

SYSTEMATIC REVIEW

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The effect of low-fat diets on appetite: a systematic review of randomized clinical trials

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Abstract

Background Adherence to low-fat (LF) diets may be inversely associated with appetite; however, findings from available randomized controlled trials (RCTs) are conflicting. The present study aimed to systematically review RCTs assessing the effects of LF diets on appetite status in adult participants.

Methods We searched PubMed, Scopus, Web of Science, and the Cochrane Library from the inception of the database to June 2, 2024, for RCTs that evaluated the effects of LF diets ($\leq 30\%$ total energy from fat), versus high-fat (HF, $> 30\%$ total energy from fat) diets on appetite status. No language restrictions were applied.

Results Initially, 2471 articles were identified, of which nine studies met the inclusion criteria. Seven studies examined the effect of LF diets on hunger response, three of which reported a significantly lower hunger response. LF diets did not exert an effect on satiety, desire to eat, and palatability. Only one study showed that the LF diet, compared to the HF diet, had greater decreases in their total appetite score over a 6-month period.

Conclusions We found that there were little or no additional benefits in changes to appetite status following LF diets in adults. However, due to methodological factors, shortcomings among studies and small number of studies, the current evidence on the effect of LF diets on appetite regulation is poor. Further long-term trials are needed to investigate the effect of LF diets on appetite and appetite-regulating hormones.

Keywords Appetite, Low-fat diet, Healthy diet, Review, Hunger, Satiety

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Background

The incidence of obesity has increased globally despite substantial improvements in its management, and this is linked to an increase in the occurrence of numerous metabolic disorders and vascular dysfunctions [1]. Obesity results from a complex interaction of factors, including but not limited to energy imbalance, where energy input exceeds output, leading to the deposition of body fat. This multifaceted issue involves the interplay of genes, environment, biology, psychology, and social factors, recognizing that energy balance is just one component within this intricate web of causation [2]. The regulation of energy balance in the body is a complex system, primarily involving signals from energy storage, which influence the sense of appetite or hunger [2]. While this pathway may be impaired in individuals with obesity, lowering food intake and consequently reducing appetite can be an effective approach for weight loss. [2].

Appetite regulation is primarily controlled by the hypothalamus, which integrates signals from the gut, fat tissue, and the nervous system. Hormones like ghrelin (which stimulates hunger), leptin, GLP-1, and PYY (which promote satiety), play key roles in signaling energy needs and fullness to the brain [3]. There are some strategies for the reduction of appetite, such as pharmacotherapy, bariatric surgery, and lifestyle modifications. Lifestyle modification is a non-invasive, life-long approach that generally involves changes in routine physical activity and diet [4]. According to a review study, when individuals engage in higher levels of physical activity, their appetite control system may become more sensitive, allowing them to better regulate their food intake in response to the increased energy expenditure from physical activity. In other words, this regulation helps individuals maintain their energy needs without excessive overeating or undereating [5]. Dietary fat intake, in particular, plays a complex role in appetite regulation. While fat is energy-dense, contributing to weight gain if consumed in excess, its influence on satiety is variable [3]. A recent clinical trial also found that women with obesity who followed a 14-day low-calorie Mediterranean diet, consisting of 1300 kcal/day and 20% of their daily energy from fat, did not experience any meaningful changes in their appetite levels [6]. On the other hand, evidence has shown that sustained weight loss can affect appetite regulation, potentially increasing hunger and impacting eating patterns [7]. Psychological and environmental factors influence appetite, and fat intake is relevant to both. High-fat (HF) foods are often more palatable, which can stimulate appetite beyond energy needs. Additionally, highly processed, HF foods are frequently more affordable and accessible, shaping dietary habits in environments with limited healthy food options [3, 8]. Consequently,

reducing dietary fat is commonly recommended for having a healthy body weight due to its higher energy content than carbohydrates or protein [9, 10]. However, it is unclear whether a low-fat (LF) diet may significantly affect the feelings of hunger and satiety. Some evidence suggests that low-carbohydrate, high-protein, and HF diets are more satiating and promote greater short-term weight loss than LF diets [11, 12], whereas some other investigations revealed that dietary energy and fat restriction reduce appetite due to the decreased glucagon-like peptide-1 (GLP-1) secretion, a hormonal regulator of food intake [13, 14]. It is reported that consumption of an HF diet attenuates gastrointestinal fat sensing and may also alter oral sensitivity, resulting in increased energy intake and subsequently, body weight gain [15]. Evidence also showed that although poly-unsaturated fatty acids (PUFAs), followed by mono-unsaturated fatty acids (MUFAs), induced the greatest satiety, subjective ratings of fullness did not differ according to the composition of dietary fatty acids [16].

It is unknown whether total dietary fat can affect appetite, and whether restricting it could have an appetite-lowering effect. This prompted us to conduct this systematic review of randomized controlled trials (RCTs) investigating the effect of an LF diet compared with an HF diet on the appetite status in adult participants.

Methods and materials

Systematic search strategy

The systematic search for the present review followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [17]. The review protocol was not prepared.

To identify all relevant RCTs, we conducted a comprehensive systematic search in PubMed, Scopus, Web of Science, and the Cochrane Library from the inception of the database to June 2, 2024, using Medical Subject Headings (MeSH) and non-MeSH terms. More details of the search strategy are provided in Additional Table 1. There were no restrictions on the language, population type, outcome measures, or year of publication. The reference lists of all the identified studies were manually screened to find additional eligible studies. Subsequently, all the records were pooled together, and duplicate articles were removed. Primary screening was performed by reading the titles and abstracts of the articles. The filtered articles were further screened by reading the full texts, and those not meeting the inclusion criteria were excluded. This search process was performed by six independent reviewers (ER, ZS, SZM, KT, MH, MM), and the final records were included in the systematic review after an iterative consensus process.

Eligibility criteria

The inclusion criteria were randomized controlled trial studies with either a parallel or crossover design that: 1) had at least one group of an LF diet intervention (i.e., 30% or less of total energy intake from fat); 2) had at least one group of an HF diet intervention (i.e., more than 30% of total energy intake from fat) as the control group. The equivalent gram value of this 30% would be 67 g for a 2000-cal diet; (it is of note that we selected the cutoff of 30% for LF and HF diets based on valid references from previous studies [18–23]); 3) included adult male or female participants aged 18 years and older with any health condition; and 4) reported values of appetite-related parameters, including hunger, fullness, prospective consumption, appetite score, food craving, satiety, and desire to eat, that were evaluated by the Visual Analogue Scale (VAS) or hyperphagia questionnaire. Changes in appetite status must be reported following a daily LF or HF diet. We had no restrictions on including studies with low-calorie or iso-calorie diets, or studies involving dietary behavioral changes, as long as both groups received these specific interventions. Studies that reported a simple fixed meal with reduced or increased fat per day were excluded. Editorials, conference proceedings, commentaries, and reviews/chapters were excluded. Besides, studies were excluded if they: 1) used only HF diets (i.e., more than 30% of total energy intake from fat), and 2), studies with no control group, no randomization process, or poorly defined outcome measures. 3) We also excluded studies that involved children, adolescents, pregnant, or lactating women as well as older individuals, as they may have different perceptions of taste and smell, potentially affecting the appetite cascade. 4) Additionally, we excluded studies involving diseased individuals who might experience blunted appetite, such as those with cachexia.

Data extraction

Data extraction was conducted independently by two reviewers (SA, FM), and the following information was extracted for each study: the last name of the first author; year of publication; country; study design; dietary percent of fat, carbohydrate, and protein for each group; duration of the intervention; sex, age, and health status of participants; number of participants in each group; method of assessing the appetite-related parameters and their corresponding values (i.e., mean changes or before/after values); if there were articles that reported the outcomes of interest in the same population, we included the study that had the largest sample size or the longest follow-up duration. Any disagreements were discussed with the corresponding author (SS).

Quality assessment

The revised Cochrane risk-of-bias tool for randomized trials (RoB2) [24] was used by two independent reviewers (ER and MM) to assess the methodological quality of the included studies. The following five sources of bias were considered: 1) bias arising from the randomization process; 2) bias due to deviations from the intended interventions; 3) bias due to missing outcome data; 4) bias in the outcome measures; and 5) bias related to the selection of reported results. Final judgments and overall risk of bias were defined as “Low” or “High” risk of bias or expressed as “Some Concerns.” Any discordance during the process of quality assessment was discussed with a third researcher (SS).

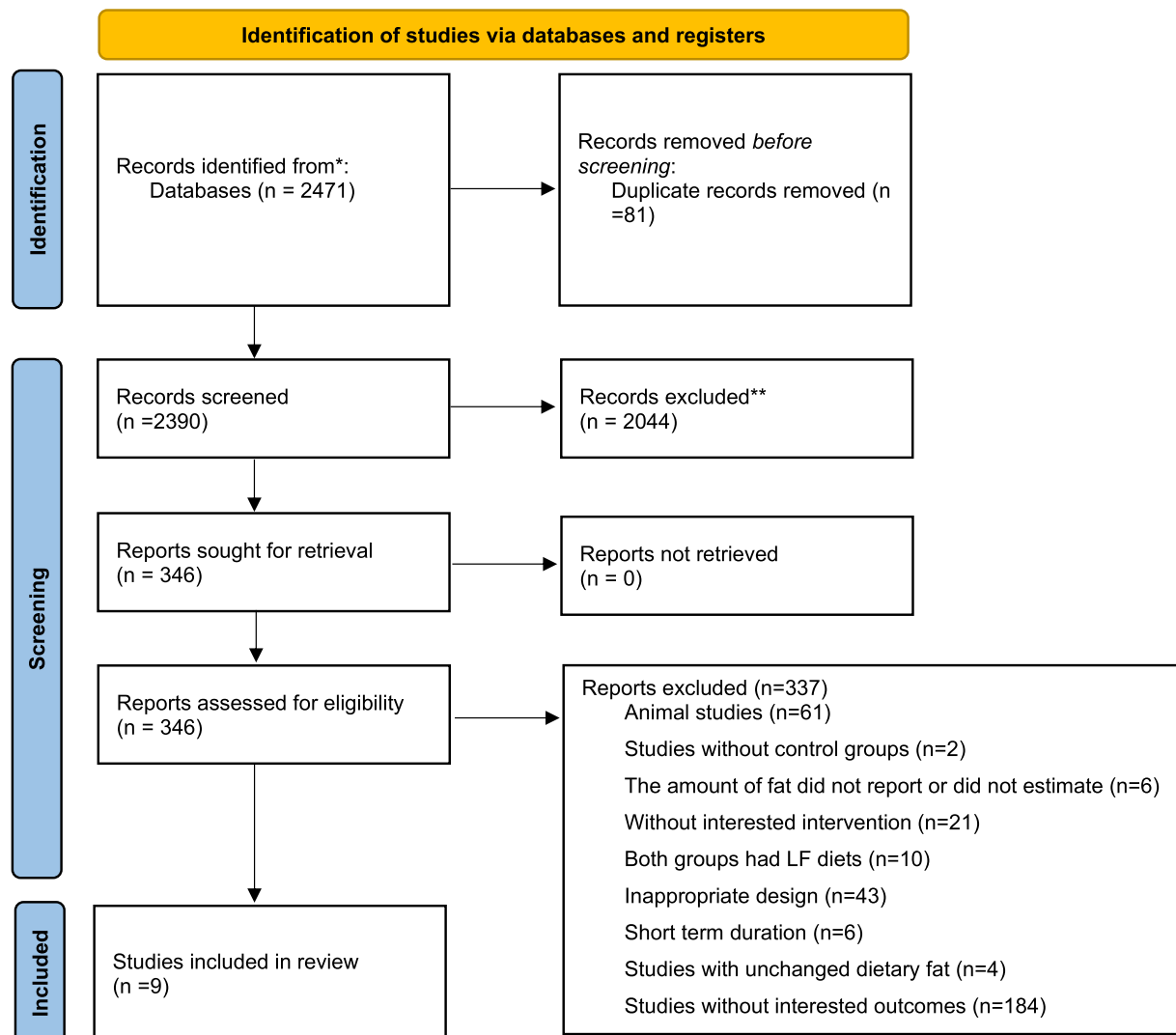
Results

Search results

The search strategy identified 2471 records. After duplicate removal, 2390 articles were selected for title and abstract screening, of which 2044 were excluded for not meeting the inclusion criteria. A total of 346 studies were reviewed in full-text and nine eligible studies were ultimately included in the systematic review [25–33]. A list of excluded studies with reasons for exclusions is provided in Additional Table 2. The study selection process is presented in Fig. 1.

Study characteristics

The characteristics of the included studies are shown in Table 1. All of the included studies were in English. Three studies included females only [28, 31, 32], one study included males only [27], and the rest of the studies enrolled both males and females [25, 26, 29, 30, 33]. Four studies were carried out in the USA [28, 29, 31, 32], while two studies were conducted in Australia [27, 30]. Additionally, one study took place in Sweden [25], one in Canada [26], and one in Denmark [33]. All but one study [27] applied a parallel design, and the duration of the intervention varied from 2 to 96 weeks. Seven studies were conducted among participants with overweight and obesity who were otherwise seemingly healthy [25, 28–33], one study enrolled patients with type-2 diabetes [26], and one study was conducted among healthy participants without obesity [27]. Except for one [27], the intervention group received an LF diet that contained 30% or less of total energy intake from fat, and the control group received an HF diet (greater than 30%). Boyd et al. used an HF and an LF diet for the intervention and the control groups, respectively. After each diet, the effects of a 90-min intraduodenal lipid infusion on gastrointestinal motility (via manometry), appetite-related hormones

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only**Fig. 1** PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

[cholecystokinin (CCK), GLP-1], and subjective appetite sensations were assessed, followed by an ad libitum buffet meal to measure actual food intake. This comprehensive protocol allowed for the evaluation of both physiological and behavioral responses to dietary fat intake. This study by Boyd et al. is the only study that utilized 11% of fat for the LF group, which is considered a very LF diet [27]. Five studies reported changes in the types of dietary fat intake- MUFA, PUFA, and saturated fatty acids (SFA)-during the intervention [26, 28–30, 33], of which only two studies revealed the association between changes in the types of dietary fat and the appetite-related parameters [26, 33].

Three studies used a daily calorie restriction of 200–1000 kcal/day in all the study groups [25, 28, 30]. In another investigation, participants in the LF diet were instructed to restrict their energy intake; yet, by the end of the study, everyone in both the LF and HF diet groups had decreased their calorie intake [31]. Another study, on the other hand, used a daily calorie reduction in the HF group; however, the calorie goal of 500–1000 kcal short in 1 month was not met, and no significant differences in daily energy intake were found between the two groups [32]. Six investigations instructed the participants in all groups to receive a standard amount of protein, which was 15–20% of their daily energy intake [25–28, 32, 33]. Li et al. used a high daily

Table 1 Characteristic of controlled trials that evaluated the effect of the low-fat vs. high-fat diet on appetite indexes were eligible to be included in systematic review

Author, year (Ref)	Country	Number of subjects (men/ women)	Mean age (year)	RCT design	Duration (week)	Prescribes diet in intervention group (%)	Prescribes diet in control group (%)	Calorie Restriction (Yes, No)	Population characteristics	Results	Tools
Aberg, 2008 (25)	Sweden	100 (M:21, W:79)	38 ± 6.2	Parallel	10	CHO: 55 FAT: 25 PRO: 20	CHO: 36 FAT: 44 PRO: 20	Yes	Overweight and obese	↓Hunger (in both groups during study; a significant decrease in those who had < 7% reduction in BMI) ↑Palatability	VAS
Barnard, 2009 (26)	USA	99 (M:39, W:60)	56	Parallel	74	CHO: 67 FAT: 22 PRO: 15	CHO: 47 FAT: 33 PRO: 20	No	T2DM	↑Dietary restraint (sig increase in both groups, more increase in HF) - ↔ Disinhibition—↔ Hunger (insignificant decrease in both groups) VAS: ↓Hunger ↔ Fullness - ↓Desire to eat ↓Hunger ↑Satisfaction ↑Fullness (decreased hunger status in both groups, with a much more reduction in LF group)	Eating Inventory
Boyd, 2003 (27)	Australia	11 (M:11, W:0)	27 ± 1.7	Crossover	2	CHO: 69 FAT: 11 PRO: 20	CHO: 46 FAT: 42 PRO: 12	No	Healthy		VAS
Klempel, 2013 (28)	USA	32 (M:0, W:32)	43 ± 9	Parallel	8	CHO: 60 FAT: 25 PRO: 15	CHO: 40 FAT: 45 PRO: 15	Yes	Overweight and obese	↓Hunger ↑Satisfaction ↑Fullness (decreased hunger status in both groups, with a much more reduction in LF group)	VAS
Li, 2020 (29)	USA	692 (M:269, W:423)	52 ± 8.3	Parallel	96	CHO: 55 FAT: 20 PRO: 25	CHO: 35 FAT: 45 PRO: 25	No	Overweight and obese	↓Hunger (in the low-fat diet group, individuals with a lower LBM-GRS had a greater reduction in hunger and prospective consumption, and a greater increase in fullness) ↑Fullness ↓Prospective consumption ↓Total appetite score ↑Craving	VAS

Table 1 (continued)

Author, year (Ref)	Country	Number of subjects (men/ women)	Mean age (year)	RCT design	Duration (week)	Prescribes diet in intervention group (%)	Prescribes diet in control group (%)	Calorie Restriction (Yes, No)	Population characteristics	Results	Tools
Luscombe-Marsh, 2005 (30)	Australia	57 (M:25, W:32)	50 ± 3	Parallel	12	CHO: 30 FAT: < 30 PRO: 40	CHO: 30 FAT: 50 PRO: 20	Yes	Overweight and obese	↓Hunger ↔ Satiety ↓desire to eat (in LF-high protein group) ↓3-h hunger response	VAS
Nickols-Richardson, 2005 (31)	USA	28 (M:0, W:28)	40 ± 6.3	Parallel	6	CHO: 60 FAT: 22 PRO: 18	CHO: 12 FAT: 61 PRO: 26	Yes (only in the LF group)	Overweight and obese	↑ Dietary restraint (in both groups) ↓Hunger (in HF group) ↔ Mean restraint eating	Eating Inventory,
Shah, 1996 (32)	USA	75 (M:0, W:75)	25–45	Parallel	24, 48	CHO: 57 FAT: 26 PRO: 17	CHO: 52 FAT: 31 PRO: 17	Yes (only in the low-calorie HF group)	Overweight and obese	↔ Satiety (decreased in both groups)	VAS
Sloth, 2009 (33)		42 (M:20, W:22)	28 ± 2	Parallel	24	CHO: 60 FAT: 22 PRO: 18	CHO: 47 FAT: 35 PRO: 18	No	Overweight and obese	↓Satiety (in both groups) ↑Appetite (in both groups) (no significant difference in appetite between groups after 6 months)	VAS

RCT randomized controlled trial, LF low-fat, HF high fat, VAS visual analogue scale, M men, W women, CHO carbohydrate, PRO protein, T2DM type-2 diabetes mellitus, LBM-GRS lean body mass genetic risk score, BMI body mass index

protein intake (> 20% of daily energy) along with both the LF and HF diets [29], while Luscombe et al. used a high protein diet only for the participants in the LF diet group [30]. On the other hand, Nichols et al. instructed the participants in the HF group to receive a high-protein diet [31]. The "eating inventory" method was employed in two research [26, 31], while a visual analogue scale (VAS) was used in the remaining trials [25, 27–30, 32, 33] to assess appetite-related outcomes, including hunger, fullness, prospective consumption, appetite score, food craving, satiety, and desire to eat. None of the included studies reported any related adverse effects.

Quality assessments

Based on the overall quality assessment of the included studies according to the Cochrane Collaboration Risk of Bias tool (Table 2), two studies were classified as "low" risk of bias (i.e., low risk of bias for all domains) [27, 28], four studies were classified as "some concerns" [25, 26,

29, 30], and the two remaining articles were classified as "high" risk of bias [31, 33]. Only two studies [27, 28] considered the blinding process to explain the details of the observed biases, and it was not clearly explained in the remaining studies [25, 26, 29–33]. Five studies had "some concerns" risk of bias [25, 26, 29, 31, 33] due to the measurements of the outcomes where outcome assessors were not blinded to the study, and two studies did not clearly report the number of participants with missing outcome data [31, 33].

Key findings

Hunger

Of the seven studies that explored the effect of an LF diet on the hunger level [25–31], five studies enrolled adults with overweight and obesity, and two studies included healthy individuals [27] and participants with type-2 diabetes [26]. Three studies applied either an alternate-day fasting diet [28], an energy-deficit diet [25], or a vegan

Table 2 Study quality and risk of bias assessment using Cochrane collaboration tool^a

Author, Year (Ref)	Randomization Process	Deviations from the intended intervention	Missing outcome data	Measurement of the outcomes	Selection of the reported results	Overall quality ^b
Aberg, 2008 (25)	✓	✗	✓	✗	✓	✗
Barnard, 2009 (26)	✓	✗	✓	✗	✓	✗
Boyd, 2002 (27)	✓	✓	✓	✓	✓	✓
Klempel, 2013 (28)	✓	✓	✓	✓	✓	✓
Li, 2020 (29)	✓	✗	✓	✗	✓	✗
Luscombe-marsh, 2005 (30)	✓	✗	✓	✓	✓	✗
Nickols-richardson, 2005 (31)	✓	✗	✗	✗	✓	✗
Shah, 1996 (32)	✓	✗	✓	✓	✓	✗
Sloth, 2016 (33)	✓	✗	✗	✗	✓	✗

^a Cochrane risk of Bias 2 (RoB2) (2019) was used for quality assessment

^b Signs indicate high risk of bias (✗), some concerns (✗) and low risk of bias (✓)

diet [26] along with the LF (25% fat) and HF (45% fat) dietary interventions with a standard daily protein intake (15% protein). The carbohydrate content of the intervention groups in these studies ranged between 55 and 67% of the total energy intake. While studies found a significant reduction in the sensation of hunger within groups, there were no significant differences between groups. Notably, Aberg et al. observed that participants who attained a median 7% drop in body mass index (BMI) tended to have a lower perceived hunger compared to those who lost less body weight [25].

Luscombe et al. compared the effects of 12-week energy-restricted LF (29% fat), and HF (45% fat) diets followed by 4 weeks of energy-balanced diets with the same macronutrient composition on hunger status. The carbohydrate content of the two diets was 30% of total energy intake, and the protein content of the LF and HF diets was 40% and 20% of daily energy, respectively. According to the results, the LF diet group experienced a significant hunger response compared to the HF diet group, from week 0 to week 16 [30].

In a study by Boyd et al., the effect of a 90-min duodenal lipid infusion on hunger was assessed immediately following 14-day periods on either an LF or HF diet among healthy men [27]. The results showed that ingestion of an HF diet (which was based on lean meat, poultry, higher-fat milk, and oil and nuts high in MUFA) significantly increased perceptions of hunger as an appetite response in participants, while after an LF diet (which was lower in energy and included lean meat, poultry, and LF dairy foods), there was an initial increase in hunger score followed by a final decrease. The carbohydrate content of the LF diet was relatively high (69% of daily energy) compared to the HF diet (46% of daily energy) [27].

Li et al. conducted a different trial and investigated whether the genetic risk score (GRS) for lean body mass modified the effects of the LF (20% of daily energy) or HF (45% of daily energy) diets on changes in hunger among individuals with overweight and obesity. Protein content was reported to be 25% of total energy intake in both diets. The authors showed that in the 2-year Preventing Overweight Using Novel Dietary Strategies (POUNDS Lost) trial, individuals with a lower lean body mass-GRS in the LF diet group had a greater reduction in hunger, while no association was found in the HF diet group [29].

In contrast to all the other studies mentioned above, Nickols et al. were the only investigators to demonstrate that premenopausal women who received an HF diet (61% of daily energy) with a high protein content (26% of daily energy) experienced a significant reduction in self-reported hunger from baseline to week 6, whereas those who received an LF/standard protein diet (22% and 15% of daily energy from fat and protein, respectively) did

not. It is noteworthy that Nickols et al. used the highest amount of dietary fat in their control group [31], compared with the rest of the studies.

Total appetite score, status of fullness, and food cravings

Two studies assessed the effects of the LF and HF diets on total appetite status by evaluating different subscales [28, 29]. Li et al. investigated the changes in the total appetite score and its individual components, including fullness, prospective consumption, and craving, across the lean body mass-GRS tertiles according to diet groups from baseline to 6 months and 2 years of visits. The authors indicated that compared to those with a higher lean body mass-GRS, participants with a lower lean body mass-GRS in the LF diet group had greater decreases in their total appetite score from baseline to 6 months, which were then increased substantially from 6 months to 2 years. They also reported a greater increase in fullness score from baseline to 6 months in the LF diet group, which was then decreased from 6 months to 2 years. No significant changes were observed in the scores of the other appetite subscales [29]. Sloth et al. assessed changes in the mean appetite score, which was derived by considering satiety, fullness, anticipated consumption, and hunger. No measurements were provided for each of the appetite subscales independently. They demonstrated that after a 6-month weight maintenance period following an initial low-energy diet in healthy individuals with obesity, no differences in the mean appetite score were seen between the LF and HF diets [33].

Two other studies also reported changes in fullness status as an appetite-related measure [27, 28]. Klempe et al. revealed that fullness and satisfaction scores decreased among women with overweight and obesity who received an LF diet for 8 weeks, in contrast to the alternate-day fasting-HF diet group [28]. On the other hand, Boyd et al. showed that ratings of fullness did not differ between the two diets among healthy men after 2 weeks [28]. In terms of the food craving parameter, Barnard et al. revealed that after 74 weeks, neither of the diets was associated with an increase in cravings among patients with type-2 diabetes [26].

Satiety, desire to eat, and palatability

Three studies reported changes in satiety [30, 32, 33]. Luscombe et al. showed that despite there being no noticeable differences in satiety between participants with overweight and obesity who followed a high-protein LF diet and those who followed a standard-protein HF diet, the amount of food desired to eat was significantly lower after 16 weeks in the high-protein LF diet group than the other group [30]. Similarly, they reported that

the desire to eat was significantly elevated after 2 weeks in the LF diet group [30]. Shah et al. also revealed that the satiety status of individuals who were given either an LF diet or a low-calorie diet with 31% of its calories from fat did not alter significantly. It is worth noting that the authors employed an average quantity of carbohydrates (54% of daily energy) and proteins (17% of daily energy) in both groups. They similarly reported insignificant changes in palatability at the end of the study [32]. Aberg et al. concluded that pronounced differences in relative and absolute fat content following an energy-restricted LF or HF diet for 10 weeks did not result in differences in palatability among individuals with overweight and obesity resulted in a significant inverse association between the hunger status and the perceived palatability of the diet. Additionally, they showed that participants who experienced a median BMI loss of 7% tended to improve their perceived palatability, but the difference was not statistically significant [25].

Discussion

This systematic review of nine RCT studies found that there would be no discernible differences in appetite-related indicators between an LF diet and an HF diet.

It seems that the effects of LF diets on appetite might be influenced by other dietary components, such as the levels of carbohydrates and proteins. In this regard, it is reported that both LF and HF diets may decrease hunger, but the strength of the effects is greatly influenced by the amounts of dietary protein [25, 26, 28]. Dietary protein may have an even stronger role than lowering dietary fat content in reducing appetite, as a study showed that a six-week intervention of an LF/high-carbohydrate diet did not change the hunger score while adhering to an HF/high-protein diet led to a lower self-rated hunger score in overweight premenopausal women [31]. For example, an LF diet with 40% protein led to a significantly greater decrease in the hunger score and desire to eat, even when the satiety status remained unchanged [30]. Luscombe et al. implied that the LF-high protein diet had a greater satiating impact than the isocaloric HF-standard protein diet, which is consistent with the desire to eat less food [30]. Nickols et al. showed that an LF diet with a high-carbohydrate content (60% of energy) did not change the hunger score in overweight premenopausal women while adhering to an HF/high-protein diet (with 61% fat and 25% protein) led to a lower self-rated hunger score over 6 weeks [31]. One of the possible reasons contributing to this significant finding might be that Nickols et al. used a self-reported score to assess the appetite-related parameters, compared with the rest of the studies, which used a VAS assessment scale [31].

Furthermore, it is important to consider what other components are included in an LF diet. For instance, it is possible that an LF diet could also be high in carbohydrates, but the type of carbohydrates used, such as diets high in fiber with low-glycemic index carbohydrates, can have an impact on appetite [34]. All these concordant findings signify the important role of protein and carbohydrate content in the final effects of an LF diet on hunger status, indicating that adhering to an LF diet without considering the amounts of other macronutrient intakes would not necessarily result in beneficial effects on appetite-related sensations. On the other hand, Li et al. revealed that genetic variations of lean body mass (LBM) may also influence the final effects of the LF diet on the regulation of appetite, specifically in individuals with overweight and obesity, and those with a higher genetic predisposition to higher LBM might benefit more in reducing hunger, total appetite, and fullness, sensations by adhering to an LF diet even without restricting energy intake [29]. In line with that, Blundell et al. conducted a 12-week study on obese adults, exploring the relationship between biological and behavioral variables in appetite management. They reported significant correlations between meal size and daily energy intake with fat-free mass (FFM), suggesting that lean mass may have a determining effect on food consumption. They reported that fat mass and body mass index (BMI) did not show significant correlations with meal size and energy intake [35]. It is well known that LBM is the main factor influencing resting metabolic rate. Also, LBM may play a role in controlling appetite through the signaling of adenosine monophosphate-activated protein kinase (AMPK) during the turnover of energy in muscle metabolism [36]. These findings have implications for understanding the molecular control of food intake and body weight management, highlighting the potential role of lean mass in appetite regulation.

It is important to note that the majority of the research, which included participants with overweight and obesity, had favorable changes in body weight as their main objectives rather than any appreciable improvements in appetite-related symptoms alone [25, 28–33]. According to the findings of Luscombe et al., the satiating properties of protein-rich foods, such as lean meat and LF dairy products in an LF/high-protein diet, caused a lower calorie intake that eventually led to a better weight loss compared to an LF/standard-protein diet [30]; they believed that reducing dietary fat intake, choosing fat from sources high in MUFA, and simultaneously replacing some dietary carbohydrates with protein from meat, poultry, and dairy foods, would result in significant beneficial changes in the appetite sensation and body weight of people with overweight and obesity [30]. On the other hand, Boyd

et al. discovered that following a duodenal lipid infusion after 14-day treatments of an LF diet compared to an HF diet, there was a substantial rise in the hunger score but no significant changes in the fullness ratings [27]. They hypothesized that this apparent discrepancy may be explained by the fact that feeling "full" is linked to gastric distension [37], but feeling "hungry" may be associated with small intestine nutrient exposure [38]. In fact, consumption of a meal high in fat and energy modulates gastrointestinal function, resulting in a reduction in tonic and phasic pyloric activity, and may increase the hunger ratings in response to intraduodenal lipid [27]. Moreover, other important mechanisms of action through which dietary fats and proteins influence appetite are mainly by affecting appetite and hunger-related hormones; certain fats, like healthy unsaturated fats, may reduce appetite through increased leptin and decreased ghrelin levels, while unhealthy trans fats might have the opposite effect [15, 39]. Protein-rich foods tend to increase levels of CCK, glucagon-like peptide-1 (GLP-1), and peptide YY (PYY), which are appetite-suppressing hormones, leading to a reduced desire to eat and prolonged feelings of fullness [40]. However, more research is required to explore the exact influence of dietary macronutrient variations on appetite hormone regulation.

Along with reducing dietary fat consumption, energy restriction was also considered an important determinant in the management of appetite. This conclusion can be drawn from the four included studies that used reducing dietary fat and energy intake while consuming less than 20% protein [25, 28, 31, 32]. These results are also consistent with the findings from a previous review by Little et al. who focused on the effects of gastrointestinal sensory contributions of dietary fats on appetite, energy intake, and body weight gain [15]. They found that eating an HF diet decreased gastrointestinal fat sensing, which may also change oral sensitivity and result in increased energy intake, ultimately leading to an increase in body weight. Energy restriction, at least temporarily, may increase gastrointestinal fat sensing, which is associated with greater energy intake suppression [15]. Sloth et al., however, presented a conflicting result. Although they found no differences in overall appetite scores after a 6-month energy-restricted LF, HF, or MUFA diet intervention, they did find a meaningful decrease in ratings of satiety in all groups. They suggested that adding an appetite-suppressing drug therapy period after any energy-restricted diet should be considered to prevent weight gain [33]. On the other hand, a previous study suggests that certain fatty acids, such as omega-3 fatty acids, may promote greater satiety and help regulate appetite, while others, like some saturated fats, may have less favorable effects on appetite control [41]. Given the significance of

this aspect, only Luscombe et al. [30] and Sloth et al. [33] utilized HF-diets rich in MUFA compared to LF-diets and reported no significant changes in appetite-related parameters. However, none of the included studies in the present review provided information on the specific fatty acid composition of LF dietary interventions, limiting a comprehensive understanding of how such diets might have influenced appetite responses.

Results from the present systematic review showed that another important contributing factor to appetite management is the palatability of foods. Two studies demonstrated that the fat content of diets had no influence on perceived hunger, the palatability of foods, or adherence [25, 32]. However, according to the study by Aberg et al., perceived hunger had a negative association with the palatability of foods, meaning that participants who experienced less hunger tended to rate the diet as more palatable [25]. Furthermore, Klempe et al. showed that satisfaction and fullness in the LF diet group steadily increased while remaining relatively high in the HF diet group [28]. These conclusions are inconsistent with previous evidence indicating that HF diets are more palatable and that a high level of palatability may play a significant role in long-term adherence to a low-calorie diet [42]. Shah et al. hypothesized that a very low-calorie diet with a goal of 20 g or perhaps double that amount of daily fat intake might not be practical for a very long time [32]. It is important to highlight that Aberg et al. carried out their investigation in the participants' home environment as a naturalistic setting, and hence their findings may be more easily transferred to such normal life conditions.

In studies utilizing calorie restrictions, either both groups received calorie restrictions by the end of the interventions or there were no significant differences in calorie intakes between the groups [25, 28, 30–32]. This suggests that any changes observed in appetite cannot be solely attributed to calorie restriction itself, as both groups experienced similar energy intake adjustments. Moreover, among these five studies [25, 28, 30–32], weight loss in both LF and HF groups did not show statistically significant differences. Although both groups experienced weight loss, the extent of weight reduction between them was not significant. An interesting observation was made in the study by Aberg et al. [25], where weight loss during the intervention did not show a significant association with appetite parameters. Furthermore, the magnitude of weight loss is essential. For instance, one study reported that a 16% weight loss at week 13 was required to increase hunger, while postprandial feelings of fullness and satiety quotient hunger were increased, and prospective food consumption was reduced [43]. In our review, the included studies showed weight loss below 10%, which was insufficient to induce appetite

changes based on documented evidence [43]. DeBenedictis et al.'s study also provides valuable insights into the impact of weight loss on appetite [44]. It discusses the lack of effect of weight loss on appetite and highlights the presence of conflicting results regarding the influence of weight reduction on appetite parameters. Despite that, research has shown that sustained weight loss may lead to significant changes in appetite regulation, which can influence an individual's overall energy intake [7]. One notable finding is that sustained weight loss would be associated with an increase in hunger, potentially influenced by changes in appetite hormones such as ghrelin and leptin. These physiological adaptations may pose challenges for appetite control, as heightened hunger sensations and food cravings could potentially impact eating patterns [7].

Interesting information concerning the changes in food quality following the LF and low-energy/HF diets was provided in one study [32]. Results showed that vitamins A and B intakes during the study were approximately 100% in both groups. However, the intake of vitamin C increased following the LF diet, which may be due to the increased consumption of fruits and vegetables. Additionally, they showed that the LF group's calcium intake was decreased substantially as a result of a reduction in the consumption of dairy foods [32]. The authors indicated that individuals who followed an LF or an energy-restricted diet should take multivitamin and mineral supplements because neither of the two groups obtained the necessary daily dose of calcium, iron, magnesium, zinc, or vitamin D and E [32]. To our knowledge, the current systematic review of RCT studies is the first to compare the impacts of an LF vs. HF diet on appetite-related parameters. As a result, it makes it possible to combine data from the gold standard in intervention-based research to produce a credible clinical application and identify any gaps in the body of knowledge in this area. Although previous research has highlighted the effects of high-protein diets on appetite reduction, our review uniquely addresses the limitations of solely focusing on LF diets for appetite control. We emphasize that the presence of protein can significantly influence the effects of LF and HF diets on appetite. By considering the interactions between fat and protein, our review provides a more nuanced understanding of appetite regulation and the complexity of dietary choices. In conclusion, while the effects of high protein diets on appetite reduction are well-known, our review's novel contribution lies in highlighting the interplay between macronutrients in influencing appetite regulation. We recognize the importance of considering the overall dietary composition rather than focusing solely on individual macronutrients. This comprehensive approach enhances our understanding of

appetite control and provides valuable insights into promoting healthier dietary choices.

However, our study has some limitations. The fact that just a relatively limited number of studies met the inclusion criteria made it difficult for the present evaluation to draw a firm conclusion. In some of the included studies, the level of adherence to each of the HF or LF diets has not been reported, and it is possible that over time, adherence to the diet may change from the established protocol. Moreover, although we considered strict eligibility criteria to include studies with LF and HF diets, in some studies the difference in the amount of fat in all groups was very small, and it is probable that this small difference renders the intervention ineffective on appetite. Moreover, the protein and carbohydrate levels in the diet differed between the intervention and control groups, potentially influencing some of the effects of the LF diet on appetite. Additionally, calorie restriction and the extent of weight loss resulting from it are among the other confounding variables that should be carefully considered in the design of future clinical trials. It is also important to note that none of the studies reported any negative side effects following the use of each diet, which may play a significant role in determining how effectively diets are followed over time. Moreover, the results should be interpreted carefully since most of the eligible studies were of medium-to-low quality. The significant inter-individual diversity among the included studies must also be emphasized. The expected clinical efficacy may vary depending on the participant's age, gender, and clinical condition. Therefore, further high-quality research is guaranteed to strengthen the evidence base in this area. In addition, although this systematic review provides valuable insights into the relationship between LF diets and appetite, future research could benefit from incorporating machine learning approaches, such as random forest models. These methods, combined with tools like SHAP (Shapley Additive Explanations) summary plots, may allow for a more nuanced understanding of the strength and direction of associations between dietary patterns and appetite. Such techniques could help identify complex interactions among variables and provide predictive insights that go beyond traditional meta-analytic approaches.

Regarding practical implications, the findings of this systematic review suggest that LF diets alone may not significantly influence appetite unless other macronutrient components, especially protein, are considered. For dietary counseling, this highlights the importance of emphasizing balanced macronutrient distribution (not simply reducing fat) for appetite control and long-term dietary adherence. Clinicians and dietitians should consider individual variability, including lean body mass and

genetic predispositions when recommending dietary patterns for weight and appetite management. In practice, LF diets that incorporate high-quality protein sources and low-glycemic index carbohydrates may be more effective in promoting satiety and reducing hunger. Additionally, factors such as food palatability, accessibility, and nutritional quality should be integrated into dietary guidance to support sustainable lifestyle changes. For future studies, clinical trials should aim to standardize macronutrient compositions more precisely and account for behavioral, metabolic, and hormonal factors. Advanced statistical tools, such as machine learning models, may also enhance our understanding of complex interactions between diet and appetite regulation.

Conclusions

According to the present systematic review, an LF diet *vs.* HF diet would not significantly alter appetite-related parameters, unless it has a high-protein or low-carbohydrate content, or it is combined with a restricted daily energy intake, specifically among individuals with overweight and obesity. This is because the dietary intake of one particular macronutrient cannot be varied independently of the other macronutrients without affecting energy. On the other hand, limited strong evidence exists regarding the association between weight loss and appetite status. Recognizing the complex interplay between weight loss and appetite regulation is crucial for developing effective strategies for managing appetite and promoting healthy eating habits. The present study also showed that the palatability of foods, fullness, and satisfaction would gradually increase following an LF diet. However, consuming 20 g of fat per day along with a very low-calorie diet may not be achievable for a long time. Taking multivitamins and mineral supplements may also be required when on an LF or energy-restricted diet. However, more research needs to be conducted to demonstrate the effects of the LF or HF diets on appetite in clinical practice, specifically in populations with overweight or obesity. To better understand whether HF or LF diets can affect appetite, future studies should more closely match the percentages of dietary components, such as other macronutrient intakes as well as fatty acids contents including saturated, monounsaturated, and polyunsaturated fats in all groups.

Abbreviations

LF	Low-fat
HF	High-fat
GLP-1	Glucagon-like peptide-1
PUFA	Poly-unsaturated fatty acids
MUFA	Mono-unsaturated fatty acids
RCT	Randomized controlled trials
PRISMA	Preferred Reporting Items for Systematic Reviews and

RoB	Meta-analyses
POUNDS	Cochrane risk-of-bias tool for randomized trials
VAS	Preventing Overweight Using Novel Dietary Strategies
LBM	Visual analogue scale
AMP-K	Lean body mass
CCK	Adenosine monophosphate-activated protein kinase
PYY	Cholecystokinin
	Peptide YY

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Authors' contributions

SS and SA conceived the idea of the study and designed the study strategy; ER, MKS, ZS, SM, KT, MH, FM, MM conducted studies screening; ER, MKS, ZS, SM conducted data extraction; KT, MH, FM conducted quality assessment; ER, SA and SS contributed to the writing and revision of the manuscript. All authors read, provided feedback, and approved the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

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