

## Revisión

# Influence of the dietary intake of medium chain triglycerides on body composition, energy expenditure and satiety; a systematic review

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## Abstract

Increased prevalence of obesity is associated with the growth of chronic degenerative diseases. One of the main factors associated with this increase is the change in nutritional status of individuals. Medium chain triglycerides (MCT) are rapidly metabolized and less stored in the adipose tissue, being a possible tool for weight control. In order to analyze the influence of consumption of this lipid on satiety, body composition and energy expenditure (EE), a literature review was performed of controlled clinical studies reported in PUBMED and ELSEVIER between the years 2000 and 2010. Fourteen articles were selected presenting short and long-term intervention. Among these, six showed a decrease in body mass of individuals, with consequent loss of weight. Only one showed a positive effect on satiety and four showed an increase in EE. Thus the results are inconclusive and there is a need for further controlled studies with standardized amounts of MCT, so that its use can become an alternative for obesity nutritional treatment.

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Key words: *Energy balance. Satiety. Medium chain triglycerides. Obesity.*

## INFLUENCIA DE LA INGESTA DIETÉTICA DE LOS TRIGLICÉRIDOS DE CADENA MEDIA SOBRE LA COMPOSICIÓN CORPORAL, EL GASTO ENERGÉTICO Y LA SACIEDAD; UNA REVISIÓN SISTEMÁTICA

## Resumen

El aumento de la prevalencia de obesidad se asocia con el crecimiento de las enfermedades crónicas no transmisibles. Uno de los principales factores asociados a este aumento es el cambio en el estado nutricional de los individuos. Los triglicéridos de cadena media (TCM) tienen el metabolismo rápido y menor capacidad de almacenamiento en el tejido adiposo, siendo una posible herramienta para controlar el peso corporal. Con el objetivo de evaluar la influencia del consumo de este lípido en la saciedad, la composición corporal y el gasto energético (GE) se realizó un levantamiento bibliográfico de estudios clínicos controlados reportados en PUBMED y ELSEVIER entre los años 2000 y 2010. Catorce artículos fueron seleccionados para la intervención en corto y largo plazo. Entre ellos, seis mostraron disminución de la masa corporal de los individuos, con la consiguiente pérdida de peso. Solamente uno mostró efecto positivo en la satisfacción y cuatro mostraron aumento en el GE de los individuos. Por lo tanto, los resultados son inconclusivos y hay necesidad de más estudios controlados con cantidades estandarizadas de TCM, para que su utilización pueda convertirse en una alternativa para el tratamiento nutricional de la obesidad.

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Palabras clave: *Balance energético. Saciedad. Triglicéridos de cadena media. Obesidad.*

## Introduction

Obesity can be defined as an excessive accumulation of fat in the adipose tissue and is associated with other morbidities such as type 2 diabetes mellitus, cardiovascular disease, stroke and some types of cancers.<sup>1</sup> An

important factor that has contributed to the rapid increase in cases of obesity among the population is the change in dietary patterns of individuals, mainly characterized by increased consumption of energy dense foods, rich in sugar and saturated fatty acids, combined with a sedentary lifestyle.<sup>2,3,4</sup>

The central nervous system (CNS) is responsible for controlling food ingestion and energy expenditure by means of short and long term mechanisms that act by stimulating or inhibiting food intake and regulating the body fat stores, respectively.<sup>5,6</sup> The ingestion of certain

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nutrients can promote physiological responses that induce greater satiation and satiety.<sup>7,8,9,10</sup> Satiation is the process initiated during food consumption which leads to cessation of appetite and determines the end of the meal. Satiety is the stage where there is a decrease of hunger as a result of ingestion, related to the time that an individual can go without food after a meal. Thus, satiation controls the size of a meal and satiety its frequency.<sup>8,11</sup> Satiety appears to be influenced by the distribution of dietary macronutrients. Studies show that lipid-rich diets result in higher energy consumption due to the fact that lipids stimulate less the pathways responsible for satiety when compared to carbohydrates and proteins.<sup>7,12,13</sup> Moreover, it is suggested that lipid quality in the diet interferes with its satiating potential. Flint et al. (2003)<sup>14</sup> reported that the lipids possess distinct metabolic pathways according to their composition, differently affecting appetite. There has been an increase in studies aimed to stimulate the consumption of lipids which are apparently more favorable to eating patterns, such as medium chain triglycerides (MCT).

The MCT are molecules consisting of three saturated fatty acids chain containing 6 to 12 carbons each. They are absorbed directly into the portal circulation and do not suffer from re-esterification in intestinal cells. MCT are transported to the liver where they are predominantly metabolized by  $\beta$ -oxidation.<sup>15</sup> In contrast, long-chain triglycerides (LCT), commonly found in Western diets, are absorbed in the intestine and incorporated to chylomicrons, where they undergo re-esterification to reach the bloodstream via the lymphatic system. Within the bloodstream, lipoprotein lipases hydrolyze the LCT into smaller molecules such as monoglycerides and fatty acids, or they can be captured by diverse tissues such as muscle tissues and undergo oxidation, or be stored in adipose tissue.<sup>16,17</sup>

In addition to faster metabolism and less storage in adipocytes, MCT promote increased total energy expenditure of the individual.<sup>18</sup> Thus, the development of preparations with a greater content of these triglycerides may aid in control of body weight and reduce the harmful effects of obesity.<sup>16,18</sup>

The objective of this literature review is to determine if consumption of MCT favors control of food intake, energy expenditure and body composition in obese individuals.

## Methodology

A literature review was performed of clinical controlled studies published in PUBMED and ELSEVIER between the years of 2000 and 2010, containing the keywords "medium-chain triglycerides", "appetite", "satiety", "body composition" and "obesity". Based on these keywords, 20 studies were consulted and included in the table those which are performed on humans, relating MCT intake, satiety, energy metabolism and body composition. Experimental studies performed on

animals and review papers were excluded. Ultimately, a total of 14 articles were analyzed that met the inclusion criteria.

The results are shown in the table, which describe the selected studies, the number of participants included, characteristics of dietary intervention, variables analyzed and their outcomes and conclusions.

## Results

A total of 14 studies were analyzed, of which 7 evaluated satiety, 8 assessed body composition and 6 assessed the energy expenditure (EE). Only one study (7%) found a positive effect on satiety, 6 (43%) found a positive effect on body composition and 4 (29%) found a positive effect on EE, with the use of MCT.

Wymelbeke et al. (2001)<sup>19</sup> was the only group that showed a positive effect of MCT consumption on satiety. The study was conducted with eutrophic individuals, who consumed the majority of MCT in meals when compared to those who also examined satiety. Studies evaluating the effect of MCT on body composition showed a positive effect related to the body mass index (BMI) of the participants. Of the 6 studies in which this effect was observed, most were performed with overweight or obese individuals (BMI < 25 kg/m<sup>2</sup>). Of the four studies in which the positive effect on the EE was observed, two showed a positive correlation with body composition, both being performed in overweight individuals.

The studies shown in the table indicate that the positive effect on body composition and EE resultant of MCT intake occurs after at least 4 weeks of consumption. However, Krotkiewski et al. (2001)<sup>20</sup> showed that this effect, at least on body composition, is only really significant in the first two weeks of consumption, thus suggesting a possible metabolic adaptation.

## Discussion

Over the years, with the increase in obesity diverse therapeutic proposals for treatment of this epidemic were emerged. Many studies have considered the important role of the fatty acids metabolism on the energy balance and hence on the regulation of food intake through different mechanisms in the central nervous system.<sup>33</sup> Wiley & Leveili in 1973,<sup>34</sup> already reported that MCT may represent a dietary tool, aiding in weight loss by interfering in the synthesis and accumulation of fat in adipose tissue. The MCT undergo rapid hepatic oxidation and are little stored, inducing adipose tissue response similar to a diet which occurs in situations of low-fat diet.

Flatt et al. (1985)<sup>35</sup> evaluated the greater efficiency of hypolipidic diets on weight loss in healthy individuals, but also reported that consumption of MCT resulted in a greater EE compared to the lipid-reduced

**Table I**  
*Influence of MCT on body composition, energetic metabolism and satiety*

Author	Participants	Characteristics of intervention	Variables analyzed	Results
Barbera et al., 2000 <sup>21</sup>	9 healthy participants: 6 ♂ and 3 ♀.	Three groups were randomly formed, receiving different infusions in 2 days: 0.9% saline, 20% LCT (oleic and linoleic) and 22% MCT (octanoic and decanoic), with the objective of analyzing endocrine, motor and sensory responses during duodenal perfusion with one of these infusions. Finally, the gastric sensation was analyzed via VAS.	Gastric sensations: satisfaction, fullness, bloating, nausea and pain; gastrointestinal hormones: somatostatin, pancreatic polypeptide, neurotensin, gastric inhibitory peptide and CCK.	The infusion of LCT induced satiety relaxed the gastric fundus and stimulated the release of hormones including CCK. The infusion of MCT only induced gastric relaxation, not sufficient to increase satiety. The gastric relaxation promoted by MCT may have been promoted by CCK-independent mechanisms.
Tsuji et al., 2001 <sup>22</sup>	78 healthy ♂ and ♀ BMI > 23 kg/m <sup>2</sup> : n = 26 (MCT) and n = 30 (LCT); BMI < 23 kg/m <sup>2</sup> : n = 15 (MCT) and n = 7 (LCT).	Individuals were randomly grouped in two groups: high MCT or LCT (60 g of total fat/day), who consumed 10 g MCT or LCT at breakfast during 12 weeks. On all days the participants filled out a alimentary diary, controlling the energy and lipid content of the meals.	Body weight; waist and hip circumferences; laboratory variables: TG, TC, ketone bodies, AST, ALT, gamma-GTP; adiposity.	In both groups weight and body fat decreased, but individuals with a BMI greater than 23 kg/m <sup>2</sup> showed a larger reduction in the MCT group (-3.86 ± 0.3 kg) compared with LCT (-2.75 ± 0.2 kg). The MCT were more effective in overweight individuals.
Wymelbeke et al., 2001 <sup>19</sup>	9 healthy ♂ (BMI: 21.9 ± 1.7 kg/m <sup>2</sup> )	Study was divided in 4 sessions, in which the standard lunch was supplemented with a lipid substitute (15 g), or MCT (35 g), or LCT (32 g), or with maltodextrin (50 g) + LCT (8 g). Dinner was composed of 30 different foods served <i>ad libitum</i> .	Sensation of hunger and food intake; Lipid, carbohydrate and protein oxidation; laboratory variables: glucose, insulin, triglycerides and fatty acids.	The oxidation of carbohydrates was lower and lipid oxidation increased after the meal supplemented with MCT and LCT. Food intake was lower after consumption of MCT, suggesting an important role of lipids on satiety, but energy expenditure did not significantly differ between groups.
Kovacs et al., 2001 <sup>23</sup>	7 ♂ and 14 ♀ overweight individuals (BMI: 27.6 ± 2.0 kg/m <sup>2</sup> )	Study was divided into three periods of intervention, lasting two weeks each. The individuals consumed three meals individually selected and four isoenergetic snacks (cereal bar) without supplementation or supplemented with 500 mg of HCA (inhibitor of ATP-citrate lyase) or supplemented with 500 mg of HCA + 3g of MCT daily.	Body weight; eating behavior; energy consumption; mood.	There was weight loss after 2 weeks of treatment, but no difference was observed between them. Energy consumption was similar among treatments, being lower than the predicted energy expenditure. Supplementation of HCA or HCA + MCT did not increase satiety or decrease energy consumption under conditions of negative energy balance.
Krotkiewski, 2001 <sup>20</sup>	66 ♀ obese individuals (BMI > 30 kg/m <sup>2</sup> )	Participants were randomized divided into three groups and received an isoenergetic diet (578.4 kcal) with very-low-calorie diet (VLCD) enriched with MCT (8 g), LCT (9.9 g) or lipids (3 g) and carbohydrates for 4 weeks. Twice a week the participants responded to VAS 5 minutes before dinner, and 5, 20, 40 and 120 minutes after dinner.	Body composition: free fat mass, body fat; body weight; BMI; waist and hip circumference; laboratory variables: glucose, insulin, C-peptide, cholesterol, and triglycerides; -hydroxy butyrate serum, concentration of nitrogen in urine; sensations of hunger and satiety.	The MCT group, unlike the LCT and hypolipidic diets showed weight loss in the first 2 weeks. The contribution of BF was higher for weight loss. There was an increase in the concentration of ketone bodies and decrease in nitrogen excretion. The sensation of hunger was lower, in parallel with changes in the concentration of ketone bodies, an effect that declined indicating a possible metabolic adaptation.
Bendixen et al., 2002 <sup>24</sup>	11 ♂ eutrophic individuals (BMI: 22.5 ± 0.6 kg/m <sup>2</sup> ).	Liquid meal with 0.9 g test fat/kg, offered at breakfast. Subjects were randomly assigned to four types of fat (conventional and modified with regards to position of MCFA) in four days for different tests. The <i>ad libitum</i> lunch was monitored and motivation eating was evaluated throughout the study by VAS.	Subjective sensations of: appetite, thirst, comfort, and desire for specific types of food; <i>ad libitum</i> energy consumption; palatability; EE; substrate oxidation.	There was no difference in EE, substrate oxidation, energy consumption and appetite among the 3 types of modified lipids, indicating that the position of MCFA in the glycerol molecule has no effect on these variables.
Kasai et al., 2003 <sup>25</sup>	82 ♂ and ♀ eutrophic individuals (BMI: 24.6 ± 0.3 kg/m <sup>2</sup> )	Participants consumed a breakfast composed of 14 g LCT or MLCT (14% MCT + 86% LCT) during 12 weeks. Large meals were standardized and consumed by both groups.	Body weight; waist circumference and abdominal circumference, body fat, visceral and subcutaneous adiposity; laboratory variables: total cholesterol and triglycerides, HDL, LDL, insulin, glucose and ketone bodies.	Consumption of the MLCT diet for 12 weeks decreases body weight and visceral and subcutaneous adiposity. It also reduced total cholesterol intake after 8 weeks. The results suggest that consumption of MLCT in the long term can reduce the weight and body fat.

**Table I (cont.)**  
*Influence of MCT on body composition, energetic metabolism and satiety*

Author	Participants	Characteristics of intervention	Variables analyzed	Results
St-Onge et al., 2003 <sup>26</sup>	24 ♂ overweight (BMI: 25-31 kg/m <sup>2</sup> ).	Subjects consumed a diet (with 40% lipid) high MCT (64.7%) or LCT (75%) for 28 days. Energy expenditure and body composition were assessed before and after intervention.	Body weight; body composition; EE; fecal fat excretion and satiety.	High MCT diet reduced the total adiposity in overweight individuals, probably due to the increase in EE (1.04 ± 0.02 kcal/min and 0.99 ± 0.03 kcal/min) and lipid oxidation (0.052 ± 0.003 g/min and 0.044 ± 0.003 g/min) for MCT and LCT, respectively.
St-Onge et al., 2003 <sup>27</sup>	17 ♀ obese (BMI: 31.8 ± 0.9 kg/m <sup>2</sup> ).	Study consisted of two phases with 27 days each (crossover), in which participants were randomly assigned to two diets (with 40% lipid): high LCT (75%) or MCT (50%). In the first phase they consumed one of the diets and in the second phase consumption was alternated. The phases were separated by a 4 to 8-week washout period.	Body weight; body composition; EE; lipid oxidation and fecal fat excretion.	The average EE values (0.95 ± 0.019 vs 0.90 ± 0.025 kcal/min) and lipid oxidation (0.080 ± 0.0026 vs 0.075 ± 0.0022 g/min) were greater in the MCT group. However, there was no association with a significant effect on body composition.
St-Onge & Jones, 2003 <sup>28</sup>	24 ♂ overweight (BMI: 28.2 ± 0.4 kg/m <sup>2</sup> ).	Study consisted of two phases with 28 days each, in which participants were randomly assigned to two diets (with 40% lipid): high LCT (75%) or MCT (50%). Two meals a day were supplied under supervision. The phases were separated by a 4-week washout period.	Body weight; body composition; EE and lipid oxidation.	Consumption of MCT increased EE and lipid oxidation, which is related to the initial BMI of the participants.
Ogawa et al., 2007 <sup>29</sup>	20 eutrophic participants: 9 ♂ and 11 ♀ (BMI: 21.7 kg/m <sup>2</sup> ).	Liquid meal with 14g MLCT [medium-chain fatty acids (12% + long)] or LCT (rapeseed oil) for breakfast.	Oxygen consumption; respiratory quotient and baseline EE.	The consumption of MLCT increased dietary induced thermogenesis, compared to LCT (EE was 13.5 kcal higher), suggesting that this may be one of the mechanisms by which MCT reduce body fat accumulation.
Roynette et al., 2008 <sup>30</sup>	23 ♂ overweight (BMI: 28.4 ± 2.81 kg/m <sup>2</sup> ).	Study consisted of two phases with 42 days each, in which participants were randomly assigned to two diets (with 40% lipid): with extra virgin olive oil (OO) or MCT (OST) (16 g/meal). A daily meal was served under supervision. The phases were separated by a 4 to 8-week washout period.	Body weight; body composition; EE and lipid oxidation.	No differences were observed between the variables. The use of OO may have been an inappropriate control for assessing EE and body composition since it also increases lipid oxidation.
St-Onge & Bosarge, 2008 <sup>31</sup>	31 ♂ and ♀ (BMI: between 27 and 33 kg/m <sup>2</sup> ).	Participants were randomly assigned to two weight loss programs (MCT or olive oil) for 16 weeks. They consumed 18-24 g of MCT or olive oil as part of a hypocaloric diet (1,500 kcal/day ♀ and 1,800 kcal/day ♂).	Body weight; body composition.	The MCT group showed greater weight loss and reduction in the percentage of total body fat and visceral adipose tissue. The authors suggest that consumption of MCT in a dietary plan increased weight loss.
Poppitt et al., 2010 <sup>32</sup>	18 ♂ eutrophic individuals (BMI: 22.8 ± 1.8 kg/m <sup>2</sup> ).	The study was divided into three occasions with intervals of 4 days. At breakfast the participants received muffins rich in the test fat type [MCT (10 g), LCT (52 g) or fractions of milk fat (3 g)]. Lunch was <i>ad libitum</i> and motivation for eating was assessed throughout the study by VAS.	Subjective sensations of hunger, satiety, satiation, and nausea; sensory evaluation of the test meals; laboratory variables: glucose, total triglycerides and insulin concentrations.	Although there is a tendency for increased TG concentrations after consumption of diets rich in MCT or milk fractions, there was no effect on satiety or food intake, compared with a diet rich in LCT.

*Legend:* ♂: Male; ♀: Female; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; BF: Body fat; BMI: Body mass index; CCK: Cholecystokinin; EE: Energy expenditure; FFM: Free fat mass; Gama-GTP: Gamma-glutamyl transpeptidase; HCA: Hydroxycitrate (induces hepatic fatty acid oxidation); LCT: Long-chain triglycerides; MCFA: Medium chain fatty acids; MCT: Medium-chain triglycerides; MLCT: Medium and long-chain triglycerides; MUFA: Monounsaturated fatty acids; OO: Olive oil; OST: Structured oil; PUFA: Polyunsaturated fatty acids; SFA: Saturated fatty acids; TC: Total cholesterol; TG: Triglycerides VAS: Visual analogue scale; VLCD: Very low calorie diet.

diet. Ogawa et al. (2007)<sup>29</sup> also reported an increase in diet-induced thermogenesis (DIT) in normal individuals after a meal rich in MCT. The DIT representing about 10% of daily EE and plays an important role in the energy balance of the individual.<sup>36</sup>

Animal studies have shown convincing results regarding the increase in EE and decrease in adipose tissue, with subsequent weight loss after the use of

MCT.<sup>15,37,38</sup> However, in humans the results are controversial, as shown by St-Onge et al., 2003<sup>26,27</sup> and St-Onge & Jones, 2003.<sup>28</sup> In the first study, the high MCT diet improved total adiposity in overweight individuals, probably due to increased EE and lipid oxidation. In the second study, the EE and lipid oxidation were higher after consumption of MCT, but was not associated with a significant effect on body composi-

tion.<sup>27</sup> In a third study, St-Onge & Jones (2003)<sup>28</sup> showed that consumption of MCT increased EE and lipid oxidation, being related to the BMI of the participants. Tsuji et al. (2001)<sup>22</sup> had already observed an improvement in lipid oxidation in subjects who were overweight when compared to health individuals. In contrast, Roynette et al. (2008)<sup>30</sup> observed no significant differences in weight, body composition, EE and lipid oxidation after consumption of olive oil or MCT in the long term, even in overweight individuals. However, these data may have resulted from the fact that olive oil was the lipid control used in this study and can increase lipid oxidation itself; MCT consumption was also lower than that of other studies.<sup>26,27,28</sup>

With the objective of evaluating the influence of nutrients on gastrointestinal sensations, Barbera et al. (2000)<sup>21</sup> compared the different effects of MCT and LCT on gastric tone and plasma concentrations of intestinal hormones. An important finding of this group was that release of CCK and other intestinal hormones was not increased after duodenal infusion of MCT, compared in the group receiving LCT. However both groups showed relaxation of the gastric fundus, which plays an important role in the induction of satiation, possibly by stimulating peripheral vagal nerves. Thus, gastric relaxation may be a possible mechanism by which MCT decrease food intake after a meal, being independent of CCK release, which differs from the LCT group.<sup>19</sup>

One of the main sources of MCT is coconut oil, in which the content of medium-chain fatty acids is about 50% of its total composition.<sup>18</sup> However, due to its low melting point, it may not be the best source of MCT to be incorporated into the diet. Study with a new oil composed of MCT and LCT in a daily dose of 14g (with 1.7 g of MCT), for 12 weeks showed a significant reduction in body weight and adipose tissue (subcutaneous and visceral), suggesting that consumption of this oil might be an efficient nutritional tool for obese individuals.<sup>25,39</sup>

In the present review it was possible to verify that data related to increased satiety after consumption of MCT are quite controversial. Most studies showed no significant difference as to increased satiety and/or satiation related to lipid consumption. However positive results in relation to consumption of MCT versus LCT appear to be consistent with the parameters of body composition and EE. A relevant fact in the lack of consensus among the studies concerns the large variation in the amount of MCT provided in different studies due to lack of reference values for a minimum, ideal and maximum consumption in literature. Moreover, there isn't enough to long-term studies to identify either beneficial effects or potential harmful effects.<sup>20,23</sup>

## Conclusion

The use of MCT may become an important alternative in the treatment of obesity, if playing a role in a

complete and balanced diet. The beneficial effects of MCT are associated with improvement in body composition and increased EE, without obvious effects on food intake. Therefore, more studies are needed to establish the adequate amounts of MCT consumption and possible long term side effects, contributing to new understandings on diminished weight gain and improved quality of life for the population.

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