REVIEW ARTICLE

Effect of the fatty acid composition of meals on postprandial energy expenditure: a systematic review

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SUMMARY

The energy imbalance produced by an increase in caloric intake and/or decrease in energy expenditure induces obesity. However, the fatty acid composition of a diet can affect the metabolism in different ways, having a role in the development of obesity.

AIM: *To determine the effect of different fatty acids types and composition on Diet-Induced Thermogenesis (DIT) and postprandial energy expenditure in humans.*

METHODS: *A search in the PubMed and Web of Science databases, yielded a total of 269 potential articles as a first result; 254 were excluded according to the criteria.*

RESULTS: *Fifteen articles were used for this systematic review. The studies analyzed report different effects of the fatty acids of the treatment on the diet-induced thermogenesis. Evidence indicates that the consumption of polyunsaturated fatty acids causes a greater DIT than saturated fatty acids. Also, the consumption of medium-chain fatty acids compared to long-chain fatty acids has been shown to increase DIT. Likewise, the use of certain oils has shown positive effects on postprandial energy expenditure, as is the case of olive oil, compared to rapeseed oil.*

CONCLUSIONS: *The use of specific types of fatty acids in the everyday diet can increase postprandial energy expenditure in humans. Nevertheless, longer-term studies are required.*

KEY WORDS: *Diet induced thermogenesis; thermic effect of food; fatty acids; energy expenditure; postprandial energy expenditure.*

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INTRODUCTION

The energy imbalance produced by a caloric intake increment and/or a decrease in energy expenditure induces obesity. However, the diet's fatty acid composition can affect the metabolism in different ways, playing a role in its development.[1,2]

AIM

This systematic review analyzes research performed on different fatty acids to determine their effect on Diet Induced Thermogenesis (DIT), also called Thermic Effect of Food (TEF), and energy expenditure in humans.

METHODS

For this review, the search for articles lasted four months (August to November 2017) and was conducted on the PubMed and Web of Science databases. We used the MeSH terms "Diet induced thermogenesis" AND "fatty acids" OR "fatty acid" OR "fats". Additionally, searches with the terms "Thermic effect of food" OR "Thermogenic effect of food" AND "fatty acids" OR "fats" OR "fat" were used. Article selection was performed taking into consideration the following inclusion criteria: the study needed to a) have been performed in humans, b) be original, c) have used at least one diet or food that includes fatty acids, d) report the fat composition of the diet or food used, e) have measured postprandial energy expenditure. Other characteristics used as eligibility criteria were publication date between 1997 and 2017 and in the English language.

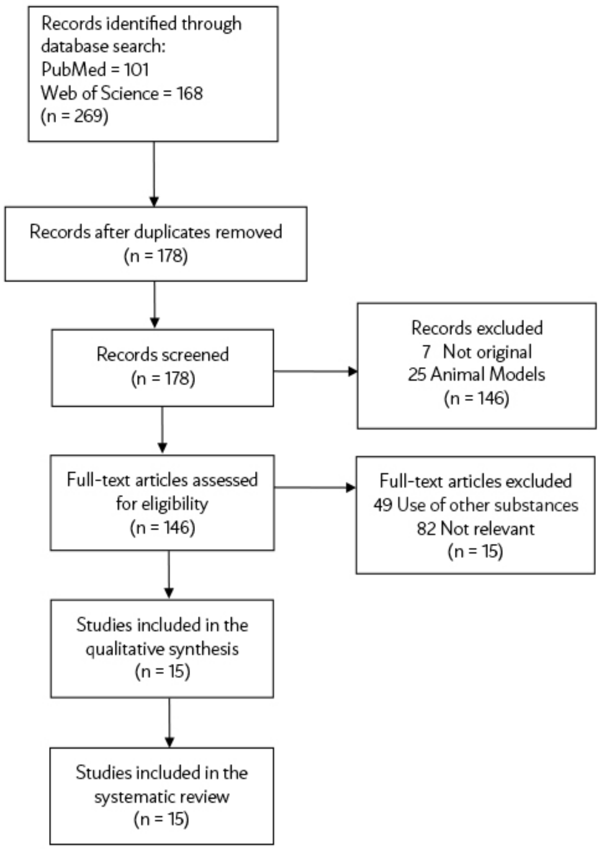
One hundred and one articles were identified in the PubMed database, of which were excluded a) 44 because they were duplicates and b) 43 for not being relevant to the topic. A total of 14 articles from this database were used. Regarding the research in the Web of Science database, from the 168 articles originally identified: a) 31 were excluded due to duplication in different searches in the database, b) 16 because they were repeated between the two databases used, c) 88 were not relevant for the subject, d) 21 were performed in animal models, and e) 7 were not original. Finally, one article from this database was used. Fifteen original articles were included in this systematic review (Figure 1). The main data of the studies can be found in the data matrix (Table 1) made using a data extraction form in duplicate. This systematic review did not require any personal information and therefore, did not require approval by the Institutional Review Board. The review protocol was made using the PRISMA reporting checklist and flowchart[3] as the basis, except for the PROSPERO registry.

RESULTS

Fifteen publications were analyzed (Table 1), seven of which were performed specifically in men,[1,4,5-9] six were carried out only with women.[2,10-14] One publication reported two experiments, one of which was made exclusively in men while the other was made exclusively in women[15] Finally, just one study included men and women.[16]

Among the eight studies that included women, it should be noted that two reported performing the interventions on days 3-9 of the participant's menstrual cycle.[2,10] In another publication, experimental sessions were described to have taken place two days in a week, with one- or two-day intervals to synchronize with either the highest or lowest temperature point in the menstrual cycle.[15] Two studies reported as

FIGURE 1. STUDY SELECTION FLOWCHART



Flow chart of the selection of papers for the systematic review of the effects of the fatty acid composition of foods on diet-induced thermogenesis and postprandial energy expenditure in humans. The papers considered not relevant did not meet any of the other inclusion criteria.

one of the participant's characteristics 28 days menstrual cycles, and interventions were made 14 days of washout apart, ensuring their participants would be in the same point of the menstrual cycle in both crossover treatments.[12,14] In one of the studies, participants were in a postmenopausal stage.[13] Finally, two of the interventions did not report controlling or recording this variable.[11,16] The study that reported the highest number of participants was performed with 71 males,[5] followed by two studies with 20 participants each.[11,16] In a decreasing order, we found one study with 19 participants,[1] two studies with 16 participants each,[10,15] and two with 15.[2,6] Among the studies with less than 15 participants, a study with 14 subjects was found,[8] as well as three with 12,[12-14] one with 11[4] and lastly, the studies with the lowest number of participants had 6 each.[7,9]

Participants ages in the different researches ranged from 18 years old for the youngest[2,10] to 73 for the oldest.[13] However, most studies had participants with an average age between 22 and 29 ranges,[2,4-6,10-12,15,16] average and standard deviation for each study are presented in Table 1.

Regarding the participant's conditions, six of the 15 publications had participants whose Body Mass Index (BMI) classified them as obese and/or overweight.[5,7,8,10,11,13] One of the studies also included among the subject's characteristics the presence of metabolic syndrome,[7] while another worked with postmenopausal participants.[13] In one of the studies, the participant's body weight was at the threshold between normal and overweight with an average BMI of 23 ± 2.6.[1] Seven of the investigations reported participants with normal BM.[2,4,6,12,14-16] Finally, one of the studies didn't report any information regarding this important variable.[9]

The studies design and length where diverse, except for two,[7,16] most studies selected for this review were randomized.[1,2,4-6,8-15] Eleven of the 15 studies had a crossover design,[1,2,4,6,9-12,14-16] two were paired comparisons,[8,13] one was a pilot study[7], and one was a one-day intervention essay.[5]

The studies were carried out in one,[5] two,[8,13,15,16] three[2,6,10] or four[4] experimental sessions, lasting from less than one day each for the shortest, to a study with a total duration of 23 weeks, which included two intervention periods of 10 weeks separated by a three-week washout for the longest.[11] Between these two extremes, we found studies with interventions of two weeks each, with an intermediate washout period of two.[1,9,12,14] Within this length of intervention periods, we can mention a pilot study that had 14 days of intervention.[7]

About the diets, eleven of the 15 studies selected indicated that participants continued with their usual diet.[1,2,5-8,10-13,15,16] At this point, it should be clarified that most of these studies carried out interventions in one or more sessions, in which the participants consumed a test food containing the fatty acids whose effects were being studied. Subsequently, measurements of postprandial energy expenditure were taken.[2,5,6,8,10,13,15,16]

In the two studies that indicated a routine diet, the supplement or food that contained the fatty acids whose effects was studied consisted either of 1,440kJ of raw unsalted almonds, [10] or 2.0 g of Eicosapentaenoic Acid (EPA) and Docosahexaenoic acid (DHA) polyunsaturated fatty acids, which should be included in said diet.[7] Three studies indicated a controlled diet.[4,12,14] In one of them a maintenance diet containing 15% proteins, 45% carbohydrates, and 40% fats was provided; 80% of the fats were part of the experimental treatment.[12] In the other, the day before each measurement, a standardized diet was provided, according to the energy requirements of each participant, with 50% of energy obtained from carbohydrates, 37% from fat and 13% from protein.[4] Finally, in the third controlled diet research, an isoenergetic diet was indicated with 40% of the energy coming from fats, 80% of which was the treatment fat.[14]

As additional information regarding the diet variable, one of the studies that indicated a routine diet provided a controlled diet during the last week of each treatment (week 10) to determine the metabolizable energy of the experimental food (1440kJ of raw unsalted almonds). However, calorimetry measurements were carried out in week one and eight, when the diet was not controlled and the routine diet was followed, with or without the almonds, according to the phase.[11] The investigation didn't specify any type of diet or dietary restriction.[9]

The treatments in six studies were described based on the saturation of the fatty acids provided.[2,7-10,13] Among them, two compared saturated fatty acids (SFA) with polyunsaturated (PUFA) and monounsaturated (MUFA) fats, using liquid isocaloric foods with an average of 735 kcal, 8 fl oz (237 ml), with 70% energy provided by fats, around 515 kcal, 40% of which (approximately 200 kcal) came from the fat used for the intervention, that is to

TABLE 1. STUDIES THAT EVALUATED THE EFFECT OF DIET'S FATTY ACID COMPOSITION ON THE THERMIC EFFECT OF FOODS.

Reference	Type of study (duration)	Groups (n)	BMI Kg/m²	Sex W/M	Age (range) years	Diet	Type and/or fatty acids amount	Intervention time before measurements	Test meal	Energy expenditure estimation method	Effect on DIT (Other variables)
Ando et al. 2016	Randomized, placebo-controlled, double-blind, crossover (2- 2w interventions, 2w wash out)	TAG (19)	23 ± 2.6	0/19	40 ± 8	Routine + TAG or ALA-DAG	5 g TAG rapeseed oil	2 w	583 kcal, 15% PS, 34% LPS, 51% CH including 5 g of TAG or ALA-DAG	Indirect calorimetry ARCO 2000	
		ALA-DAG (19)					5 g ALA-DAG				(↑* fat oxidation) (↑*PEE)
Bendixen et al. 2002	Randomized, double-blind, crossover (4separete tests for 2 to 4 w)	Conventional (11)	22.5 ± 0.6	0/11	25.1 ± 0.5	Standardized provided by the researchers	Rapeseed oil	Same day	34% CH, 60% LPS 32(91% test fat), 6% PS. Composed of bread, jam, 2 orange slices, and a chocolate drink with the test fat	Indirect calorimetry with an open-air- circuit	
		Lipase-structured (11)					Lipase-structured fat				
		Chemically-structured (11)					Chemically structured fat				↑*
		Physically-mixed (11)					Physically mixed fat: rapeseed oil and trioctanoate				
Clevenger et al. 2014	Randomized, single-blinded, cross-over (3 sessions with at least 4 d between sessions)	MUFA (15)	21.5 ± 1.9	15/0	24.5 ± 4.3 (18-35)	Routine	735 kcal 70% fat = 42% MUFA or 42% PUFA or 40% SFA	Same day	Liquid meals (735 kcal) 8 fl oz (237 ml) Ensure, soy lecithin and Nesquik, 70% fat = 42% MUFA or 42% PUFA or 40% SFA)	Indirect calorimetry ParvoMedics TrueOne 2400 Canopy System (ParvoMedics, Sandy, UT, USA)	
		PUFA (15)									↑ *
		SFA (15)									
Clevenger et al. 2015	Single-blinded randomized cross-over (3 sessions with at least 4 d between sessions)	MUFA (16)	30-40	16/0	23.6 ± 6 (18-39)	Routine	MUFA: canola and olive oil	Same day	Liquid meals (735 kcal) 8 fl oz (237 ml) Ensure®, soy lecithin and Nesquik®, 70% fat = 42% MUFA or 42% PUFA or 40% SFA)	Indirect calorimetry ParvoMedics True-One® 2400 Canopy System (ParvoMedics, Sandy, UT)	NS
		PUFA (16)					PUFA: sunflower and linen oil				
		SFA (16)					SFA: butter, palm, and coconut oil				
Duarte Moreira Alves et al. 2014	Randomized trial (One-day)	Control (CT) (24)	(26 to 35) 29.8 ± 0.3	0/71	27.1 ± 0.9	Routine	Control biscuits	Same day	56 g of peanuts, CVP or HOP	Indirect calorimetry: Deltatrac II, MBM-200; Datex Instrumentarium Corporation	
		Conventional peanuts (CVP) (23)					56 g of CVP				
		High-oleic peanuts (HOP) (24)					56 g of HOP				↑* (↑*PEE VS CVP)

Reference	Type of study (duration)	Groups (n)	BMI Kg/m^2	Sex W/M	Age (range) years	Diet	Type and/or fatty acids amount	Intervention time before measurements	Test meal	Energy expenditure estimation method	Effect on DIT (Other variables)
Hollis & Mattes 2007	Randomized cross-over (2-10 w interventions, 3 w wash out)	Control (20)	23 – 30	20/0	24 ± 9		Routine Routine diet	10 w	1672kJ portion of almonds and 250 ml of water within a 15 min period	Indirect calorimetry SensorMedics Vmax 29 n metabolic cart (SensorMedics, Anaheim, CA, USA)	NS
		Almond (20)					Habitual diet + 1440kJ portion of raw, unsalted almonds each day				
Jones et al. 2008	Randomized crossover design (3-1 d sessions)	Olive oil (15)	23 ± 1.9 (20 - 25)	0/15	28.6 ± 6.2	Routine	Olive oil rich in oleic acid (18:1n-9)	Same day	Identical in composition except for the type of oil. 60% LPS, 30% CH, and 10% PS	Indirect calorimetry (Deltatrac Metabolic Monitor) (Sensormedics, Anaheim, CA)	(↑* EE VS flaxseed oil) (↑ EE VS sunflower oil)
		Sunflower oil (15)					Sunflower oil rich in linoleic acid (18:2n-6)				(↑ EE VS flaxseed oil)
		Flaxseed oil (15)					Flaxseed oil rich in linolenic acid (18:3n-3)				
Kasai et al. 2002	Double-blind, crossover (Study 1: 3 d at 1 or 2 d intervals. Study 2: 2 d in a week at 1 or 2 d intervals)	10M (8)	Males: 22.7± 0.8	0/8	Males: 26.8 ± 0.7	Routine	10 g MCT	Same day	Liquid meal containing 10 g MCT or 5 g MCT and 5 g LCT or 10 g LCT	Aeromonitor AE-300S (Minato Medical Science, Osaka, Japan)	↑ ** VS 10L
		5M5L (8)					Mixture: 5 g MCT and 5 g LCT				↑ * VS 10L
		10L (8)					10 g LCT				
		Mayonnaise (7)	Females: 18.8 ± 0.4	8/0	Females: 28.1 ± 1.4		5 g of MCT		Sandwich with mayonnaise or clear soup with margarine		↑ * VS LCT
		Margarine (8)					5 g of LCT				
Matheson et al. 2011	Pilot study (2 w)	Intervention group (6)	37.2 ± 5.60 obese	0/6	46.7 ± 12.1	Routine + 2 g per day of EPA and DHA	2.0 g per day of n-3 PUFA	2 w	250 mL of Break-free Omega-3 eggs, 200 g of strawberry yogurt, 1 Cali-Wrap tortilla, and 250 mL orange juice	Indirect calorimetry (MAX II Metabolic System, AEI Technologies, Napierville, IL)	↑ *
Ogawa et al. 2007	Double-blind cross-over (2 experimental sessions separated by 2 days or more)	LCT (20)	21.7 ± 0.3	11/9	24.0 ± 0.9	Routine	14 g of Long-chain Triacylglycerols	Same day	Liquid meal 500 Kcal 14.8% PS, 25.2% GS, 60% CH. Including 14 g of LCT or MLCT	(Innovision A/S, Denmark)	
		MLCT (20)					14 g of Medium- and Long Chain Triacylglycerols				↑ *
Papamandjaris et al. 1999	Randomized cross-over (2- 2 w feeding periods separated by a 2 w washout)	MCT (12)	21.5 ± 0.8	12/0	22.7 ± 0.7	WM diet: 15% Ps, 45% Ch, and 40% fat, 80% of which was treatment fat	26%(MCFA) and 74% (LCFA)	Day 7 and 14	Scheduled breakfast	RGE (Deltatrac Metabolic monitor, Sensormedics, Anaheim, California, USA)	NS
		LCT (12)					2% MCFA and 98% LCFA				

Reference	Type of study (duration)	Groups (n)	BMI Kg/m²	Sex W/M	Age (range) years	Diet	Type and/or fatty acids amount	Intervention time before measurements	Test meal	Energy expenditure estimation method	Effect on DIT (Other variables)
Piers et al. 2002	Randomized, paired comparison (2 intervention sessions separated by 1-2 w)	SFA (14)	27.8 ± 3.2 (21.1 – 32.0)	0/14	38 ± 9 (24–49)	Routine	SFA breakfast: 92 g of muesli, 57 g of cream and 275 g of skim milk	Same day	SFA breakfast: 92 g of muesli, 57 g of cream and 275 g of skim milk	Indirect calorimetry Deltatrac II metabolic monitor (Datex, Finland)	
		MUFA (14)					MUFA breakfast: 285 g of skim milk and 96 g of baked muesli with 20 g of EVOO		MUFA breakfast: 285 g of skim milk and 96 g of baked muesli with 20 g of EVOO		↑ * in subjects HWC ≥ 99 cm
Soares et al. 2004	Single-blinded, randomized, paired comparison (2 trials, 1 to 4w interval between them)	Cream (12)	21·9–38·3	12/0	64 ± 4.5 (57–73)	Routine	65 g natural Swiss muesli, 40 g thickened cream and 188 g skimmed milk	Same day	65 g natural Swiss muesli, 40 g thickened cream and 188 g skimmed milk	Indirect calorimetry Vmax-29 metabolic monitor (Sensor Medics)	NS
		Extra virgin olive oil (12)					66 g and 195 g of the same brand of muesli and skimmed milk, 15 g Extra virgin olive oil		66 g and 195 g of the same brand of muesli and skimmed milk, 15 g Extra virgin olive oil		
Van Marken Lichtenbelt et al. 1997	Randomized crossover (2-2w intervention, 2 w wash out)	High P/S ratio (6)	NE	0/6	25-48	NE	P/S ratio 1.67	2 w	46% LPS, 37% CH, 17% PS	Indirect calorimetry (ventilated hood)	↑ *
		Low P/S ratio (6)					P/S ratio 0.19				
White et al. 1999	Single-blinded randomized crossover (2-2w intervention, 2 w wash out)	MCT-enriched diet (12)	21.4 ± 2.0	12/0	22.8 ± 2.2	Isoenergetic diets 40% of energy as fat (80% of which was the treatment fat)	MCT-enriched diet 80% of the diet's fat	7 and 14 d	Standardized breakfast	Indirect calorimetry Deltatrac metabolic monitor (Sensormedics, Anaheim, CA)	(↑*BMR) (↑*TEE day 7) (↑TEE day 14)
		LCT-enriched diets (12)					LCT-enriched diet 80% of the diet's fat	7 and 14 d			

ABBREVIATIONS:
* Statistically significant differences between groups (p<0,05)
** Statistically significant differences between groups (p<0,01)
10M: 10 g MCT
5M5L: 5 g MCT and 5 g LCT
10L: 10 g LCT
ALA-DAG: Alpha Linolenic Acid-enriched Diacylglycerol
BMI: Body Mass Index
BMR: Basal Metabolic Rate
CH: Carbohydrates
cm: Centimeters
CT: Control
CVP: Conventional Peanuts
d: days
DHA: Docosahexaenoic acid
DIT: Diet-Induced Thermogenesis
EE: Energy expenditure
EVOO: Extra Virgin Olive Oil
EPA: Eicosapentaenoic Acid
fl oz: Fluid ounces
g: Grams
HOP: High oleic Peanuts
h: Hours
HWC: High Waist Circumference
kJ: Kilojoules
kg: Kilograms
LCFA: Long Chain Fatty Acids
LCT: Long-Chain Triacylglycerols
LPS: Lipids
M: Men
m: Meter
min: minute
ml: Milliliters
MCFA: Medium Chain Fatty Acids
MCT: Medium Chain Triacylglycerols
MUFA: Monounsaturated Fatty Acids
NS: Non-Significant
NE: Not specified
PEE: Postprandial Energy Expenditure
P/S: Polyunsaturated/Saturated
PS: Proteins;
PUFA: Polyunsaturated Fatty Acids
SCFA: Short Chain Fatty Acids
SFA: Saturated fatty acids
TAG: triacylglycerol
TEE: Total energy expenditure
VS: versus
w: weeks
W: Women
WM: Weight maintenance

say saturated (from butter, palm and coconut oils), monounsaturated (canola and olive oils) or polyunsaturated (sunflower and linen oils). The food was composed of chocolate flavored Ensure®, soy lecithin, Nesquick®, and the treatment fat, in a crossover with three sessions of one day each.[2,10] Two studies compared only two fatty acid types: saturated and monounsaturated.[8,13] In the first, the test breakfast was high in saturated fat and consisted of 92 g of muesli, 57 g of cream and 275 g of skimmed milk, while the high-monounsaturated fat treatment consisted of 285 g of skimmed milk and 96 g of baked muesli with 20 g of extra virgin olive oil in two intervention sessions.[8] In the other study, the first group's breakfast consisted of 65 g of muesli, 40 grams of cream and 188 g of skimmed milk, while the other contained 66 and 195 g of muesli and skim milk respectively and 15 g of extra virgin olive oil.[13] There was another study that followed this same type of intervention, in which the effects of two diets with different proportions of polyunsaturated/saturated fatty acids, 1.67 and 0.19 respectively, were compared.[9] This research did not specify the composition of the two-week crossover treatments and only mentions that the meal previous to the postprandial energy expenditure determination had the same fatty acid composition as the diet, and the energy came 46% from fat, 37% from carbohydrates and 17% from proteins without further details.[9]

Finally, we also found a pilot study[7] in which two grams of polyunsaturated omega-3 fatty acids (Eicosapentaenoic acid, EPA; and docosahexaenoic acid, DHA) were added daily to the participant's usual diet, for two weeks.

In four publications,[12,14-16] treatments were described according to the provided fatty acid chains length, comparing the effects of short-, (SCFA) medium- (MCFA) or long-chain (LCFA) fatty acids. Specifically, there was one that presented two experiments[15]; in the first they analyzed the effects of providing three different treatments: 10 g of LCFA, 10 g of MCFA or a mixture of 5 g of MCFA and 5 g of LCFA, in a liquid food with an average of 246 kcal coming from 21% proteins, 36% fats and 43% carbohydrates. In the second experiment, the effects of providing 5 g of MCFA or 5 g of LCFA using a clear soup and a sandwich with mayonnaise or margarine as food, were compared. Mayonnaise contained vegetable oils, vinegar, starch, mustard, sucrose and no eggs. The margarine contained hydrogenated fats, powder skimmed milk and salt. The sandwich included bread, lettuce and tomato. The meal's energy with 5 g of LCFA and 5 g of MCFA was 253 and 249 kcal/test respectively, for mayonnaise, 244 and 240 kcal/test for margarine with the energy coming 10% from protein, 40% from fats and 50% from carbohydrates for both. In turn, a liquid food was used[16] with 500 kcal obtained 14.8% from protein, 25.2% from fat and 60% from carbohydrate, which included 14 g of LCFA from rapeseed oil, or the same amount of a combination of LCFA and MCFA. Another investigation[12] compared the effects of two MCFA and LCFA proportions, in maintenance diets whose energy came from 15% protein, 45% carbohydrate and 40% fat, 80% of which was the treatment's fat, which included 26% MCFA and 74% LCFA in one treatment, or 2% MCFA and 98% LCFA in the other. Finally, one research[14] compared the effects of isoenergetic diets in which 40% of the energy came from fats, 80% of which was the test's fat, represented by medium-chain triacylglycerols (MCTs) in one treatment, or long-chain triacylglycerols (LCTs) in the other. These fats came from butter and coconut oil, or beef tallow respectively, in a crossover with two intervention periods of two weeks each.

In addition, two of the investigations studied the effect of specific foods.[5,11] In the first one, the effect of three foods was compared: 56 g of conventional peanuts, 56 g of peanuts with high oleic content, and biscuits as control.[5] In the second, the effect of adding 1,440 kJ of raw unsalted almonds to the participant's usual diet was evaluated in a crossover with two 10 weeks interventions.[11] Lastly, three studies evaluated the effects of providing specific oils.[1,4,6] The first, compared the effects of providing 5 g of alpha-linolenic acid-enriched diacylglycerol, ALA-DAG, or 5 g of triacylglycerol, TAG, from rapeseed oil ingested daily for two weeks.[1] In the second one,[4] the effect of a conventional fat composed of rapeseed oil and three modified fats was studied in four sessions: lipase structured fat, chemically structured fat, and physically mixed fat. Fats were provided at a pre-measurement breakfast containing 4,698 ± 174 kJ, 34% from carbohydrate, 60% fat, 91% of which were the experimental fat, and 6% protein. The test meal consisted of bread, ham, two slices of orange and a chocolate drink containing the test fat; in this investigation, the diet on the previous day was controlled.[4] The third study[6] analyzed the effect of a breakfast with 60% (50.4 g on average) of the energy from 3 sources of fat: oleic acid-rich olive oil (18: 1n-9), linoleic acid-rich sunflower oil (18: 2n-6), and linolenic acid-rich rapeseed oil (18: 3n-3).

The differences between the treatments were found to be statistically significant only in nine of the 15 publications analyzed.[1,2,4-7,9,15,16] When analyzing these differences in depth according to the type of fatty acids provided, three of the publications described a DIT increment with the use of polyunsaturated fatty acids.[2,7,9] The first[2] described greater DIT with a liquid food with PUFA added in comparison with the MUFA or SFA addition; in these, the fatty acids contributed approximately 200 kcal. The second[7] described an increase in the Thermic Effect of Foods (TEF) after two weeks of adding 2.0 g a day of PUFA n-3 (EPA and DHA) to the participant's usual diet, compared to the values before the intervention. The third[9] reported an increase in the basal metabolic rate and DIT as an effect of two weeks with a diet high in a polyunsaturated/saturated ratio.

Considering the classification of fatty acids according to chain length, we found two publications that reported a greater DIT as a result of the use of MCFA.[15,16] One[15] reported a greater DIT with the use of foods with 10 g of added MCFA or with a combination of 5 g of MCFA and 5 g of LCFA, compared to the use of 10 g of LCFA. Additionally, in their second experiment, they reported a higher DIT with the use of mayonnaise or margarine containing 5 g of MCFA compared to the addition of 5 g of LCFA.[15] The other investigation[16] described a higher DIT with the use of medium- and long-chain triacylglycerols (MLCT) when compared to the use of long-chain triacylglycerols (LCT).

Finally, among the investigations that reported the use of specific foods or oils, four reported statistically significant differences.[1,4-6] They found greater postprandial fat oxidation and higher postprandial energy expenditure with the use of ALA-DAG compared to TAG.[1] Another research[4] reported higher postprandial oxidation and higher postprandial energy expenditure with the three modified fats, compared to the effect of conventional fat or rapeseed oil. Other study[6] found an increase in postprandial energy expenditure with the use of oleic acid-rich olive oil (18: 1n-9), when compared with linolenic acid-rich rapeseed oil, (18: 3n-3) or with linolenic acid rich sunflower oil (18: 2n-6). Finally, greater thermogenesis was observed induced by diet and higher postprandial energy expenditure with the consumption of 56 g of oleic rich peanuts, in comparison with the consumption of conventional peanuts.[5]

Although the rest of the investigations did not report significant differences between the treatments, two of them[8,14] found differences in subgroups, depending on specific characteristics of the participants or moments of the investigation. In one case,[8] significant differences were found when comparing treatments consisting of breakfast with MUFA or SFA, with a greater TEF with the MUFA in subjects with larger waist circumference (≥ 99 cm). In the other investigation,[14] they found significantly higher total energy expenditure and basal metabolic rate with the use of medium-chain triacylglycerols (MCT) compared to long-chain triacylglycerols at the midpoint of a 14-day treatment, on day seven, and although at the end of the treatment they also described a greater total energy expenditure, this was not significant.

Despite the fact that one of the studies found no significant differences between the groups,[11] these researchers emphasized that their treatment, the addition of 1,440 KJ of almonds to the participant's habitual diet, did not modify body weight after 10 weeks, suggesting that this food and dose does not represent a risk of weight gain.

Quantitative data from the TEF or DIT records are omitted because not all studies reported it as an absolute value. Some present figures in which the difference or change is represented, reporting the statistical significance of the finding without specifying the values.[6] Among the authors who present quantitative data, this is measured in different periods and expressed with different units, even as a percentage of change or difference. So, as an example, we have those who present their quantitative data of DIT as Cal/kg[15], kcal per minute[7], kcal * 5 h[10], kJ/5h[8] and kcal/6h[16]. Units like Kcal/day[12,13] and kJ/min[9,14] are also used. This means that the DIT numerical data is not comparable and representing it in the manuscript could represent a source of confusion.

DISCUSSION

The studies selected for this systematic review stand out for their differences. We found various fatty acids proportions, types, and even classifications. In addition, the conditions of the participants, the diets, designs, and lengths also differ. More research is required, for longer periods and with greater control and number of participants in order to reproduce, quantify, and predict the effects of different fatty acids types and proportions in the diet.

It is noteworthy that while some studies show different effects in single-session tests with the treatment,[2,4,6,8,15,16] others show significant effects in periods of seven days, which then lose significance when prolonging treatment to 14 days,[14] while others show significant differences in treatments of 14 days.[1,7,9] Taking into account that the effect may diminish or be lost over time, it is advisable to carry out more research with intervention periods longer than two weeks.

Another aspect of great importance is the high percentage of energy that comes from fats in the test meals, which differs in the studies from 34%,[1] 36 and 40%,[15] 46%,[9] 60%[4,6] and up to 70%.[2,10] In other cases, it was not the test meal, but the diet that provided participants a percentage of energy from fats higher than recommended.[12,14]

Tendencies indicate an increase of the DIT with the use of polyunsaturated fatty acids in comparison with saturated or monounsaturated.[2,7,9] This effect was also observed with the use of MCFA, which can lead to greater postprandial energy expenditure than LCF.[15,16] Regarding the use of specific oils in an analogous way, it is worth mentioning the greater DIT caused by the consumption of foods containing olive oil, instead of sunflower oils, rapeseed, as well as the use of cream or saturated fatty acids foods.[6]

Regarding the selection bias, of the 15 studies selected, 12 were randomized, although the method used to generate the allocation sequence was not described. In the remaining publications, one was a pilot study[7] with only one intervention group, so there was no randomization. Another publication[15] included two experiments and described the random assignment in the first but did not mention this aspect in the second. The remaining study[16] does not mention this characteristic.

Additionally, regarding the performance bias, it should be mentioned that in most studies[1,2,4-10,12-16] the participants had no knowledge of the assigned intervention, that is, the type or percentage of fatty acid in the meals, the exception was a study where almonds were provided to the participants as treatment.[11]

When analyzing the results of each study, regarding the detection bias, the totality does not specify whether the evaluators were aware of the intervention applied to each participant when carrying out energy expenditure measurements. However, these measurements were made in the participants of each study with the appropriate equipment, in the same conditions and for the same periods of time.[1,2,4-16]

CONCLUSIONS

Studies on the effect of different fatty acids in the diet have been varied, using different proportions, types, classifications, and doses. Additionally, the participant's characteristics, including their sex, age, health conditions, body weight, and others, have also been diverse. Although more research, in particular for longer periods, is still required regarding the effects of different types and percentages of fatty acids on the basal metabolic rate, thermogenesis induced by diet, and energy expenditure, some effects are starting to stand out, showing potential lines of research. Greater postprandial energy expenditure is described; specifically, greater diet-induced thermogenesis with the intake of polyunsaturated fatty acids in comparison with the saturated fatty acids. Greater DIT has also been documented with the use of MCFA compared to LCFA. Finally, the beneficial effect of extra virgin olive oil on the metabolism is highlighted, causing a higher DIT than other oils such as sunflower and rapeseed oil.

Authors Contribution

LCVC, AGMM, ALP, and ACEG contributed equally to the development of the systematic review protocol. LCVC and AGMM conducted the search and identified papers for inclusion, with ALP providing advice and expert opinion in this stage. LCVC and ACEG conducted the data extraction, with AGMM providing advice and expert opinion in this stage. This paper was translated by ACEG. LCVC, AGMM, ALP, and ACEG all contributed equally to the development of the manuscript.

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Conflict of Interest

The authors have no conflicts of interest to declare.

RESUMO

O desequilíbrio energético produzido pelo aumento da ingestão calórica e/ou diminuição do gasto energético provoca obesidade. Sem embargo, a composição de ácidos graxos da dieta pode afetar diferencialmente o metabolismo, tendo um papel no desenvolvimento da obesidade.

OBJETIVO: *Determinar os efeitos de diferentes tipos de ácidos graxos e sua composição na termogênese induzida por dieta e no gasto energético pós-prandial em humanos.*

MÉTODOS: *Uma busca nas bases de dados da PubMed e da Web of Science gerou um total de 269 artigos potenciais como primeiro resultado; 254 foram excluídos de acordo com os critérios.*

RESULTADOS: *Quinze artigos foram utilizados para esta revisão sistemática. Os estudos analisados informam os efeitos diferenciais dos ácidos graxos no tratamento da termogênese induzida pela dieta. As evidências indicam que o consumo dos ácidos graxos poli-insaturados ocasiona maior DIT que os ácidos graxos saturados. Além disso, demonstra-se que o consumo dos ácidos graxos da cadeia média, em comparação com os ácidos graxos da cadeia longa, aumenta o DIT. Do mesmo modo, o uso de certos azeites demonstra os efeitos positivos sobre o gasto de energia pós-prandial, como é o caso do azeite de oliva, em comparação com o azeite de colza.*

CONCLUSÃO: *O uso de tipos específicos de ácidos graxos na dieta habitual pode aumentar o gasto de energia pós-prandial nos seres humanos. Sem embargo, é necessária maior investigação no longo prazo.*

PALAVRAS-CHAVE: *Termogênese induzida pela dieta. Efeito térmico dos alimentos. Ácidos graxos. Gasto de energia. Gasto da energia pós-prandial.*

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