. Secondly, given the small sample size of the present study, Cohen's d values and *posteriori* power data were calculated to present the effect sizes and statistical power for the main outcome variables (Table 6). The results showed that the d values/*posteriori* power for body mass, BMI, BF% and total FM were 1.25/0.833, 1.26/0.833, 1.05/0.691 and 1.13/0.753, respectively, which present large effect sizes and statistical power. Therefore, the observed differences in weight and FM loss between the Exe and Exe + Edu groups are real rather than type II errors. Thirdly, cognition–behaviour changes were not monitored in the present study. Given the obtained benefits in weight loss, future health and nutrition education interventions carried out should be analysed in depth. Cognition–behaviour changes such as level of knowledge, attitudes, eating habits and physical activity time should be assessed and monitored to explain the cause for the greater loss in body mass and FM. Lastly, this study only includes young obese women, therefore the findings of this study may not be sufficient to infer other populations. For future studies aimed at controlling obesity, it is better to carry out long-term projects managed in the form of residential camps in larger population groups, and to use standardized meals and standardized concurrent training protocols, in order to more strictly control the confounding factors.

5. Conclusion

The 8-week concurrent training intervention was effective at improving body composition, fasting glucose, blood lipids and obesity-related hormones in obese Chinese females, which is of significance in reducing the risks of cardiovascular disease. The multicomponent intervention (i.e. the combination of concurrent training and health and nutrition education) achieved better body composition outcomes than concurrent training alone, despite the health and nutrition education failing to show additional benefits for glycolipid regulation and related hormones. Therefore, health and nutrition education should be introduced into weight-control programmes to alleviate knowledge inequalities and promote more effective weight control.

Author contributions

Y.H., X.D., L.X., X.C. and S.S. conceptualized and designed the study; X.D., L.X. and X.C. administrated the project and data collection; Y.H. and S.S. coordinated and supervised data collection; X.D., L.X. and X.C. performed data analysis; Y.H. acquired funding support; Y.H. and S.S. drafted the initial manuscript; and S.S. critically reviewed and revised the manuscript. All the authors read and approved the final version of the manuscript.

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Declaration of competing interest

The authors declare no conflicts of interest.

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