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REVIEW ARTICLE

Epidemiology and Population Health

Effects of intermittent versus continuous dieting on weight and body composition in obese and overweight people: a systematic review and meta-analysis of randomized controlled trials

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Abstract

Background Intermittent dieting may be an alternative to continuous dieting for weight reduction.

Objective To evaluate the effect of intermittent dieting versus continuous dieting on weight and body composition in overweight or obese adults.

Design A systematic review and meta-analysis of randomized controlled trials (RCTs). Five databases were searched until February 2018 for RCTs comparing intermittent versus continuous dieting. Intermittent dieting consisted of two types: regular intermittent was caloric restriction interspersed with days of weight maintenance or ad libitum eating; intensified intermittent was caloric restriction interspersed with days of even lower caloric restriction. Continuous was continual caloric restriction. Primary outcomes were weight, body fat, lean mass, waist circumference, hip circumference, and energy expenditure. Data were pooled by the inverse variance method using random-effects models and expressed as mean differences (MD) and their 95% confidence intervals (CI).

Results Nine trials met the inclusion criteria ($n = 782$), six comparing regular intermittent vs continuous ($n = 553$), and three comparing intensified intermittent vs continuous ($n = 229$). Populations were heterogeneous: obese only in five studies, and overweight or obese (mixed) in four studies. Lean mass was significantly lower in regular intermittent vs continuous (MD −0.86 kg; 95% CI −1.62 to −0.10; $p = 0.03$). No differences were found for the remaining outcomes for both comparisons (regular intermittent or intensified intermittent vs continuous). There was low heterogeneity of effects across trials. Subgroup effects by time to follow-up, gender, per-protocol versus intention-to-treat, enforced exercise, and diabetes were similar to main analyses.

Conclusions This systematic review in obese and overweight individuals showed that regular intermittent dieting decreased lean mass compared to continuous dieting. There were no differences in effects for either intermittent vs continuous interventions across all other outcomes. In contrast to previous systematic reviews, this study suggested that lean mass is better preserved in continuous dieting compared to regular intermittent dieting.

Introduction

The attainment and maintenance of a normal body weight in people who are overweight or obese is an important health intervention to lower morbidity and mortality [1]. However, the long-term impact on body weight from major diet plans are similar, few patients are able to achieve their goal weight, and even fewer can maintain their new lower body weight over time [2, 3].

Instead of adjusting what people are eating, another line of investigation is assessing different intensities of dieting [4]. There are two main groupings of intermittent dieting trials. The first group are trials comparing periods of active

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dieting interspersed with periods of dietary rest (regular intermittent) versus continuous dieting [4]. Regular intermittent dieting is defined as periods of caloric restriction interspersed with periods of weight maintenance or ad libitum eating. The second group are trials comparing periods of low calorie dieting interspersed with periods of more intense caloric restriction (intensified intermittent) versus continuous dieting [5]. Intensified intermittent dieting is defined as periods of caloric restriction interspersed with days of even lower caloric restriction. Continuous dieting is defined as continual consistent caloric restriction over time.

The objective of this systematic review and meta-analysis was to determine the impact of each of the intermittent dietary approaches versus standard continuous dieting on weight loss, body composition, and energy expenditure.

Methods

The systematic review was conducted in accordance to the PRISMA (Preferred reporting items for systematic reviews and meta-analysis) guidelines [6].

Study search and selection criteria

We searched PubMed, EMBASE, Scopus, The Web of Science, and Cochrane Library for RCTs evaluating intermittent dieting vs continuous dieting until February 2018. The PubMed search strategy is available in the Supplemental file. We included all published RCTs regardless of the study setting, language, sample size, and follow-up time. Included trials assessed either one of two types of intermittent dieting vs continuous dieting on body composition in adult individuals who were obese or overweight. We excluded case reports, editorials, meta-analyses, narrative reviews, animal studies, and studies with individuals <18 years old. Two sets of authors independently reviewed abstracts and full-text articles, respectively, and determined eligibility for inclusion into the meta-analysis. Selections were compared for final inclusion among the two sets of authors, and any concerns or discrepancies were discussed with the senior investigator.

Types of intermittent dieting

Regular intermittent dieting was defined as periods of caloric restriction interspersed with periods of weight maintenance or ad libitum eating. Intensified intermittent dieting was defined as periods of caloric restriction interspersed with days of even lower caloric restriction. Continuous dieting was defined as continual consistent caloric restriction over time. There was no minimum or maximum limit on the length of diet cycles nor the number of cycles of intermittent dieting. Caloric restriction was broadly defined as energy restriction below estimated / calculated daily requirements. Other interventions were allowed (e.g. exercise) if they remained equal across all arms of a trial.

Outcomes

The primary outcomes of this study were weight (kg), body fat (kg), lean mass (kg), waist circumference (cm), hip circumference (cm), and energy expenditure (kJ/day). The data closest to the end of the active dieting phases in both groups were used as the primary outcome.

Data extraction

Data extraction was completed independently by two authors, reconciled, and recorded on a purpose-designed Microsoft Excel® spreadsheet. Extracted data included year of publication, number of participants, mean body mass index (BMI), follow-up time, gender, mean age, percent with diabetes, description of diet regimens (regular intermittent or intensified intermittent and continuous), primary outcomes, and attrition rate. Any discrepancies between the two investigators were resolved by consultation with the senior investigator.

Risk of bias assessment

Two investigators independently used the Cochrane Collaboration tool [7] to assess the risk of bias for each included trial. Any discrepancies between the two investigators were resolved by consultation with the senior investigator. The following items were evaluated: random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and other bias. All items were identified as low, high, or unclear risk of bias. Any trial which demonstrated high risk of bias for the domains of selection bias, performance bias, or detection bias were automatically considered high risk.

Statistical analysis

The random-effects model with inverse variance methods was used for meta-analyses. Effects of intermittent dieting interventions vs continuous dieting on body composition outcomes were expressed as mean differences (MD) and their 95% confidence intervals (CI). Indirect comparisons

between regular and intensified intermittent dieting were performed using the Bucher et al. [8] method for indirect meta-analysis when data were available.

Heterogeneity was identified by the inconsistency (I^2) metric [9]. Degrees of statistical heterogeneity were: low (I^2 < 30%), moderate (30–60%), and high (>60%). Heterogeneity was explored with the use of subgroup analyses by time to follow-up (12–20 weeks vs 26–52 weeks), gender (women only vs men only vs mixed), RCT analysis (intention-to-treat [ITT] vs per protocol [PP]), diabetes (diabetic patients vs non-diabetic patients), and exercise (exercise enforced vs exercise not enforced).

All analyses were done with Review Manager (RevMan 5.3; Cochrane Collaboration, Copenhagen, Denmark), R 3.3.2 (www.r-project.org) and Indirect & Mixed Treatment Comparisons Calculator (Spanish Council for Scientific Research, Version 1.0.1).

Results

Selection of trials

A total of 3616 abstracts of RCTs were identified through database searching; 18 RCTs were identified from other sources. Eight hundred and ninety-four duplicate abstracts were removed. Of the 2740 abstracts screened, 2717 were excluded. A total of 23 full-text RCTs were assessed for eligibility. Nine trials ($n = 782$) [4, 5, 10–16] met the inclusion criteria for the meta-analysis, six comparing regular intermittent vs continuous dieting ($n = 553$) [4, 12–16] and three comparing intensified intermittent vs continuous dieting ($n = 229$) [5, 10, 11]. Fourteen trials were excluded for the following reasons: no continuous diet arm in eight trials, fixed percent weight loss in two trials, 2-day cross-over trial in one trial, incomplete outcomes data in one trial, no intermittent diet arm in one trial, and an unclear protocol in one trial. Fig. 1 summarized the full algorithm.

Trial characteristics

The main characteristics of this meta-analysis are summarized in Table 1.

Regular intermittent vs continuous

One trial [4] included only obese individuals and five trials [12–16] included both obese and overweight individuals. The mean BMI for the study population was 32.6 (5.0) kg/m^2; the majority of patients were female (81.4%.). The mean age was 47.3 (11.5) years. One trial [16] included only diabetic patients, and three trials [4, 12, 14] excluded

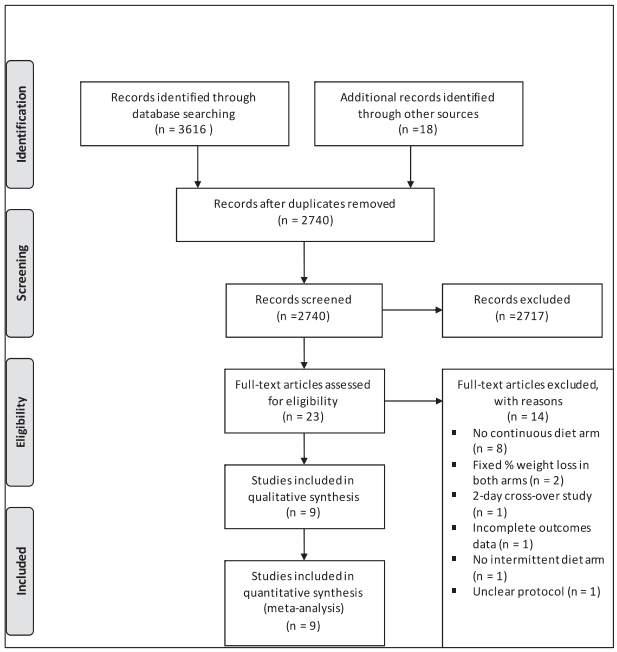

Fig. 1 Flow diagram of selection of studies

diabetic patients. Follow-up ranged from 12 to 52 weeks. The total number of trials investigating each primary outcome are as follows: weight (six trials; $n = 553$) [4, 12–16], fat mass (four trials; $n = 336$) [4, 12, 14, 16], lean mass (four trials; $n = 336$) [4, 12, 14, 16], waist circumference (three trials; $n = 297$) [12, 14, 15], hip circumference (three trials; $n = 297$) [12, 14, 15], and energy expenditure (two trials; $n = 158$) [4, 14]. Harvie et al. 2013 [12] had two regular intermittent arms that were deemed similar enough to combine into one arm. Wing et al. [13] had two regular intermittent arms that were deemed dissimilar and evaluated against the continuous arm separately.

Intensified intermittent vs continuous dieting

One trial [5] included only obese individuals and two trials [10, 11] included both obese and overweight individuals. The mean BMI for the study population was 35.7 (6.2) kg/m^2. Viegener et al. [11] did not report BMI. The majority of patients were female (63.3%). The mean age was 50.7 (9.3) years. Two trials [5, 10] included only diabetic patients, and one trial [11] excluded diabetic patients. Follow-up ranged from 12 to 48 weeks. The total number of trials investigating each primary outcome are as follows: weight (three trials; $n = 229$) [5, 10, 11], fat mass (one trial; $n = 51$) [10], and waist circumference (one trial; $n = 51$) [10]. Ash et al. [10] had two continuous arms, which were deemed similar enough to combine into one arm.

Table 1 Study and patient characteristics in included randomized controlled trials

Author, ref.	Sample	Population	Follow-up time	Female (%)	Mean age (SD)	Diabetes (%)	Intermittent diet regimen	Continuous diet regimen	Outcomes	Attrition
Regular intermittent versus continuous trials										
Wing et al. [13]	142	Overweight and obese (15–70% above IBW) Mean BMI (SD): 33.1 (3.3)	20 weeks	84.5%	42.6 (9.3)	NR	IDa: LB group took 6-week break after the 7th session (total of 6 weeks off the program); ad libitum on breaks IDb SB group took 2-week breaks after the 3rd, 6th, and 9th lessons (total of 6 weeks off the program); ad libitum on breaks 14 group lessons (lessons focused on diet, exercise, behavioral strategies); frequency depended on when energy restriction occurred; assigned a calorie goal of 1000–1500 kcal/day depending on baseline weight. 13 high-fat foods prohibited; exercise gradually increased until 150 min/week reached. Encouraged to maintain new eating/exercise habits—data measured at week 20	Continuous 1000–1500 kcal/day diet based on baseline weight x 14 consecutive weeks 14 group lessons (lessons focused on diet, exercise, behavioral strategies); frequency depended on when energy restriction occurred; assigned a calorie goal of 1000–1500 kcal/day depending on baseline weight. 13 high-fat foods prohibited; exercise gradually increased until 150 min/week reached. Encouraged to maintain new eating/exercise habits—data measured at week 20	Weight	16.9% (6.4% LB; 23.4% SB; 20.8% CD)
Harvie et al. [14]	107	Overweight and obese (BMI 24–40) Mean BMI (SD): 30.6 (5.1)	26 weeks	100%	40.0 (4.0)	0%	25% total weekly restriction as VLCD × 2 days/week (75% restriction below estimated requirements—2700 kJ/day), followed by no restriction 5 days/week (Mediterranean-type diet)	25% restriction below estimated requirements (Mediterranean-type diet)	Weight, body fat, fat free mass, waist circumference, hip circumference, energy expenditure	16.8% (20.8% ID; 13.0% CD)
Harvie et al. [12]	115	Overweight & obese (BMI 24–45) Mean BMI (SD): 31.0 (5.3)	13 weeks	100%	47.4 (7.8)	0%	IDa: 2-consecutive day 70% restriction, 40 g carbs max (2500–2717 kJ/day) then 5-day eunergetic Mediterranean type diet IDb: 2-consecutive day 70% restriction, 40 g carbs max	25% energy restriction; Mediterranean-type diet, relatively high in protein (25% protein, 45% carbs. 30% fat, 15% MUFA, 8% PUFA, 7% SFA)	Weight, body fat, fat free mass, waist circumference, hip circumference	15.7% (10.8% IDa; 18.4% IDb; 17.5% CD)

Table 1 (continued)

Author, ref.	Sample	Population	Follow-up time	Female (%)	Mean age (SD)	Diabetes (%)	Intermittent diet regimen	Continuous diet regimen	Outcomes	Attrition
							(2500–2717 kJ/day—unrestricted diet of lean meat, fish, eggs, tofu, MUFA, and PUFA; ad libitum protein and fat) and 5-day eunergetic Mediterranean type diet			
Keogh et al. [15]	75	Overweight and obese (BMI > 27) Mean BMI (SD): 33.1 (5.8)	52 weeks	100%	60.1 (10.5)	1.3%	5500 kJ energy restriction × 1 week, followed by "normal" diet × 1 week Attended the research site q2 weeks × 8 weeks; then at week 52; asked to continue their assigned diet strategy from week8–week52; instructed to keep exercise constant over the 52 weeks	5500 kJ energy restriction CSIRO 'Total Wellbeing Diet' Attended the research site q2 weeks × 8 weeks; then at week 52; asked to continue their assigned diet strategy from week8–week52; instructed to keep exercise constant over the 52 weeks	Weight, waist circumference, hip circumference	52% (51.3% ID; 52.8% CD)
Carter et al. [16]	63	Overweight and obese (BMI ≥ 27) Mean BMI (SD): 35.5 (5.0)	12 weeks	52.4%	61.5 (8.3)	100%	1670–2500 kJ/day × 2 days, followed by 5 days habitual eating + dietary education Diet composition → CSIRO "Total Wellbeing Diet"	5000–6500 kJ/day + dietary education Diet composition →CSIRO "Total Wellbeing Diet"	Weight, body fat, fat free mass	22.2% (19.4% ID; 25.0% CD)
Byrne et al. [4]	51	Obese (BMI 30–45) Mean BMI (SD): 34.5 (3.7)	30 weeks	0%	39.6 (8.0)	0%	8 × 2-week blocks of energy restriction (33% reduction in kcal/day) alternating with 7 × 2-weeks energy balance	16 weeks continuous dieting (33% reduction in kcal/day)	Weight, body fat, fat free mass, energy expenditure	19.6% (26.9% ID; 12.0% CD)
Intensified Intermittent versus continuous trials										
Viegener et al. [11]	85	Overweight and obese (25–99% overweight-based on Metropolitan Life Insurance Company, 1983 height–weight table)	26 weeks	100%	47.1 (8.1)	0%	Behavioral therapy + 800 kcal/day low-fat diet × 4 days/week and 1200 kcal/day × 3 weeks (pattern of diet chosen by participant); instructed to restrict intake of fats ≤25% on high calorie days and ≤15% low calorie days; nutrition education = significant focus Diet composition per ADA 1986 guidelines; exercise	Behavioral therapy + 1200 kcal/day "balanced deficit diet" Diet composition per ADA 1986 guidelines; exercise regimen (target 30 min/day × 6 days/week)	Weight	25.9% (26.2% ID; 25.6% CD)

Table 1 (continued)

Author, ref.	Sample	Population	Follow-up time	Female (%)	Mean age (SD)	Diabetes (%)	Intermittent diet regimen	Continuous diet regimen	Outcomes	Attrition
							regimen (target 30 min/day × 6 days/week)			
Wing et al. [5]	93	Obese (> 30% IBW or > 18 kg above IBW) Mean BMI (SD): 37.9 (6.3)	48 weeks	64.5%	51.8 (9.7)	100%	Week 1–12: 400–500 kcal/day (Optifast 70-liquid) or as lean meat fish/fowl Week 12–24: 1000–1200 kcal/day Week 36–48: 1000–1200 kcal/day Year-long behavioral treatment program w/ group meetings qweek; provided weekly exercise goals	1000–1200 kcal/day × 48 weeks encouraged to limit dietary fat <30% Year-long behavioral treatment program w/ group meetings qweek; provided weekly exercise goals	Weight	15.1% (15.6% ID; 14.6% CD)
Ash et al. [10]	51	Overweight and obese (BMI 25–40) Mean BMI (SD): 31.7 (3.3)	12 weeks	0%	54.5 (8.5)	100%	Liquid meal replacement (Modifast: 1000 kcal/day [4180 kJ/day]) × 4 consecutive days followed by defined caloric ad libitum similar to dietary stabilization phase (1400–1700 kcal/day) × 3 days	CD (pre-portioned meals): Meals provided to participants (average 1650 kcal/day [6900 kJ/day]) (51% carbs, 20% protein, 29% fat) CD (self-selected meals): Advised to continue preparing meals per dietary recommendations given (similar to dietary stabilization phase; 1400–1700 kcal/day)	Weight, body fat, waist circumference	27.5%

BMI body mass index, *CD* continuous diet, *CSIRO* Commonwealth scientific and industrial research organisation, *IBW* ideal body weight, *ID* intermittent diet, *LB* long break, *SB* short break, *SD* standard deviation

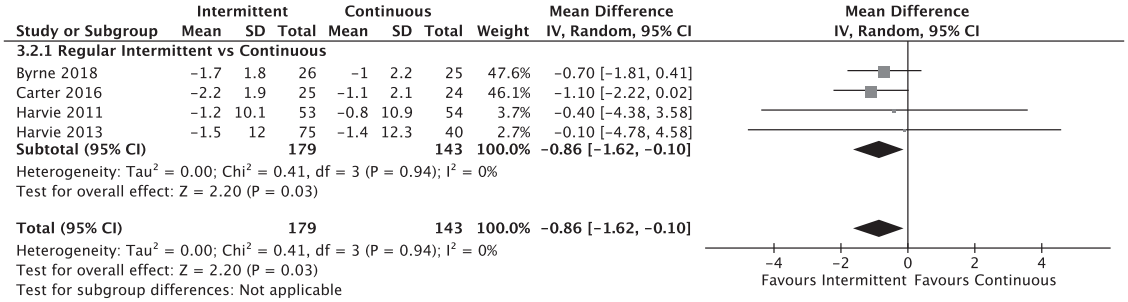

Fig. 2 Effect of regular intermittent dieting versus continuous dieting on lean mass

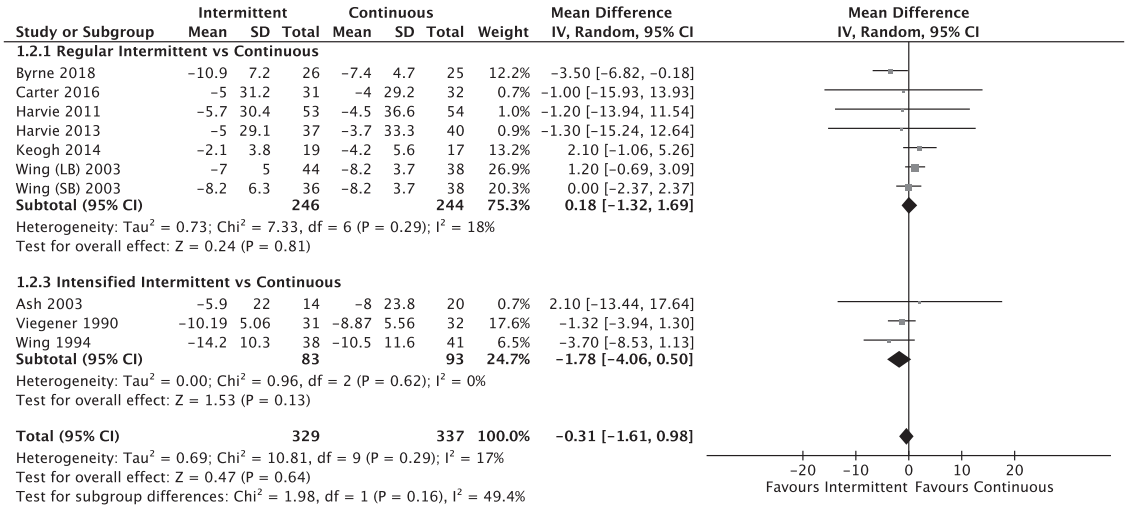

Fig. 3 Effect of regular intermittent and intensified intermittent dieting versus continuous dieting on weight

Risk of bias assessment for included trials

All trials demonstrated an overall high risk of bias due to performance bias. Eight out of nine trials [4, 5, 10, 11, 13–16] had a high risk for detection bias. With regards to selection, reporting, and other bias, all trials demonstrated either low or unclear risk. Attrition bias was split among all three categories (Supplemental Figs. 1 and 2).

Effects of intermittent dieting on body composition

Regular intermittent vs continuous

Lean mass was significantly lower in regular intermittent vs continuous (MD −0.86 kg; 95% CI −1.62 to −0.10; $p = 0.03$) (Fig. 2). The remaining outcomes were not statistically significant: weight (MD 0.18 kg; 95% CI −1.32 to 1.69; $p = 0.81$) (Fig. 3), body fat (MD −0.51 kg; 95% CI −1.93 to 0.91; $p = 0.48$) (Fig. 4), waist circumference (MD −0.64 cm; 95% CI −3.59 to 2.31; $p = 0.67$) (Fig. 5), hip circumference (MD 0.53 cm; 95% CI −1.87 to 2.94; $p = 0.66$) (Supplemental Fig. 3), and energy expenditure (MD −44.56 kJ/day; 95% CI −757.15 to 668.03; $p = 0.90$) (Supplemental Fig. 4). Statistical heterogeneity of effects across trials was low.

Intensified intermittent vs continuous dieting

All outcomes were not statistically significant: weight (MD −1.78 kg; 95% CI −4.06 to 0.50; $p = 0.13$) (Fig. 3), body fat (MD −0.10 kg; 95% CI −1.22 to 1.02; $p = 0.86$) (Fig. 4), and waist circumference (MD, 0.80 cm; 95% CI −10.13 to 11.73; $p = 0.89$) (Fig. 5). Statistical heterogeneity of effects across trials was low.

Indirect comparison between regular and intensified intermittent dieting

We only evaluated the indirect comparison between intensified intermittent vs regular intermittent for weight due to scarce data for other outcomes. Mean BMI, age, and gender were deemed similar enough to perform the indirect comparison. There was no effect in weight loss between the intensified intermittent vs regular intermittent arms (MD −1.96 kg 95% CI −4.69 to 0.77; $p = 0.16$).

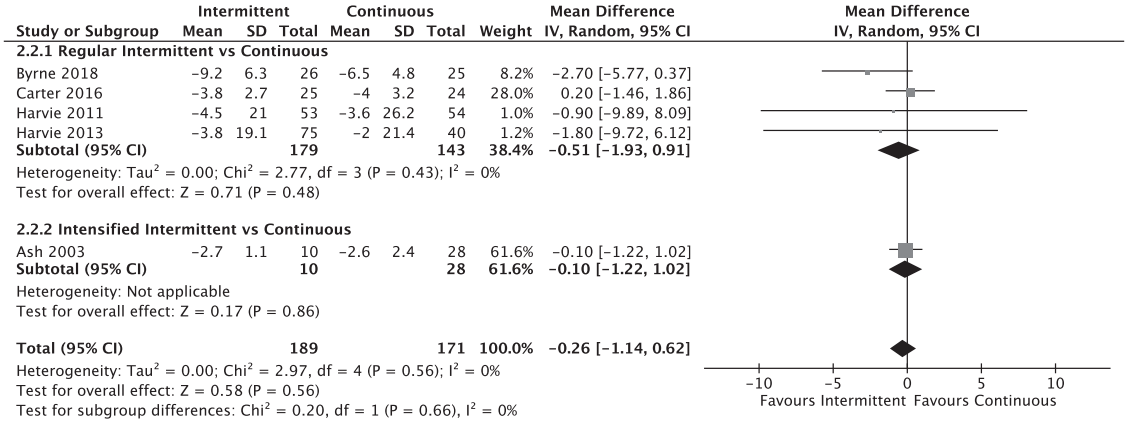

Fig. 4 Effect of regular intermittent and intensified intermittent dieting versus continuous diet on fat mass

Subgroup analyses

The ITT vs PP subgroup demonstrated an effect for the difference in weight between the regular intermittent and continuous arms such that the difference in weight loss was greater in the ITT arm compared to the PP arm [(MD −3.15 kg; 95% CI −6.22 to −0.09) vs (MD 0.98 kg; 95% CI −0.36 to 2.32) respectively; p for interaction = 0.02] (Supplemental Fig. 5). There were no differences in effects for all other subgroup analyses across all other outcomes (Supplemental figures 6 to 23). Subgroup analysis for population (obese vs overweight) could not be performed because no trials included solely overweight individuals.

Discussion

Main findings

In our systematic review and meta-analysis, we were unable to find significant benefits for either regular intermittent dieting or intensified intermittent dieting versus continuous dieting on body weight, fat mass, hip or waist circumference, or in energy expenditure. We did find that regular intermittent dieting was associated with more lean mass loss, an effect not seen with intensified intermittent dieting versus continuous dieting. Effects across studies had low heterogeneity, and subgroup analyses were consistent with main analyses.

What is known in the literature about the research question

There have been four previous systematic reviews without or with meta-analyses mostly focused on body weight (Supplemental Table 1). Two systematic reviews evaluated both RCTs and observational studies [17, 18], and two others evaluated RCTs only [19, 20]. Horne et al. [18] in 2015 evaluated 3 RCTs and 2 observational studies comparing intermittent fasting vs standard diet or no-intervention, without specification of the populations. The authors concluded that data were too scarce to reach conclusions. Davis et al. [17] in 2016 evaluated 4 RCTs and 4 observational studies comparing intermittent dieting vs daily energy restriction with comparable overall energy restriction in obese and overweight populations. Although these authors did not perform meta-analyses, they found similar weight, fat mass, fat-free mass, and waist circumference loss between interventions across studies.

Headland et al. [20] in 2016 conducted a systematic review and meta-analysis comparing intermittent energy restriction vs continuous energy restriction. They included six RCTs in their meta-analysis of weight including three that were also included in our meta-analysis [5, 14, 15]. There were no differences in weight between treatment arms at the end of the study, and although only reported in the abstract, there were no differences for glucose, insulin or blood lipids either.

Harris et al. [19] in 2018 conducted a systematic review and meta-analysis comparing intermittent energy restriction to continuous energy restriction. They included five RCTs in their meta-analysis of which only the two trials from Wing (1994, 2004) were included in our study [5, 13]. They included three RCTs (Arguin 2012, Coutinho 2018, Lantz 2003) where the diets were intensified or lessened to achieve a set percentage weight loss at periodic intervals. This can cover up the inadequacies of a dietary approach over time by intensifying calorie restriction in one group versus another so we excluded these types of studies in our meta-analysis [21–23]. Harris et al. [19] found no significant differences between intermittent dieting and continuous dieting in weight loss between the two groups immediately post-dieting (weighted mean difference

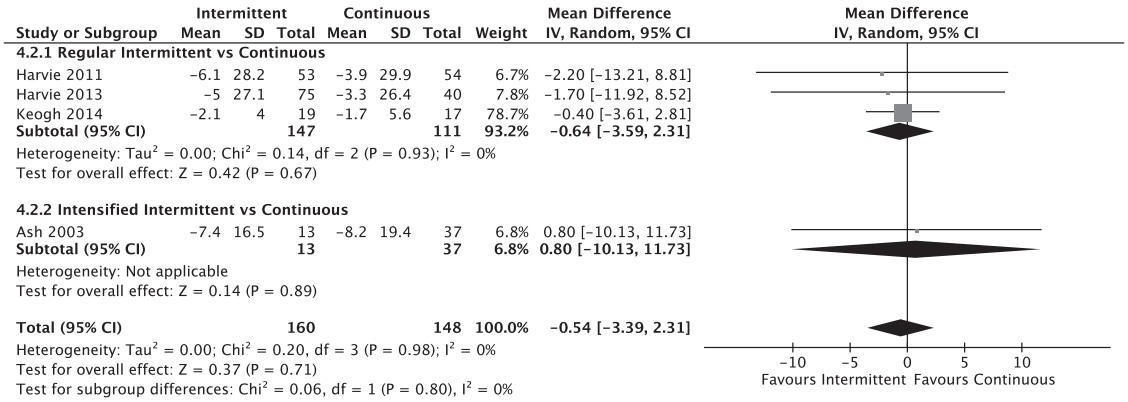

Fig. 5 Effect of regular intermittent and intensified intermittent dieting versus continuous dieting on waist circumference

[WMD] −1.36, 95%CI −3.23 to 0.51) or at subsequent follow-up (WMD −0.82, 95%CI −3.76 to 2.11).

Both Headland et al. [20] and Harris et al. [19] included studies where dieting intensity was altered in each group based on whether weight loss metrics were being met and they also combined regular and intensified intermittent strategies together. When designing our meta-analysis, we felt it was possible that metabolic adaptation might occur to different extents in those with true dietary rest (regular intermittent dieting) versus those dieting continuously but with different calorie restriction intensity over time (intensified intermittent dieting) [3]. Lastly, we excluded from our study three other RCTs included in Headland et al. and Harris et al. meta-analyses: Hill et al. [24] that did not provide data for outcomes in the publication and after direct communication with authors, Wadden et al. [25] that did not have an actual intermittent dieting arm, and Rossner et al. [26] that incompletely described its continuous dieting arm.

Neither of these meta-analyses included Byrne et al. [4], the newest RCT examining weight loss, body composition, and energy expenditure using a regular intermittent versus continuous dietary approach. The previous meta-analyses did not include the studies by Carter (2016), Ash (2003), or Viegener (1990) that we included [10, 11, 16]. Viegener (1990) was of sufficient duration and study methodology to be included in both aforementioned meta-analyses while Carter (2016) was too new to be included in the Headland (2016) meta-analysis [11, 16]. However, both of these studies were not detected by their search strategies. Ash (2003) did not originally break out data between their intensified intermittent and continual dieting groups precluding previous inclusion but the investigators generously provided us the data for inclusion in our meta-analysis [10].

Strengths of the study

Our meta-analysis has several strengths. We did not restrict for duration of interventions or language. We only included RCTs that compared a fixed regimen of dieting, either intermittent or continuous, so the innate ability of the diet regimens to impact meta-analysis variables could be assessed. Also, we broke out intermittent dieting into regular intermittent or intensified intermittent dieting and analyzed them separately to see whether the periodic absence of dieting results in different effects than just altering the intensity of dieting. An indirect comparison of the effect of regular vs intensified intermittent dieting on weight was also performed. We looked not only at body weight but on several intermediate outcomes of body composition and energy expenditure as well. We explored methodological and statistical heterogeneity across trials by performing subgroup analyses by trial duration, gender, trial population (ITT vs PP), diabetes, and exercise enforcement. Finally, we rated the risk of bias to better discern the strength of the evidence base and to provide insight into future studies to move the field forward.

Limitations of the study

While our meta-analysis did not find clinically or statistically significant benefits resulting from regular intermittent dieting on weight loss, body composition, or energy expenditure, there are several caveats that need to be described. As seen in Table 1, studies in our meta-analysis have a large to very large attrition rate and not all of the trials used ITT analyses. For body weight, only four of the six studies used ITT analyses. As depicted in Supplemental Fig. 5, all of the trials that used ITT analyses had a direction of effect for body weight suggesting benefit for regular intermittent dieting and the pooled effect showed significant benefit as well. In contrast, pooling the subgroup reporting only PP analyses showed no benefits from regular intermittent dieting at all.

The trial by Keogh et al. [15] had a direction of effect suggesting better effects from continuous dieting but this study was characteristically different than the others

included in our meta-analysis. In this trial, participants dieted at the same intensity each week they were actively dieting but the regular intermittent dieting group dieted for half the number of weeks as the continuous dieting group. Intuitively, only losing 2.1 kg less body weight after dieting for half the number of weeks at the same weekly calorie restricting intensity would seem to be a success but in our meta-analysis, it worked against our pooled findings [15]. All of the other studies we included in the regular intermittent dieting versus continuous dieting meta-analyses had weekly decreases in calories during active diet weeks that were approximately the same across groups and the number of weeks of active dieting were the same [4, 12, 14, 16]. Byrne et al. [4] had weeks of equivalent intensity dieting between groups so that, by the end of the study, both groups actively dieted for 16 weeks (one group dieting for 16 continuous weeks while the other had 16 active diet weeks with 16 weeks of periodic dietary rest). The other studies [12, 14, 16] had a similar cut in weekly calories in the two groups but in the regular intermittent dieting group the calories were dramatically cut over a couple of days with no calories restriction on the other days of the week.

Since it is ultimately fat mass loss that improves health indices and not the loss of muscle, the significantly greater loss of lean mass in the regular intermittent dieting group versus the continuous dieting group is concerning and needs to be further assessed. If regular intermittent dieting ultimately reduces both fat mass and lean mass to a greater extent than continuous dieting this may be an acceptable trade-off but this has not been demonstrated in our meta-analysis. Keogh et al. [15] was not included in fat mass and lean mass assessments so it is not a confounder for these variables.

These two aforementioned caveats do not seem to apply to intensified intermittent dieting versus continuous dieting. This suggests that the approach of continuously restricting calories but fluctuating the intensity of the restriction is less likely to yield benefits versus continuous dieting with further investigation. As such, these approaches may be considered similar. This makes scientific sense since the continuous caloric restriction in both the groups can induce metabolic adaptation [3].

Finally, the presence of lack of blinding in most of the studies introduced both performance and detection biases to our effect estimates. Both are indicative of high risk of bias in individual trials. We expect that performance bias due to lack of blinding of participants and personnel may introduce extra treatments in the intervention arm (e.g. extra exercise). Also, detection bias due to lack of blinding of outcome assessors may introduce differential misclassification of outcomes (e.g. more careful weight measures for individuals in the intervention arm). However, it is difficult to predict the direction of these biases, as intervention effects can be overestimated or underestimated.

Conclusions

While the base case analyses found no significant benefits on body weight loss, body composition, or energy expenditure between regular or intensified intermittent dieting, we did find significantly more loss of lean body mass with the regular intermittent approach. In subgroup analyses, limiting to studies only using ITT analyses suggested significant reductions in body weight with regular intermittent approaches, warranting further research. Future studies should only compare regimens where the weekly calorie decreases during active dieting weeks are similar between the regular intermittent and the continuous dieting groups and should assess not only body weight but fat and lean mass as well.

Author contributions The authors' responsibilities were as follows—YMR, CMW, AVH: conceived, designed, and conducted the research study; MCD, TME, VP, YMR, AVH: collected and interpreted the data; MCD, TME, YMR, AVH: analyzed the data; MCD, TME, CMW, YMR, AVH: wrote the initial manuscript; and all authors: contributed toward the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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