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Effects of intermittent dieting with ad-libitum break periods on body composition and metabolic adaptation in physically inactive females with obesity: A randomized controlled trial

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Abstract

Background

Continuous energy restriction (CER), the conventional weight-loss approach, often induces metabolic adaptation, mood disturbances, and poor long-term adherence. Intermittent dieting incorporating short breaks with ad libitum energy intake (INTB-AdI)—commonly termed “cheat meals”—have gained popularity in fitness communities as a potentially viable weight reduction strategy to attenuate these negative effects. This three-arm randomized controlled trial investigated the effects of INTB-AdI on body composition and metabolic adaptation, as compared to the CER approach.

Methods

77 physically inactive females aged 18–35 years with obesity were randomized to 8 weeks of either: (1) CER with 70% energy balance daily (n = 26), (2) INTB-AdI with 70% energy balance on 5 days/week and 2 ad libitum feeding days/week (n = 26), or (3) control group (CON) maintaining habitual diet (n = 25). Physiological outcomes including body weight as the primary outcome were assessed at baseline, post- intervention, and at 3-month follow up.

Results

During the 8-week intervention, both CER and INTB-AdI resulted in significant weight loss compared to CON (CER: mean difference [95% Confidence Interval] − 2.8 kg [− 3.5 to − 2.0]), P < 0.001; INTB-AdI: −3.1 kg [− 3.9 to − 2.3], P < 0.001), with no differences between CER and INTB-AdI (P = 0.792). Resting metabolic rate (RMR) decreased significantly more in CER than in INTB-AdI (-69.9 kcal [− 114.3 to − 25.5], P < 0.001). Improvements in certain cardiometabolic health markers were observed in CER only. However, a small regain of body mass (P = 0.035) and fat mass (P = 0.006) 3-month post intervention was seen in INTB-AdI only.

Conclusions

Both 8-week CER and INTB-AdI interventions led to significant weight loss, with INTB-AdI attenuating the adaptive reduction in RMR more effectively than CER. However, INTB-AdI did not produce significant improvements in cardiometabolic markers, and its efficacy for post-diet weight maintenance remains uncertain. Further research is warranted to evaluate its long-term effectiveness and potential health implications.

Introduction

Obesity has been an alarming public health issue worldwide, with the World Health Organization (WHO) classifying it as an epidemic responsible for over 2.8 million deaths annually [1]. Weight reduction has been shown to mitigate associated metabolic diseases [2, 3]. The conventional approach - continuous energy restriction (CER) involves sustained energy deficits whereby energy intake remains consistently below expenditure, leading to a significant weight loss [4]. However, persistent energy restriction induces a series of physiological responses in the human body, notably a decline in resting metabolic rate (RMR) known as metabolic adaptation [5]. It may reduce efficiency of weight loss and increases the likelihood of weight rebound. Additionally, extended dieting periods may provoke adverse psychological effects, including irritability, mood swings, and decreased adherence, which may ultimately impede weight management efforts [5, 6].

Rather than a continuous approach, intermittent dieting with break periods (INTB) has gained popularity within fitness communities [7–9]. This strategy involves intermittent break periods that elevates energy intake to varying degrees, frequencies, and durations, including “diet breaks” lasting from 4 days to several weeks, and “refeeds” lasting 1–3 days, both with energy intake targeted at a neutral energy balanced level [7, 8, 10]. It has been proposed that INTB strategies may preserve metabolic rate and provide psychological relief during dieting [7–9, 11, 12].

A specific form of INTB, commonly referred to as “cheat meals” or “cheat days”, is characterized by a relaxed, ad-libitum energy intake (INTB-AdI) without specific energy or macronutrient targets, often involving indulgence in energy-dense foods, either within a single meal or across multiple days, such as weekends [10]. The prominence of cheat meals is exemplified by their extensive presence on social media platforms, with over 1.6 million images tagged “cheat meal” on Instagram (Meta Platforms, California, United States) [13]. Furthermore, a study involving over two thousand Canadian adolescents and young adults reported that more than half engaged in cheat meals at least once weekly over the course of a year [14]. A recent scoping review suggests that cheat meals may facilitate effective weight loss, however the evidence concerning their effect on mitigating metabolic adaptation remains inconclusive [10]. Nevertheless, concerns persist regarding the potential adverse psychological implications of cheat meals. While they may serve as goal-directed behaviors that positively influence eating habits [15], they may also contribute to disordered eating patterns or exacerbate pre-existing eating disorders [14, 16].

Existing experimental trials examining INTB-AdI remain limited and of low evidentiary quality as indicated by the scoping review [10]. Two studies were conducted on bodybuilders and were constrained by small sample sizes, with one lacking a comparison arm [17] and the other a control group [18]. In addition, one study contained clear methodological errors [19], while another had high risk of bias [20]. Given the popularity of cheat meals, alongside the limited scientific evidence supporting their purported benefits and the potential for harm—particularly among young individuals heavily influenced by social media—there is an urgent need for high-quality randomized controlled trials with robust study designs in this area.

The present 3-arm randomized controlled trial aims to rigorously examine the physiological and psychological outcomes associated with INTB-AdI compared with CER in physically inactive individuals with obesity. The primary objective was to investigate the effect of an 8-weeks intermittent diet with ad libitum intake on body composition and metabolic adaptation among young females with obesity during weight reduction. Our goal was to evaluate whether INTB-AdI may serve as a feasible and safe alternative to traditional CER for weight management while providing insights to inform more effective interventions against the global obesity epidemic.

Methods

Study design

The study was a three-arm, repeated measures randomized controlled trial conducted at a single research facility in Hong Kong from November 2025 to March 2026. Participants were randomly allocated to 3 groups: (1) a continuous energy-restricted diet (CER); (2) an intermittent diet including 2 consecutive days of ad libitum intake within a week of energy restriction (INTB-AdI); and (3) a control group maintaining their habitual diet (CON). Assessments were conducted at baseline (pre-intervention), at the end of the 8-week intervention (post-intervention), and after a 3-month follow-up period. Ethical approval was obtained from the Human Research Ethics Committee of the Education University of Hong Kong (reference number: A2024-2025-0346-01), and the study was registered at the Chinese Clinical Trial Registry (registration number: ChiCTR2500112339). The reporting of this trial follows the Consolidated Standards of Reporting Trials (CONSORT) 2025 guidelines [21].

Recruitment and randomization

Participants were recruited from the general community through advertisement posters on social media platforms, community outreach and referrals. Initial screening was conducted via a questionnaire assessing obesity status, overall health, and physical activity levels. Eligible individuals were invited for subsequent in-person evaluation at the laboratory. Those meeting the eligibility criteria received detailed study information and provided written informed consent prior to enrollment. Randomization into one of the 3 groups in a 1:1:1 ratio was conducted using an online random number generator. Allocation concealment was ensured through the use of sequentially numbered, opaque, sealed envelopes managed by an independent researcher, thereby minimizing selection bias. Due to the nature of the intervention, participants and the registered dietitian could not be blinded to the intervention assignment.

Participants

Inclusion criteria were as follows: female Chinese adults (age 18–35 years) with obesity (BMI ≥ 25 kg/m^2); physically inactive (< 150 minutes of moderate-intensity activity or < 75 minutes of vigorous-intensity activity per week assessed by the International Physical Activity Questionnaire (IPAQ)) [22]; weight stable (± 2 kg) for 6 months prior to participation; willing to use smartphone application to log dietary intake daily. Exclusion criteria were as follows: pregnancy or lactating women, history of eating disorders, psychological disorders, chronic illnesses or other health problems that may affect participation; and recent engagement (within the past 12 months) in any dietary interventions for weight management.

Sample size

The required sample size was estimated with the assumption of an F-test for repeated measures ANOVA with a within-between interaction. An effect size (f = 0.25) was derived from a previous study that examined and compared the effects of INTB versus CER in females over a 6–8 week period [23]. A total sample size of 54 participants, with 18 participants per group, was deemed adequate to detect differences between groups concerning the primary outcome (i.e., body weight), with a statistical power of 90% at a two-sided significance level of $\alpha = 0.05$, as calculated using G*power software (version 3.1) [24]. To accommodate an anticipated dropout rate of 25%, the study aimed to enroll a total of 69 participants, with 23 participants allocated to each of the 3 groups.

CER group

Participants assigned to the CER group were instructed to follow a diet set at a daily 30% energy restriction for 8 weeks. Indirect calorimetry was used to measure RMR, which was then multiplied by a physical activity level (PAL) of 1.4, consistent with sedentary activity and minimal leisure

exertion [25], to determine individual energy balance. A registered dietitian prescribed a healthy meal plan according to the Hong Kong government's healthy eating guideline [26], meeting the calculated energy intake target with macronutrient distribution comprising 25% fat, 25% protein, and 50% carbohydrates (Sample meal plans are illustrated in Supplement S1). Participants were instructed to track their food intake daily using the smartphone application MyFitnessPal (Francisco Partners, Austin, United States), which has been validated for dietary assessment and self-monitoring efficacy [27]. To ensure proper food logging techniques and adherence to meal plan, participants received a tutorial video with dietitian's instructions, and were supported by informational materials. All participants had to demonstrate competency and familiarization in food logging through a sample day of meal entry using the app, and were assessed by the dietitian before they commenced the intervention. During the intervention, daily food logging was instructed to be completed by the end of each day, with data synchronization allowing real-time support and monitoring of adherence. Feedback was provided by the dietitian via smartphone communication application WhatsApp (Meta Platforms, California, United States) twice a week, and any suspected inaccuracies prompted participants to submit meal photographs immediately. Adherence was defined as a self-reported daily energy intake within ± 10% of energy target for > 95% of energy-restricted days (i.e. ≤ 3 days of non-adherence out of 8 weeks). This stringent criterion was applied to preserve the intended contrast between the CER and INTB-AdI groups. Any energy intake or macronutrient off target was promptly communicated to participants with advice to improve adherence. Participants also recorded their fasted morning body weight daily on a synchronized Google sheet to monitor progress. At week 5, the energy target was reduced by 5% to account for potential reductions in RMR during weight loss[28] to maintain the desired energy deficit. Additionally, they were asked to maintain their habitual sedentary physical activity levels, assessed via the online IPAQ every 4 weeks.

INTB-AdI group

Participants in the INTB-AdI group followed the prescribed diet and food logging protocols as per the CER group for 5 days in a week (Monday to Friday). The remaining 2 days (Saturday and Sunday) were designated as ad libitum feeding days, during which food logging on MyFitnessPal was suspended to minimize energy intake calculations; instead, participants recorded detailed written food records. Almost all ad libitum feeding days were set on Saturday and Sunday, with the exception of 2 participants where the ad libitum days were tailored to align with their work schedule. Participants were asked to maintain their habitual sedentary physical activity levels, assessed via the online IPAQ every 4 weeks.

CON group

Participants assigned to the CON group were instructed to maintain their usual dietary habits and sedentary physical activity levels throughout the study duration. They did not receive any specific dietary guidance during this period. Weekly check-ins were conducted to confirm continued participation and adherence.

3-month follow-up

After post-intervention assessments, participants in both CER and INTB-AdI groups were provided with healthy eating advice and a sample meal plan set at 100% of their energy target by the dietitian for reference to support weight maintenance, and physical activity was permitted in any form. They were asked to return after 3 months for a follow-up assessment.

Outcomes

Pre- and post-intervention assessments were conducted to evaluate various outcome measures. All sessions took place in the morning hours between 9am and 12pm. Participants were instructed to arrive following an overnight fast of 10–12 hours, and to abstain from exercise, caffeine, and alcohol for at least 24 hours prior to each session. For the INTB-AdI group, the final ad libitum feeding days were scheduled at least 2 days prior to post-intervention assessments to prevent any potential acute effects on outcome measurements. They were instructed to continue with the prescribed energy-restricted diet until post-intervention assessments were completed. The outcome assessor was blinded to group allocation throughout the assessment of outcomes.

Primary outcome

Body mass was assessed using a bioelectrical impedance analyzer (MC-780 MA, Tanita, Japan). Participants wore light, form-fitting attire and were barefoot during the measurement, with a constant deduction of 0.2 kg applied to account for clothing weight. Prior to the measurement, they were asked to void their bladder before the measurement. Participants' date of birth, gender, and height were entered into the analyzer.

Secondary outcomes

Additional body composition assessments were conducted: Height was measured with participants standing upright against a wall, to the nearest 0.1 cm using a stadiometer (Seka, Leicester, UK). Fat mass, body fat percentage, and fat-free mass (FFM) were assessed via the same bioelectrical impedance analyzer (MC-780 MA, Tanita, Japan), which has been validated against dual-energy x-ray absorptiometry [29]. BMI was

calculated using the standard formula: BMI = weight (kg) / height (m)². Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest with a tension tape accurate to 0.1 cm [30].

RMR was determined through indirect calorimetry using an integrated metabolic measurement system (QUARK RMR, Cosmed, Rome, Italy), which its accuracy has been validated for normal and overweight adults [31]. The metabolic measurement system was calibrated prior to each testing session. Participants rested supine under a canopy hood in a dark and quiet environment for 30 mins. The first 5-minute interval was discarded and the 5-minute steady-state period defined as the coefficients of variation (CV ≤ 10%) for both VO_2 and VCO_2 was recorded to determine RMR [32].

Fasting capillary blood samples (40µl each) were obtained via fingerstick to measure lipid profile (including total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), LDL/HDL ratio (LDL/HDL), and fasting glucose (FG) using the analyzer (Cholestech LDX Analyzer, Abbott, United States). Its accuracy has been validated against venous samples [33, 34]. Blood pressure was measured after a 10-minute rest using a clinical automatic blood pressure monitor (M7 Intelli IT, Omron, Japan). The cuff was placed around the participant's brachial artery (left arm), and systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded.

Dietary intake was self-reported using the MyFitnessPal smartphone application. A validated 3-day food record (comprising 2 weekdays and 1 weekend day) was completed at baseline for all participants and post-intervention for the control group [35]. Detailed food records were also taken during ad libitum feeding days. Completed dietary records were analyzed by a registered dietitian utilizing the online nutrition database provided by the Centre for Food Safety, Hong Kong (available at http://www.cfs.gov.hk/) and the United States Department of Agriculture (USDA) FoodData Central (available at http://fdc.nal.usda.gov/), to assess energy and macronutrients intake.

The validated 100-mm Visual Analogue Scale (VAS) [36] was used to assess the subjective appetite. This scale comprised items anchored by descriptors representing the extremes of hunger, fullness, satiety and prospective food consumption. A composite satiety score (CSS) was derived from these measures using the following formula [37]:

CSS = [Satiety + Fullness + (100 - Prospective Food Consumption) + (100 - Hunger)] / 4

Additionally, participants completed questions (adapted from Coelho de Vale et al., 2016 [15]) to assess the motivation to adhere to the dietary intervention protocols. The questions included: (1) How hungry do you feel? ('not hungry' to 'very hungry'); (2) How full do you feel? ('not full at all' to 'very full'); (3) How satisfied do you feel? ('completely empty' to 'I cannot eat more'); (4) How much food do you think you could eat now? ('nothing at all' to 'a lot'); (5) How motivated are you to strictly follow this plan? ('not motivated at all' to 'very motivated'); and (6) For how long do you think you can keep on this diet plan? ('for a little time' to 'for a very long time'). These measurements were conducted at baseline weekly (on non-ad libitum feeding days) and post-intervention, in a fasted state to standardize measurement conditions. This approach provides a reliable marker of changes in appetite and motivation over time while minimizing participant burden. However, the findings may not fully generalize to postprandial states.

The 18-item Three Factors Eating Questionnaire (TFEQ-R18) [38] was used to assess 3 domains of eating behavior: cognitive restraint, uncontrolled eating, and emotional eating. Responses were recorded on a 4-point Likert scale at baseline and post-intervention.

3-month Follow up

Participants in the CER and INTB-AdI groups were asked to return after 3 months of their intervention for a fasted morning assessment. Outcomes measured included body mass, BMI, fat mass, FFM, waist circumference, TFEQ-R18, VAS-derived metrics for CSS and motivation.

Statistical Analyses

Data were expressed as mean ± standard deviation (SD). Changes were estimated with 95% Confidence Intervals (CI). An intention-to-treat approach was employed including all randomized participants in the analyses. A linear mixed model with random intercepts was utilized to evaluate the effects of time (pre-intervention vs post-intervention vs follow-up), group (CER, INTB-AdI, or control), and the group-by-time interaction on each outcome measure. Time, group, and group-by-time interaction were treated as fixed effects, while participant was included as a random effect. No imputation was performed for missing data as the mixed model approach inherently handle missing data flexibly. Baseline values were adjusted to account for baseline differences between groups. In addition, RMR was adjusted for FFM as a covariate. Bonferroni correction was applied to correct for multiple comparisons. Extreme outliers in body fat percentage, fat mass, and FFM at the post-intervention measurement were excluded for a participant in the CER group. In addition, machine error resulted in missing LDL, HDL, and LDL/HDL values at baseline (CER: n = 2; INTB-AdI: n = 1). All statistical analyses were performed using SPSS, version 30.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at $P < 0.05$.

Results

Participants

A total of 77 eligible female participants were enrolled in the trial, with 64 participants (83.1%) adhering to the 8-week intervention. 3 participants in the CER group and 4 in INTB-AdI group did not adhere to the dietary protocol. Additionally, 6 participants withdrew due to unrelated illnesses, lost to contact, or dissatisfaction with group allocation. The participant flow throughout the trial is illustrated in Fig. 1. No adverse events were reported during the trial. Baseline characteristics including age, height, body mass, BMI, body fat percentage, fat mass, FFM, waist circumference, RMR, daily energy intake, macronutrient distribution (carbohydrate, protein, and fat percentage), and physical activity levels (moderate to vigorous physical activity (MVPA) and metabolic equivalents (METs)) are detailed in Table 1, with no significant differences observed among groups. MVPA was low across all groups, with averages < 30 minutes per week. Similarly, average METs were < 600 MET-minutes per week for all groups, indicating a low level of physical activity from baseline.

Table 1
Baseline Characteristics of Participants

Characteristic	**Participants (N = 77)**		
	CER (n = 26)	**INTB-AdI (n = 26)**	**CON (n = 25)**
Age, years	29.8 ± 3.8	29.8 ± 3.4	29.8 ± 4.0
Height, cm	162.8 ± 5.9	160.1 ± 5.7	160.8 ± 5.0
Body mass, kg	75.3 ± 10.0	75.2 ± 12.1	74.5 ± 10.7
Body mass index, kg/m^2	28.5 ± 3.5	29.2 ± 3.4	28.8 ± 3.5
Body fat percentage, %	41.3 ± 5.1	41.5 ± 4.8	41.5 ± 4.3
Fat mass, kg	31.5 ± 8.2	31.7 ± 8.6	31.2 ± 8.0
Fat free mass, kg	43.8 ± 3.3	43.5 ± 4.3	43.2 ± 3.4
Waist circumference, cm	85.1 ± 9.1	85.2 ± 8.2	84.6 ± 7.4
Resting metabolic rate, kcal	1404.5 ± 154.4	1365.3 ± 186.8	1414.2 ± 198.1
Energy intake, kcal	1678.9 ± 295.2	1796.7 ± 481.5	1765.0 ± 399.5
Carbohydrate percentage, %	45.3 ± 7.9	44.1 ± 6.0	41.0 ± 7.1
Protein percentage, %	19.0 ± 4.6	18.9 ± 3.9	20.2 ± 3.8
Fat percentage, %	35.3 ± 6.4	36.7 ± 5.1	38.8 ± 5.4
MVPA, min/week	20.0 ± 45.2	18.7 ± 37.1	25.2 ± 34.4
METs, MET-min/week	551.7 ± 454.9	549.0 ± 602.5	539.2 ± 628.7

Data are presented as mean ± standard deviation. Abbreviations: CER continuous energy restricted group; CON, control group; INTB-AdI, intermittent dieting with ad libitum intake group; METs, metabolic equivalents; MVPA, moderate-to-vigorous physical activity.

Body mass

The primary outcome of this study was body mass. The changes in body mass over the 8-week intervention are illustrated in Fig. 2. Both CER and INTB-AdI groups demonstrated significantly greater reductions in body mass compared to CON (CER vs. CON: −2.8 kg [− 3.5 to − 2.0]; P < 0.001; INTB-AdI vs. CON: −3.1 kg [− 3.9 to -2.3]; P < 0.001). However, there was no significant difference in body mass reduction between the CER and INTB-AdI groups (0.4 kg [− 0.4 to 1.1]; P < 0.792) (Table 2).

Table 2
Data Related to Anthropometric Measurements, Resting Energy Expenditure and Cardiometabolic Health Parameters

	Measurement	Group	Baseline		Post-intervention		Difference (group x time)					
							Compared with CON			Compared with INTB-AdI		
			n	Mean ± SD	n	Mean ± SD	Estimated effect	95% CI	P value	Estimated effect	95% CI	P value
Anthro-pometric measurements	Body mass, kg	CON	25	74.5 ± 10.7	21	73.1 ± 9.2						
		CER	26	75.3 ± 9.8	24	71.7 ± 10.7**	-2.8	-3.5 to -2.0	**< 0.001**	0.4	-0.4 to 1.1	0.792
		INTB-AdI	26	75.2 ± 12.1	21	70.8 ± 11.5**	-3.1	-3.9 to -2.3	**< 0.001**			
	Body mass index, kg/m^2	CON	25	28.8 ± 3.5	21	28.2 ± 3.2						
		CER	26	28.5 ± 3.4	24	26.9 ± 3.5**	-1.0	-1.4 to -0.8	**< 0.001**	0.2	-0.1 to 0.5	0.479
		INTB-AdI	26	29.2 ± 3.4	21	27.7 ± 3.5**	-1.2	-1.5 to -0.9	**< 0.001**			
	Body fat percentage, %	CON	25	41.5 ± 4.3	21	40.6 ± 4.0						
		CER	26	41.3 ± 5.0	23	39.1 ± 5.8**	-1.4	-2.0 to -0.8	**< 0.001**	-0.3	-0.8 to 0.3	0.692
		INTB-AdI	26	41.5 ± 4.8	21	39.7 ± 5.3**	-1.1	-1.7 to -0.6	**< 0.001**			
	Fat mass, kg	CON	25	31.2 ± 8.0	21	30.0 ± 6.8						
		CER	26	31.5 ± 8.0	23	28.5 ± 8.8**	-2.0	-2.7 to -1.4	**< 0.001**	0.0	-0.6 to 0.7	1.000
		INTB-AdI	26	31.7 ± 8.6	21	28.6 ± 8.3**	-2.1	-2.7 to -1.4	**< 0.001**			
	Fat free mass, kg	CON	25	43.2 ± 3.4	21	43.2 ± 3.2						
		CER	26	43.8 ± 3.2	23	43.0 ± 3.7**	-0.7	-1.1 to -0.3	**< 0.001**	0.3	-0.1 to 0.7	0.226
		INTB-AdI	26	43.5 ± 4.3	21	42.2 ± 4.0**	-1.0	-1.5 to -0.6	**< 0.001**			
	Waist circumference, cm	CON	25	84.6 ± 7.4	21	83.1 ± 7.6						
		CER	26	85.1 ± 8.9	24	81.4 ± 8.4**	-2.1	-3.3 to -0.8	**< 0.001**	0.5	-0.7 to 1.8	0.928
		INTB-AdI	26	85.2 ± 8.2	21	82.0 ± 8.8**	-2.6	-3.9 to -1.3	**< 0.001**			

Data are presented as mean ± standard deviation. Bold P-values indicate a significant main effect of group-by-time interaction (P < 0.05), calculated from linear mixed-model analyses adjusting for baseline outcome values. A significant pairwise within group difference over time with one asterisk (*) indicates P < 0.05 and two asterisks (**) indicate P < 0.01. Abbreviations: CER continuous energy restricted group; CON, control group; INTB-AdI, intermittent dieting with ad libitum intake group; LDL, low-density lipoprotein cholesterol; LDL/HDL, low-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio.

	Measurement	Group	Baseline		Post-intervention		Difference (group x time)					
							Compared with CON			Compared with INTB-AdI		
Resting energy expenditure	Resting metabolic rate, kcal	CON	25	1414.2 ± 198.1	21	1409.0 ± 158.0						
		CER	26	1404.5 ± 151.4	24	1316.9 ± 150.1**	-97.9	-142.1 to -53.8	**< 0.001**	-69.9	-114.3 to -25.5	**< 0.001**
		INTB-AdI	26	1365.3 ± 186.8	21	1325.6 ± 128.4	-28.0	-73.8 to 17.8	0.422			
Cardio-metabolic health markers	Total Cholesterol, mmol/L	CON	25	4.60 ± 1.08	21	4.55 ± 1.01						
		CER	26	4.72 ± 0.97	24	4.47 ± 0.82*	-0.22	-0.51 to 0.07	0.205	-0.10	-0.39 to 0.19	1.000
		INTB-AdI	26	4.94 ± 1.06	21	4.77 ± 1.19	-0.12	-0.42 to 0.18	1.000			
	LDL, mmol/L	CON	25	2.58 ± 1.06	21	2.69 ± 0.91						
		CER	24	2.80 ± 0.97	24	2.60 ± 0.67*	-0.31	-0.57 to 0.04	**0.017**	-0.20	-0.46 to 0.07	0.241
		INTB-AdI	25	2.90 ± 1.08	21	2.82 ± 1.09	-0.11	-0.39 to 0.16	0.947			
	HDL, mmol/L	CON	25	1.22 ± 0.23	21	1.26 ± 0.19						
		CER	24	1.28 ± 0.38	24	1.25 ± 0.34	-0.04	-0.15 to 0.07	1.000	0.10	0 to 0.21	0.065
		INTB-AdI	25	1.42 ± 0.30	21	1.29 ± 0.33**	-0.14	-0.25 to -0.03	**0.005**			
	LDL/HDL	CON	25	2.18 ± 0.99	21	2.18 ± 0.83						
		CER	24	2.43 ± 1.15	24	2.25 ± 0.86**	-0.22	-0.44 to 0.01	0.067	-0.30	-0.53 to 0.07	**0.006**
		INTB-AdI	25	2.17 ± 1.00	21	2.24 ± 0.69	0.08	-0.15 to 0.31	1.000			
	Triglyceride, mmol/L	CON	25	1.77 ± 0.89	21	1.31 ± 0.51*						
		CER	26	1.65 ± 1.37	24	1.36 ± 0.77	0.11	-0.34 to 0.56	1.000	-0.11	-0.56 to 0.34	1.000
		INTB-AdI	26	1.59 ± 1.27	21	1.45 ± 0.59	0.22	-0.24 to 0.68	0.736			
	Fasting Glucose, mmol/L	CON	25	5.28 ± 0.33	21	5.26 ± 0.36						
		CER	26	5.20 ± 0.40	24	5.03 ± 0.41*	-0.20	-0.41 to	0.064	-0.14	-0.35 to	0.348

Data are presented as mean ± standard deviation. Bold P-values indicate a significant main effect of group-by-time interaction (P < 0.05), calculated from linear mixed-model analyses adjusting for baseline outcome values. A significant pairwise within group difference over time with one asterisk (*) indicates P < 0.05 and two asterisks (**) indicate P < 0.01. Abbreviations: CER continuous energy restricted group; CON, control group; INTB-AdI, intermittent dieting with ad libitum intake group; LDL, low-density lipoprotein cholesterol; LDL/HDL, low-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio.

	Measurement	Group	Baseline		Post-intervention		Difference (group x time)					
							Compared with CON			Compared with INTB-AdI		
								0.01			0.07	
		INTB-AdI	26	5.40 ± 0.50	21	5.26 ± 0.46	-0.07	-0.28 to 0.15	1.000			
	Systolic Blood Pressure, mmHg	CON	25	103.84 ± 11.08	21	104.43 ± 11.07						
		CER	26	108.23 ± 11.17	24	104.79 ± 9.72**	-4.23	-8.68 to 0.22	0.069	-1.96	-6.37 to 2.45	0.851
		INTB-AdI	26	109.77 ± 11.22	21	106.24 ± 11.97	-2.27	-6.85 to 2.31	0.696			
	Diastolic Blood Pressure, mmHg	CON	25	75.36 ± 7.47	21	74.33 ± 7.99						
		CER	26	78.58 ± 8.69	24	74.71 ± 7.77**	-3.10	-6.14 to -0.05	**0.045**	-3.02	-6.04 to 0	0.050
		INTB-AdI	26	79.58 ± 10.23	21	77.67 ± 8.23	-0.08	-3.22 to 3.06	1.000			

Data are presented as mean ± standard deviation. Bold P-values indicate a significant main effect of group-by-time interaction (P < 0.05), calculated from linear mixed-model analyses adjusting for baseline outcome values. A significant pairwise within group difference over time with one asterisk (*) indicates P < 0.05 and two asterisks (**) indicate P < 0.01. Abbreviations: CER continuous energy restricted group; CON, control group; INTB-AdI, intermittent dieting with ad libitum intake group; LDL, low-density lipoprotein cholesterol; LDL/HDL, low-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio.

Other body composition parameters

Changes in these body composition parameters are illustrated in Fig. 2. Compared to CON, significant group-by-time interaction effects were observed in several other body composition parameters for both the CER and INTB-AdI groups: BMI (P < 0.001), fat mass (P < 0.001), body fat percentage (P < 0.001), FFM (P < 0.001), and waist circumference (P < 0.001) (Table 2).

Resting energy expenditure (REE)

Changes in RMR are illustrated in Fig. 3. A significant group-by-time interaction effect was observed for RMR, with a significantly larger drop in CER compared to CON (-97.9 kcal [− 142.1 to -53.8], P < 0.001). In contrast, the RMR change observed in the INTB-AdI group was not significantly different from CON (-28.0 kcal [− 73.8 to 17.8], P = 0.422). The decrease in RMR was significantly greater in CER compared to INTB (P < 0.001) (Table 2). After adjusting for FFM as a covariate in the model, this difference between groups remained statistically significant (-71.3 kcal [-114.7 to -27.8], P < 0.001).

Cardiometabolic health parameters

The CER group resulted in greater reductions in LDL/HDL compared to the INTB-AdI group (-0.30 [− 0.53 to 0.07], P = 0.006). Relative to CON, CER significantly lowered LDL (-0.31 [-0.57, -0.04], P = 0.017). Within-group analyses revealed significant improvements in TC, LDL, LDL/HDL, FG, SBP, and DBP in the CER group only (all P < 0.05). Conversely, the INTB-AdI group exhibited no significant within-group changes, except for a notable decrease in HDL (P < 0.01) (Table 2). Changes in cardiometabolic health parameters are illustrated in Supplementary S2.

Energy and macronutrient intake

Both CER and INTB-AdI groups demonstrated substantial reductions in energy intake compared to CON (CER vs. CON: -256.6 kcal [-403.9 to -109.4], P < 0.001; INTB-AdI vs. CON: -176.5 kcal [-327.3 to -25.6], P = 0.016) at post-intervention. The difference in energy intake between CER and INTB-AdI was however not statistically significant (-80.2 kcal [-226.8 to 66.4], P = 0.560). Both interventions also led to a reduction in fat intake relative to CON (P < 0.001). Additionally, CER led to a large reduction in carbohydrate intake compared to CON (P = 0.029), whereas within-group reduction in carbohydrate intake was seen in INTB-AdI group (P < 0.01). Changes in protein intake (measured in grams) were not significant in either CER or INTB-AdI compared to the control group; however, changes of protein intake (expressed as percentage) increased significantly in both groups (P < 0.001) (Supplementary S1).

During ad libitum feeding days, the mean energy intake was 1913.4 kcal ± 422.4 (range: 644–4496 kcal), representing an increase of an average of 691.5 kcal compared to energy-restricted days (Table 3). Energy intake from fat accounted for 41.6% of the extra energy intake on ad libitum

days. Hence, fat intake contributed a higher proportion of total energy intake during ad libitum days (38.5% ± 2.8) compared to energy-restricted days (31.5% ± 3.0). Energy from carbohydrates also accounted 40.9% of the extra energy intake, while protein contributed 20.4%.

Table 3
Energy and macronutrient intake of INTB-AdI during energy-restricted days and ad libitum feeding days

Energy intake, kcal	**Energy-restricted days** *(n = 21)*	**Ad libitum feeding days** *(n = 21)*
	1221.9 ± 139.3	**1913.4 ± 422.4**
Carbohydrate percentage, %	44.9 ± 3.6	43.3 ± 3.4
Protein percentage, %	26.3 ± 1.9	18.3 ± 2.0
Fat percentage, %	28.7 ± 3.7	38.5 ± 2.8
Carbohydrate, g	137.5 ± 20.8	208.2 ± 52.6
Protein, g	80.2 ± 10.1	115.5 ± 25.1
Fat, g	38.9 ± 6.4	81.6 ± 18.2
Data are presented as mean ± standard deviation. Abbreviation: INTB-AdI, intermittent dieting with ad libitum intake group.		

Satiety, motivation, and eating behaviour

CSS was used to evaluate the changes in satiety levels, with no significant group-by-time interaction observed among all groups (P = 1.000). Motivation to adhere to prescribed diets, assessed via VAS also showed no significant interaction effect (P = 0.123). Regarding eating behaviour assessed through TFEQ-R18, cognitive restraint increased significantly (P < 0.001), and uncontrolled eating decreased significantly (P < 0.001) in both CER and INTB-AdI groups when compared to CON. No significant differences were observed between CER and INTB-AdI in these measures (P = 1.000). Scores for emotional eating did not differ among groups (P > 0.05); however only the CER group exhibited a significant reduction in emotional eating (P < 0.01) (Supplementary S1 & S2).

Follow up

At follow-up, no significant group-by-time interactions were observed for body mass between the CER and INTB-AdI groups. However fat mass (p = 0.002) and body fat percentage (P = 0.029) increased significantly in the INTB-AdI group compared to CER. Notably, increases in body mass, BMI, fat mass, and waist circumference were observed exclusively in the INTB-AdI group (p < 0.05). A significant reduction in cognitive restraint was noted in the INTB-AdI group relative to CER (-2.0 [-0.8 to -3.2], P = 0.001). No significant differences were found between groups in other eating behaviour measures including emotional eating and uncontrolled eating (P > 0.05). The CSS remained comparable across groups, but motivation to maintain weight dropped significantly in the INTB-AdI group only (P < 0.01), despite the absence of a significant group-by-time interaction compared to CER. Details of follow-up data are shown in Supplementary S1.

Adherence rate

The adherence rate was 84.6% for CER, with energy intake reaching 96.5% of the target. For INTB-AdI, adherence was 80.8%, with energy intake at 95.6% of the target during energy-restricted days. The control group maintained an adherence rate of 84.0%. During the 3-month follow up, there were 3 dropouts in both the CER and INTB-AdI groups, hence retention rate remained high at 86–88% in both groups during this period.

Discussion

This study evaluated and compared the effects of CER and INTB-AdI on body mass, body composition, RMR, and cardiometabolic health markers in physically inactive young women with obesity over an 8-week period. Despite the additional energy intake during the 2 days of ad libitum feeding/week in INTB-AdI, both CER and INTB-AdI interventions were effective in reducing body mass and other body composition parameters associated with adiposity. Notably, the INTB-AdI group demonstrated less attenuation of RMR, while improvements in cardiometabolic health markers were predominantly observed in the CER group. A small but significant regain in body mass and other body composition parameters during the follow up was seen in the INTB-AdI group only. High adherence rates across all groups, coupled with the absence of adverse effects, suggest that INTB-AdI may serve as a viable weight reduction strategy for addressing obesity concerns, but long-term efficacy and health implications warrants further investigations.

Over the 8-week intervention, CER and INTB-AdI achieved body mass reduction of 4.1% (3.1 kg) and 4.5% (3.4 kg), respectively. These reductions were close to the minimal clinically important difference (MCID) of > 5% body weight reduction [39], indicating both diet protocols' potential efficacy in promoting weight loss. Fat mass also decreased substantially in both groups by 2.5 kg. Expressed as a percentage of total weight

loss, the proportion of weight loss as FFM in the both INTB-AdI (26.5%) and CER (19.4%) were comparable to that reported in typical weight-loss studies [40], with no significant difference between the groups. Nevertheless, waist circumference, an indirect estimate of visceral fat, decreased notably by 3.2% (2.7 cm) and 3.8% (3.2 cm) in CER and INTB-AdI respectively, with no significant between-group difference.

A significant finding of the present study was the differential impact of two interventions on RMR. The CER group exhibited a greater reduction in RMR (− 69.9 kcal/day) compared to INTB-AdI. After adjusting for FFM as a covariate, the reduction in RMR remained significantly greater than INTB-AdI ($P < 0.001$). Our result aligns with the favourable mitigation of the compensatory reduction in RMR seen in other types of INTB (i.e. diet breaks/refeeds) when comparing to CER in prior evidence [7]. This attenuation in RMR may be mediated by the temporal reversal of suppressed hormones such as thyroid hormones, insulin, leptin and testosterone during ad libitum feeding days with elevated energy [9]. Given the "ad libitum" nature (i.e., without a specified energy target) of the 2 non-restricted days per week, it is of interest to examine whether energy intake was elevated on these days. The average energy intake during these feeding periods (1913.4 kcal) was close to estimated energy balance and did not constitute an exceedingly large surplus. This intake was comparable to the estimated REE of 1952.2 kcal measured via indirect calorimetry adjusted for PAL. Baseline energy intake, estimated from 3-day food records (1746.6 kcal) was 11.8% lower than this estimated requirement, consistent with previous research indicating underestimations of 7–20% with food record methods [41]. Furthermore, we observed that 56.4% of weeks (i.e., > 4 out of 8 weeks) involved ad libitum intakes at or above energy balance, and 81.0% of participants (17 out of 21) had ad libitum days which exceeded energy balance, while 4 participants did not despite some elevation in energy intake from energy-restricted days. Due to the small within-group sample size and an RMR standard deviation of approximately 150–200 kcal/day observed in the control group, the dose-response relationship (i.e., the magnitude and frequency of these breaks) in mitigating metabolic adaptation warrants further investigation. Interestingly, despite the additional energy intake during ad libitum days in INTB-AdI, weight loss appeared comparable to that observed in the CER group. The extra ~ 700 kcal/day during ad libitum days led to a ~ 200 kcal/day smaller calorie deficit compared to CER. However, the attenuation of RMR reduction (~ 70 kcal/day) and the potential synergistic increase in other forms of energy expenditure such as non-exercise activity thermogenesis [42], may have contributed to aligning the overall calorie deficit with that of CER.

Both CER and INTB-AdI interventions resulted in significant increases in cognitive restraint and decreases in uncontrolled eating compared to CON, with no differences between CER and INTB-AdI. These behavioural changes are associated with improved weight loss outcomes [43, 44]. Consequently, both dietary approaches effectively promoted weight reduction. However, despite no marked differences seen between the INTB-AdI and CER, emotional eating was significantly reduced only in the CER group. Given that individuals with higher levels of emotional eating are more likely to consume foods high in fat, sugar and calories in response to negative emotions [45], and that emotional eating has demonstrated convergent validity with disordered eating behaviours such as binge eating [46], our current finding suggests that INTB-AdI may not be the optimal strategy for individuals prone to emotional eating. In addition, inter-individual variability observed in energy intake during ad libitum feeding days indicated that some participants may be more susceptible to overeating during unrestricted periods than others. Future studies should examine whether baseline eating behaviour traits predict this response.

Despite statistically insignificant differences in body mass reductions between the INTB-AdI and CER groups, CER appeared to exert more favourable effects on cardiometabolic health markers, whereas minimal changes were observed in the INTB-AdI group. A previous INTB study [47] which examined women with obesity, reported comparable reductions in TC and TG with both INTB and CER. However, the diet breaks utilized in the study were aimed at “weight stabilization”, and intake during these periods were not ad libitum. Differences in the changes in cardiometabolic health markers may reflect the higher intake of unhealthy fats (i.e. saturated and trans-fats) during the ad libitum days for the INTB-AdI group, as evidenced by food records documenting consumption of pastries, cakes, and deep-fried foods. Diets high in saturated fats have been shown to attenuate the beneficial effects of weight loss on LDL [48]. In our study, it is plausible that 2 days of consuming foods high in unhealthy fats and sugars may have impeded improvements in cardiometabolic health markers during dieting.

Satiety assessed via the CSS did not differ significantly among groups, with only reductions in satiety that were statistically insignificant noted in both the CER and INTB-AdI groups. This finding contrasts with previous studies on INTB where breaks were set at specific energy and macronutrient targets, which reported lower measures of hunger and greater satisfaction during INTB compared to CER, along with higher concentrations of the satiety hormone peptide YY [20, 49]. In our study, the consumption of large quantities of foods high in sugar and fat during ad libitum feeding days may have contributed to increased hunger sensations in subsequent meals [50], as well as a reduced preference for low-fat diets and an upregulation of brain responses associated with the consumption of highly palatable, energy-dense foods [51]. The negligible change in satiety observed in both groups may also be attributed to the dietary plans on energy-restricted days, which were aligned with healthy eating guidelines including 3 servings of vegetables per day. Some participants reported feeling full and experiencing difficulty adhering to the diet during energy-restricted days, likely due to the increased vegetable intake compared to their usual diets.

Despite a high adherence rate (80–85%) across all groups, motivation to adhere to diet decreased slightly in both CER and INTB-AdI after the 8-week intervention, with no significant differences between groups. However, during the 3-month follow-up, motivation declined significantly in the INTB-AdI group, despite similar number of dropouts (3 participants per group). This decline was accompanied by a notable drop in cognitive restraint as measured by the TFEQ-R18, and small but significant regain in body mass, BMI, fat mass and waist circumference, although these body measures remained below baseline levels. In contrast, the CER group did not exhibit such rebound effects. Our findings during the follow up

period differ from previous studies on INTB, which have reported a lesser weight rebound in INTB compared to CER [20, 52]. Some participants in our CER group reported transitioning to a more “flexible dieting” approach post-intervention, allowing for less restrictive eating during social occasions such as gatherings and holidays, and subsequently returning to a healthier regular diet which may have facilitated weight maintenance. Consequently, the typical negative effects of rigid dieting such as the abstinence-violation effect (an all-or-nothing mindset) and disinhibition [53] were likely minimized in this group. In contrast, the inherently flexible nature of the INTB-AdI approach may have escalated in the absence of a strict structure of planned breaks during the follow-up period, potentially leading to more frequent breaks and larger energy surpluses. This is supported by the observed significant reductions in cognitive restraint and motivation to adhere to the diet in the INTB-AdI group. While these explanations are speculative, future research should explore the behavioural aspects influencing adherence and weight regain in greater depth.

Our intervention provides valuable insights into a widely popular weight-reduction strategy which has not previously been adequately explored. This study design incorporated rigorous daily monitoring of diet adherence, which facilitated prompt feedback and enhanced the accuracy and robustness of the results. However, several limitations should be acknowledged. First, the 8-week intervention period restricts the generalizability of the findings to longer durations, which are generally considered more meaningful for producing sustainable improvements in weight management and metabolic health [54–56]. Additionally, the participants were relatively healthy young women, therefore the applicability of the findings to individuals with pre-existing metabolic health risks may be limited. Furthermore, inter-individual variability in ad libitum intake may have influenced the results and should be considered when interpreting the findings. Finally, the study did not include structured qualitative assessments to capture participants’ experiences, thereby limiting a comprehensive understanding of the behavioural changes associated with the intervention.

Conclusions

In summary, both the INTB-AdI and CER interventions resulted in effective weight loss, with no significant difference between groups over the 8-week period. Furthermore, INTB-AdI notably mitigated the adaptive decline in RMR relative to CER, indicating a potential physiological advantage in preserving energy expenditure. Despite the effective weight loss, no significant improvements were observed in cardiometabolic health markers within the INTB-AdI group, thereby challenging its potential to confer broader health benefits during dieting. Additionally, reductions in motivation and cognitive restraint may pose challenges to the long-term sustainability of this dietary strategy. Further research is necessary to elucidate its long-term efficacy and health implications.

Declarations

Author Disclosures

None reported.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT (GPT-3.5) in order to correct grammatical errors. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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Data availability:

Data described in the manuscript, code book, and analytic code will be made available upon request pending application.

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Figures

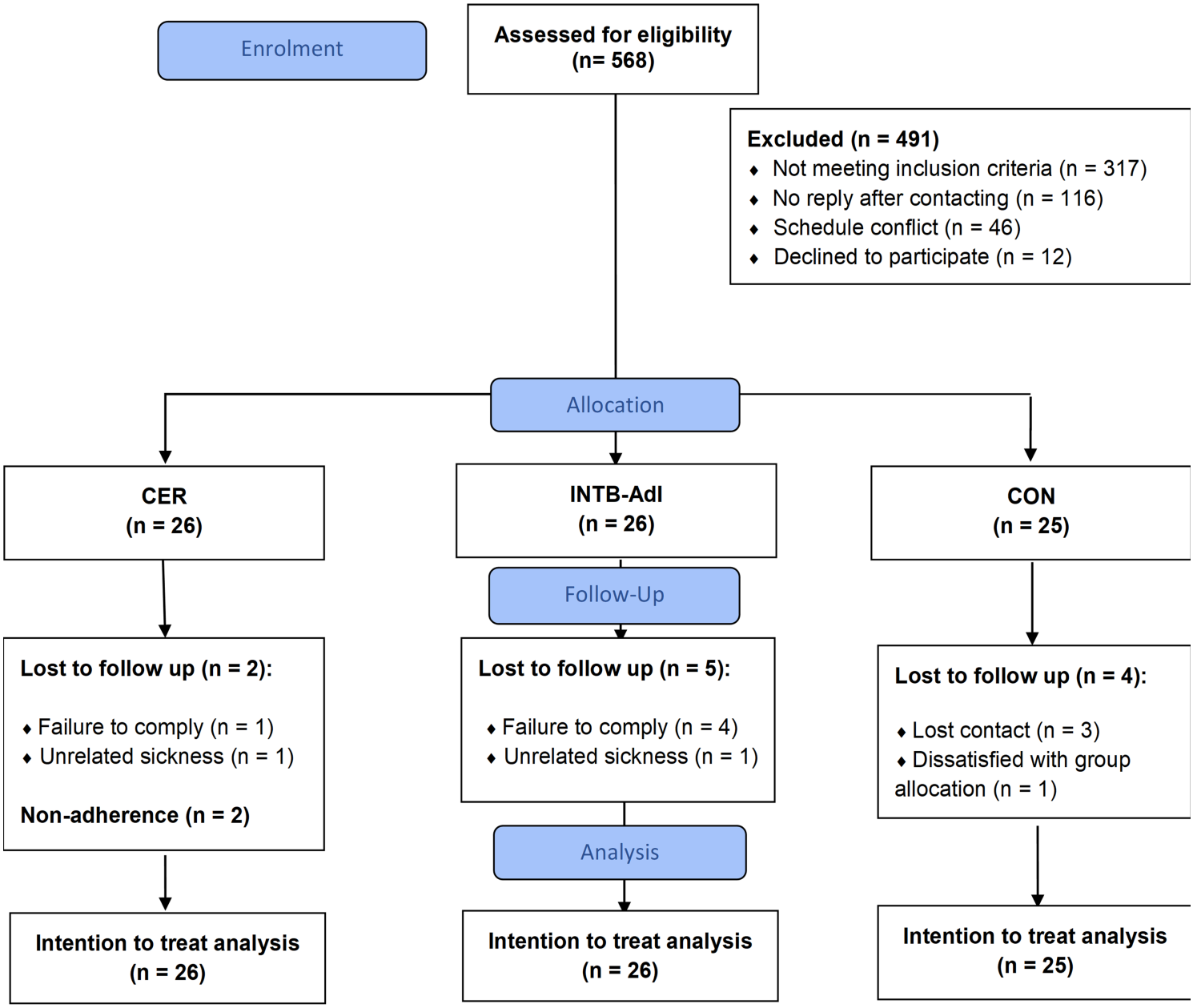


Figure 1

CONSORT Diagram

Abbreviations: CER continuous energy restricted group; CON, control group; INTB-AdI, intermittent dieting with ad-libitum intake group

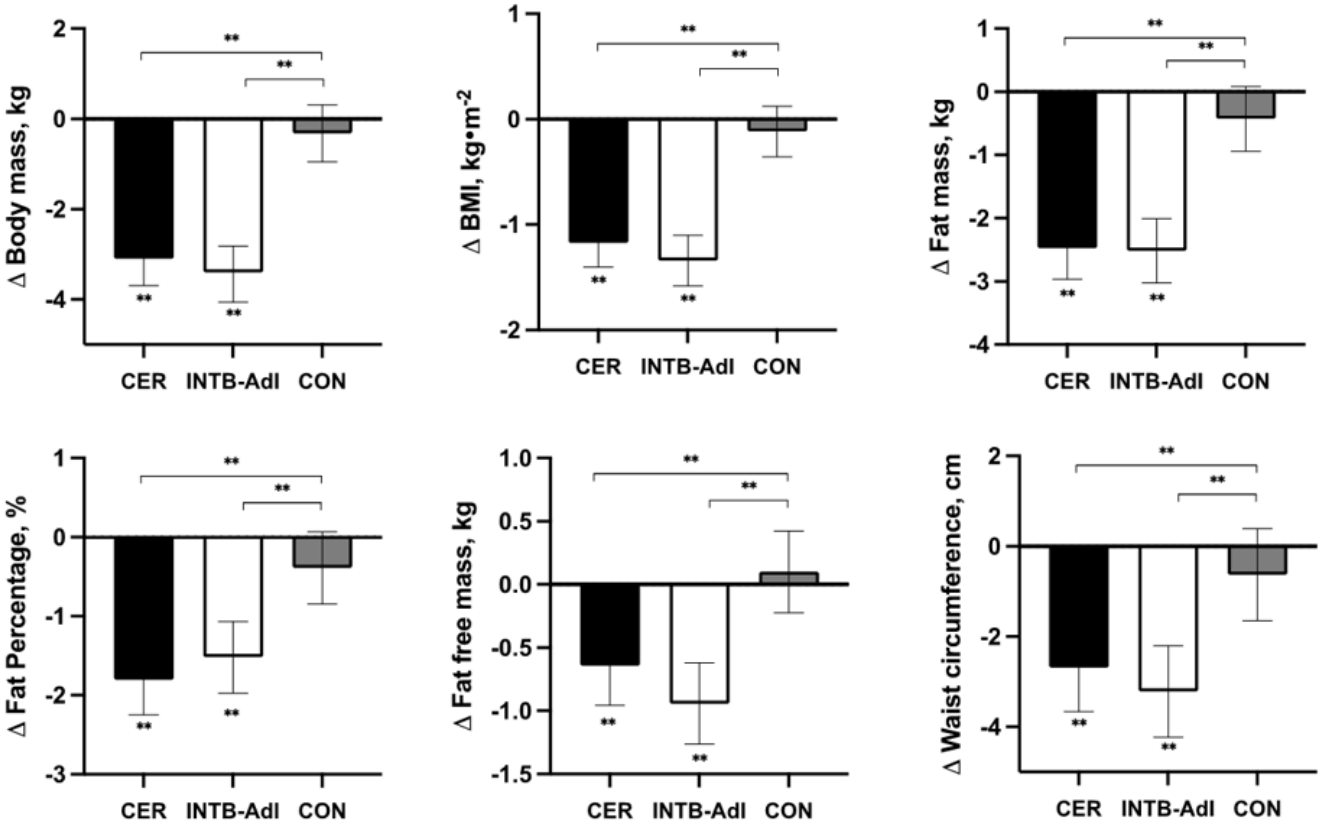


Figure 2

Changes in Body Composition Parameters

Two asterisks (**) indicate P < 0.01. Abbreviations: CER continuous energy restricted group; CON, control group; EB, energy balance; INTB-AdI, intermittent dieting with ad libitum intake group.

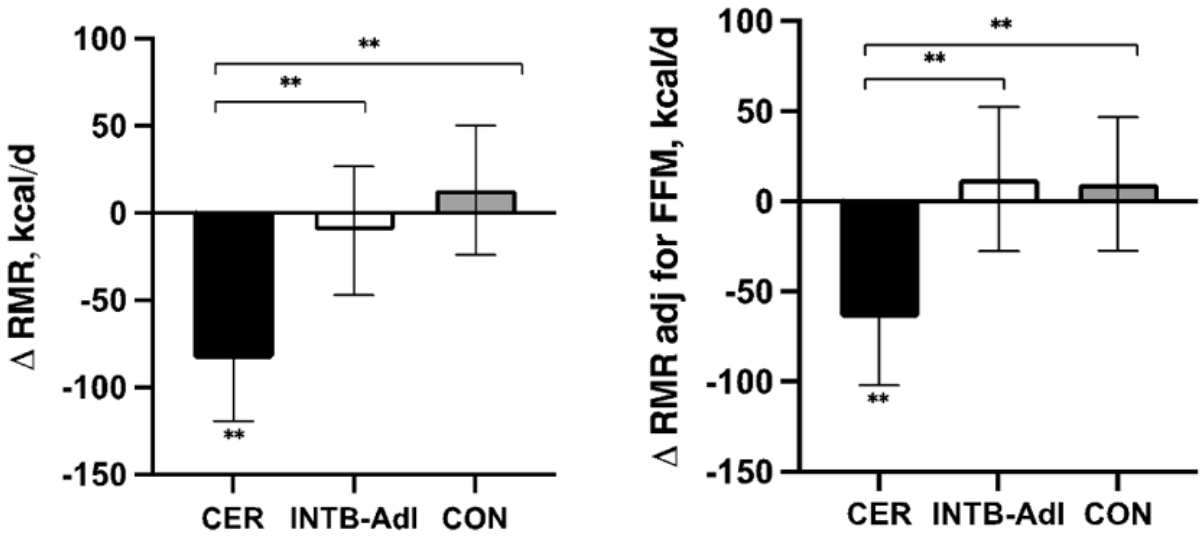


Figure 3

Changes in Resting Metabolic Rate

Two asterisks (**) indicate P < 0.01. Abbreviations: CER continuous energy restricted group; CON, control group; FFM, fat-free mass; INTB-AdI, intermittent dieting with ad-libitum intake group; RMR, resting metabolic rate.

Supplementary Files

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