Effects of diets rich in monounsaturated fatty acids on the management and prevention of insulin resistance: A systematic review

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SUMMARY: Insulin resistance (IR), which is linked to obesity, is a mechanism associated with metabolic diseases, mainly type 2 diabetes mellitus. Studies have shown that monounsaturated fatty acids (MUFAs) have anti-inflammatory and anti-oxidative properties which positively affect IR. This systematic review examined the effects of MUFAs from different sources on IR in obese or overweight patients with or without metabolic syndrome. A search was carried out in the PubMed/Medline and Bireme/VHL databases, and data from 16 studies were analysed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The intervention time ranged from 1 day to 5.2 years. All participants were overweight or obese; some had central obesity, a moderate risk of cardiovascular disease, low high-density lipoprotein levels, altered fasting glucose levels, prediabetes or type 2 diabetes mellitus. This systematic review provides evidence that MUFA-rich diets can improve IR.

KEYWORDS: Metabolic syndrome; Monounsaturated fatty acids; Obesity; Systematic review.

RESUMEN: Efectos de dietas ricas en ácidos grasos monoinsaturados en la gestión y prevención de la resistencia a la insulina: Una revisión sistemática. La resistencia a la insulina (RI), que está ligada a la obesidad, es un mecanismo asociado a enfermedades metabólicas, principalmente diabetes mellitus tipo 2. Los estudios han demostrado que los ácidos grasos monoinsaturados (AGMI) tienen propiedades antinflamatorias y antioxidantes, que afectan positivamente a la RI. Esta revisión sistemática examinó los efectos de los AGMI de diferentes fuentes sobre la RI en pacientes obesos o con sobrepeso con o sin síndrome metabólico. Se realizó una búsqueda en las bases de datos PubMed/Medline y Bireme/VHL, y se analizaron los datos de 16 estudios de acuerdo con las pautas Preferred Reporting Items for Systematic Reviews and Meta-Analyses. El tiempo de intervención osciló entre 1 día y 5,2 años. Todos los participantes tenían sobrepeso u obesidad; algunos tenían obesidad central, riesgo moderado de enfermedad cardiovascular, niveles bajos de lipoproteínas de alta densidad, niveles alterados de glucosa en ayunas, prediabetes o diabetes mellitus tipo 2. Esta revisión sistemática proporciona evidencia de que las dietas ricas en MUFA pueden mejorar la RI.

PALABRAS CLAVE: Ácidos grasos monoinsaturados; Obesidad; Revisión sistemática; Síndrome metabólico.


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1. INTRODUCTION

Obesity is highly prevalent among adults and increases costs for public health systems worldwide (Bovolini et al., 2021). Obesity usually occurs when energy intake exceeds energy expenditure from metabolic and physical activities, leading to fat accumulation, mainly in visceral depots (Crudele et al., 2021). Excessive fat accumulation is a risk factor for many chronic diseases, including type 2 diabetes mellitus (T2DM). Although the exact aetiology of obesity is unknown, insulin resistance (IR) is a common factor that links obesity to T2DM and other metabolic disorders (Cho et al., 2017). IR is defined as a subnormal response to insulin-stimulated glucose uptake in skeletal muscles and adipose tissue and/or the suppression of hepatic gluconeogenesis. The development of IR is mainly associated with low-grade chronic inflammation induced by pro-inflammatory cytokines (e.g. interleukin-1 beta, interleukin-6, and tumour necrosis factor-alpha) and increased macrophage infiltration into peripheral tissues (Rehman and Akash, 2016). Oxidative stress may also be involved in the development of IR (Furukawa et al., 2004; Hurrle and Hsu, 2017).

Dietary patterns may play a dual role in determining the positive and negative effects of the onset and management of metabolic diseases. A systematic review and meta-analysis showed that altered nutritional habits play an essential role in the risk of IR development (Clifton, 2019). While Western dietary patterns, which are characterized by excessive consumption of ultra-processed foods, soft drinks, carbohydrates, and saturated fatty acids, and low or no physical exercise can lead to the onset of obesity, IR, and T2DM. A balanced diet which is low in sugar, simple carbohydrates, and saturated fatty acids and high in vegetables fiber, monosaturated fatty acids (MUFAs), and polyunsaturated fatty acids (PUFAs) has positive effects on metabolic risk factors (Clifton, 2019).

The beneficial properties of fatty acids are undervalued. Recent studies indicate that fatty acids, especially MUFAs, are essential for human health. Studies have shown that MUFAs play a pivotal role in health owing to their anti-inflammatory and anti-oxidative properties, which positively affect IR (Clifton, 2019; Ravaut et al., 2021). Interestingly, diet supplementation with olive oil (a component of the MUFA-rich Mediterranean diet) correlates with a low incidence of obesity and metabolic diseases and, therefore, low rates of chronic inflammation and mortality (Ravaut et al., 2021). This study aimed to systematically review and summarize the existing evidence on the effect of a MUFA-rich diet on IR in overweight or obese individuals with or without metabolic syndrome (MetS).

2. MATERIALS AND METHODS

2.1. Study design

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

2.2. Eligibility criteria

We included randomized, controlled studies involving men and women aged 20–65 years who were overweight or obese (body mass index ≥ 25 kg/m²) and either did or did not have MetS. Studies using MUFA-rich diets (e.g. the Mediterranean diet) or MUFA supplements (e.g. nuts or vegetable oils with emphasis on olive oil [discussion item 4.3]) as the mode of intervention were included. We adopted IR-related biochemical parameters (e.g. blood glucose, insulin, homeostatic model assessment of insulin resistance [HOMA-IR], C-peptide, glucagon-like peptide 1 [GLP-1], and glycosylated haemoglobin levels) as the main outcome measures.

2.3. Exclusion criteria

We excluded intervention studies involving healthy individuals or pregnant women and experimental studies. Articles published more than 10 years ago were also excluded.

2.4. Research methods

PubMed and Bireme/VHL (Virtual Health Library) were searched for articles published between 2010 and 2020. No publication language restrictions were imposed. In both databases, the search was performed by combining keywords related to MUFA (“monounsaturated fatty acids” OR “MUFA”; “extra virgin olive oil” OR “olive oil”; “nuts” OR “nut”; “Mediterranean diet”) and the expected results related to IR assessment (“Insulin Resistance” OR “Insulin Sensitivity” OR “Insulin” OR “HOMA”). Only randomized clinical trials were included (Figure 1).
2.5. Data extraction and management

Three researchers independently selected the articles. Discrepancies were discussed with two other review researchers until a consensus was reached. The following data were extracted from each study: author; publication year; number and characteristics of participants; age group; MUFA intervention duration, quantity, and type; control type; and main results with research outcomes (Table 1).

3. RESULTS

3.1. Literature search

The search identified 124 articles in Pubmed and 21 articles in Bireme: 30 using “monounsaturated fatty acids” OR “MUFA,” 30 using “extra virgin olive oil” OR “olive oil,” 36 using “nuts” OR “nut,” and 49 using “Mediterranean diet.” After excluding duplicate, reviews, and irrelevant articles, 67 were subjected to full-text review, and 16 of them were finally included (Figure 1).

3.2. Study characteristics

Sixteen studies were included in this systematic review. The intervention time ranged from 1 day to 5.2 years. The analysed studies included 1341 participants from countries on all continents except Africa. Nine studies were randomized crossover studies, five were randomized clinical trials, one was a randomized, parallel-arm controlled trial, and one was a nonrandomized clinical trial. Table 1 summarizes the information extracted from the included studies. All participants were overweight or obese. Some had MetS, central obesity, a moderate risk of cardiovascular disease, a low high-density lipoprotein (HDL) level, an altered fasting glucose level, prediabetes, or T2DM.

3.3. Intervention with MUFAs

The interventions proposed by the analysed studies are detailed in Table 1. The main interventions were supplementation with extra virgin olive oil or nuts, MUFA-rich diets including different sources of vegetable oils, and/or a Mediterranean diet.

4. DISCUSSION

This systematic review explores the effects of MUFA-rich diets on IR in adults and older individuals. In most of the included studies, improvements were observed in IR-related parameters (i.e. reduction in blood glucose, insulin, and HOMA-IR levels) after short- or long-term consumption of MUFA-rich diets; whereas the other studies did not report negative results, reinforcing the safety and importance of dietary MUFAs.

4.1. MUFA-rich diets from the consumption of extra-virgin olive oil

One study revealed that short-term extra virgin olive oil consumption, compared with a diet without olive oil consumption, resulted in a 20% decrease in postprandial serum glucose levels and a 40% increase in insulin levels among patients with impaired fasting glucose (Carnevale et al., 2017). The authors suggested that the inhibition of DPP-4 activity is a potential mechanism for GLP-1 and insulin upregulation. A study by D’Amore et al. (2016) showed improved blood glucose and insulin sensitivity after short-term consumption of high-polyphenol extra virgin olive oil versus low-polyphenol extra virgin olive oil in individuals without MetS. Polyphenol-rich oil also promoted the transcription of genes and miRNAs involved in anti-inflammatory responses and energy homeostasis. Interestingly, these effects were partially lost in patients with MetS and those consuming low-polyphenol extra virgin olive oil, highlighting the importance of the phenolic fraction and the individual’s health status. In another two studies involving olive oil supplementation, Valente et al. (2018) did not observe any effects of short-term consumption of extra virgin olive oil versus coconut oil in overweight women and Galang et al. (2020), in a randomized controlled crossover trial, identified significantly increased postprandial glucose levels in patients with type 2 diabetes mellitus, after adding a tablespoon of extra-virgin olive oil.

4.2. MUFA-rich diets from the consumption of nuts

Three studies which examined the effects of nut consumption were included in this review. Hernández-Alonso et al. (2017) observed that a 4-month pistachio-enriched diet positively modulated the expression of some insulin sensitivity-related miRNAs in pre-diabetic individuals. In contrast, Liu et al. (2017) did not observe any effects of short-term peanut consumption on glycaemic and insulin responses.
<table>
<thead>
<tr>
<th>Studies</th>
<th>Country</th>
<th>Design</th>
<th>Population</th>
<th>Duration of intervention</th>
<th>Intervention with MUFA</th>
<th>Secondary intervention/control</th>
<th>Results with MUFA related to insulin resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassi et al. (2017)</td>
<td>Italy</td>
<td>RCT</td>
<td>30 women and men</td>
<td>1 day per intervention</td>
<td>Meal with 10g of EVOO</td>
<td>Control meal without EVOO</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>D’Amore et al. (2016)</td>
<td>Italy</td>
<td>CT</td>
<td>24 women and men</td>
<td>1 day per intervention</td>
<td>Meal with 25ml of virgin coconut oil</td>
<td>Control meal without EVOO</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Cipollino et al. (2016)</td>
<td>Italy</td>
<td>CRD</td>
<td>12 women and men</td>
<td>1 day per intervention</td>
<td>Standard breakfast with one tablespoon of EVOO</td>
<td>Control meal {matched for energy and macronutrient content}</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Hernandez-Alonso et al. (2017)</td>
<td>Spain</td>
<td>RCTC</td>
<td>49 women and men</td>
<td>50ml of high-polyphenols EVOO</td>
<td>Breakfast with 25ml of EVOO</td>
<td>Control meal {matched for energy and macronutrient content}</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Liu et al. (2017)</td>
<td>USA</td>
<td>RCT</td>
<td>15 men</td>
<td>1 day per intervention</td>
<td>Breakfast with 10g of EVOO</td>
<td>Control meal without EVOO</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Abbaspour et al. (2019)</td>
<td>United States</td>
<td>RCT</td>
<td>48 women and men</td>
<td>4 months per intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Montenegro et al. (2018)</td>
<td>Brazil</td>
<td>RCTC</td>
<td>16 men</td>
<td>1 day per intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Liao et al. (2017)</td>
<td>Spain</td>
<td>RCT</td>
<td>15 men</td>
<td>8 weeks intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Li et al. (2016)</td>
<td>Spain</td>
<td>RCTC</td>
<td>361 women and men</td>
<td>4 months per intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Chapman et al. (2016)</td>
<td>Canada</td>
<td>RCTC</td>
<td>47 women and men</td>
<td>6 weeks per intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Chang et al. (2015)</td>
<td>Canada</td>
<td>RCTC</td>
<td>105 women and men</td>
<td>16 weeks intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Grassi et al. (2017)</td>
<td>Australia</td>
<td>RCTC</td>
<td>24 women and men</td>
<td>1 day per intervention</td>
<td>Breakfast with 25ml of EVOO</td>
<td>Control meal without EVOO</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Mancini et al. (2017)</td>
<td>Italy</td>
<td>RCT</td>
<td>13 women and men</td>
<td>5.2 years intervention</td>
<td>Breakfast with 25ml of EVOO</td>
<td>Control meal without EVOO</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Grassi et al. (2017)</td>
<td>Italy</td>
<td>RCT</td>
<td>47 women and men</td>
<td>4 weeks per intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Mancini et al. (2017)</td>
<td>United Kingdom</td>
<td>RCT</td>
<td>64 women and men</td>
<td>4 weeks per intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
<tr>
<td>Grassi et al. (2017)</td>
<td>Australia</td>
<td>RCTC</td>
<td>215 women and men</td>
<td>1 year intervention</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>Breakfast with MUFA (defatted olive oil)</td>
<td>No significant effect between the diets</td>
</tr>
</tbody>
</table>

*Studies involved in the systematic review: Randomized, Parallel-arm Controlled Trial; FA: Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; SFA: Saturated Fatty Acids; CHO: Carbohydrate; PTN: Protein.*
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in overweight individuals. Unlike previous studies, Abbaspour et al. (2019) reported blood glucose and insulin level reductions in overweight individuals after an 8-week diet with mixed-nut supplementation. This beneficial effect on glycaemic control can be attributed, in part, to the replacement of carbohydrates by MUFA's. Notably, the proteins and fibers contained in nuts can also contribute to this hypoglycaemic effect (Azzout-Marniche et al., 2014; Weickert and Pfeiffer, 2008). Another finding of this study was body weight reduction in the nut consumption group (Abbaspour et al., 2019). According to Qian et al. (2016), the effects of a MUFA-rich diet on metabolic risk factors may be partially mediated by changes in body weight. The introduction of a variety of nuts to the diet is interesting, as it can prevent food monotony and maintain consumption. In addition, nuts differ in their nutrient and bioactive compound contents; thus, a combination of nuts provides a greater range of health benefits (Abbaspour et al., 2019).

FIGURE 1. PRISMA Flow Diagram detailing the database searches, the number of abstracts screened and the full texts retrieved. BMI: Body Mass Index; MUFA: Monounsaturated Fatty Acids; IR: Insulin Resistance

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4.3. MUFA-rich diets including different sources of vegetable oils

Seven studies on MUFA-rich diets using different vegetable oil sources were included in this systematic review. Montserrat-de la Paz et al. (2018) evaluated the effects of a short-term diet with the three meals containing different sources of fat (saturated fatty acids [milk cream], MUFA [refined olive oil], MUFA plus n-3 PUFAs [refined olive oil plus fish oil with EPA and DHA], and no-fat meals) among individuals with MetS. All meals were supplemented with 2 g of niacin. Compared to meals containing saturated fatty acids, meals containing MUFA improved glycaemia and postprandial insulinaemia and increased C-peptide levels, and showed greater insulin production. The same group of researchers previously demonstrated that the nature of dietary fats in meals influences postprandial triglyceride levels and the control of insulin secretion and sensitivity among individuals with normal or elevated fasting triglyceride levels (López et al., 2008; López et al., 2011). The results of these studies showed improved postprandial beta-cell function and lower IR when the proportion of MUFA versus that of saturated fatty acids in the diet was increased (Lopez et al., 2011; López et al., 2008).

In a study by Luis et al. (2017), obese participants consumed a high-MUFA hypocaloric diet (including virgin olive oil) or a high-PUFA hypocaloric diet for 3 months. In the high-MUFA hypocaloric diet group, individuals with the AA genotype (wild type) showed a reduction in insulin and HOMA-IR levels. This result shows that a single nucleotide polymorphism (SNP) in the brain-derived neurotrophic factor gene (rs10767664 variant) modifies IR after weight loss following a high-MUFA hypocaloric diet. However, the effect of dietary fat composition on the metabolic parameters related to this SNP remains unclear.

Another study which compared the effects of a MUFA-rich diet versus a PUFA-rich diet for 45 days in obese women (BMI > 35kg/m²) was conducted by Lago et al. (2016). Although the authors did not identify the MUFA and PUFA sources used, they emphasized that the diet was individualized and had a caloric restriction of about 500 to 1000 kcal per day. At the end of the study, no statistical differences were observed when comparing the PUFA-rich diet and the MUFA-rich diet, but the intragroup evaluation showed a drop in the level of fasting glucose, insulin levels and HOMA-IR, in the MUFA-rich group. These results suggest that the MUFA-rich diet was more efficient in reducing insulin resistance in the studied population.

Two studies did not show the potential benefit of MUFAs versus other fatty acids on IR; however, a high-carbohydrate diet produced interesting results. Chang et al. (2018) compared the effects of replacing 7% of one’s dietary energy with carbohydrates (simple sugar supplied as sweetened drinks), MUFAs (high-oleic sunflower oil blend), or saturated fatty acids (palm oil) for 6 weeks in individuals with abdominal obesity. The use of MUFAs or saturated fatty acids had no differential impact on glucose and insulin homeostasis and gastrointestinal peptides (GLP-1, GIP, ghrelin, PYY, and CCK) in the fasting or postprandial periods. The diet with refined carbohydrates had greater adverse effects on insulin secretion. In another study, Chang et al. (2016) evaluated individuals with MetS who consumed high-fat meals (enriched with saturated fatty acids, MUFAs [high-oleic sunflower oil], or n-6 PUFAs) or low-fat/high-sucrose meals. The short-term consumption of fatty acids (saturated fatty acids, MUFA, and n-6 PUFAs) resulted in similar insulin, glucose, and C-peptide responses over time (Chang et al., 2016). Compared to high-fat meals (regardless of the fatty acid type), the low-fat/high-sucrose meal induced a greater response for C-peptide (45%), insulin (45%), and glucose (49%).

Two other studies also showed no benefit of MUFAs versus other fatty acids on IR, but positive results were observed for MetS-related parameters. Vafciadou et al. (2015) evaluated the effects of the consumption of three isoenergetic diets rich in saturated fatty acids (butter), MUFAs (refined olive oil and olive oil/rapeseed oil blended spread), or n-6 PUFAs (safflower oil and spread) for 16 weeks in individuals with a moderate cardiovascular disease risk. Replacing saturated fatty acids with MUFAs attenuated nocturnal systolic blood pressure. Regarding the patients’ fasting lipid profiles, replacing saturated fatty acids with MUFAs or n-6 PUFAs reduced the total (28.4% and 29.2%, respectively) and low-density lipoprotein (LDL) (211.3% and 213.6%, respectively) cholesterol levels, and the total cholesterol to HDL cholesterol ratio (25.6% and 28.5%, respectively), without significant difference.
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4.4. Mediterranean diet

Two studies included in the review evaluated the effects of a Mediterranean diet in patients with T2DM, and long-term follow-ups showed benefits in terms of IR. The Mediterranean diet is one of the most widely described and evaluated diets in scientific literature. It is characterized by a high intake of nuts, vegetables, legumes, fruits, grains, fish, seafood, and extra virgin olive oil and a moderate intake of red wine (Schwingshackl et al., 2020). A large body of observational and experimental evidence suggests that greater adherence to the Mediterranean diet is related to glucose homeostasis, with an emphasis on reduced IR (Roldan et al., 2019; Vitale et al., 2018; Park et al., 2017; Zhong et al., 2016). This beneficial effect is probably related to its contents of MUFAs; PUFAs; fiber; and bioactive compounds such as polyphenols, vitamins, and minerals which result in anti-inflammatory and anti-oxidant actions, GLP agonists, and changes in the intestinal microbiota (Schwingshackl et al., 2020; Martin-Peláez et al., 2020). The PREDIMED study showed that adherence to a Mediterranean diet enriched with either an average of 50 mL/day of virgin olive oil or 30 g/day of nuts for 5 years, compared with a low-fat diet, in participants with MetS decreased xanthine oxidase activity and increased plasma superoxide dismutase and catalase activities (Sureda et al., 2016). Notably, the unique actions of different nutrients or compounds and their derived metabolites can be enhanced by interactions and synergies, making the Mediterranean diet an invaluable tool for the prevention and control of metabolic diseases (Tosatti et al., 2021; Martin-Peláez et al., 2020).

4.5. Limitations

Although this systematic review supports the beneficial role of MUFAs in IR, whether these effects are a primary or secondary outcome of the improvement in obesity-associated chronic inflammation and oxidative stress remain unclear. Another limitation is the diversity of the included publications. Heterogeneity in study characteristics is common in nutritional intervention studies. Therefore, unsurprisingly, the studies selected for the present analysis varied with regard to the type of diets, definition of MUFA-rich diets, study population, intervention duration, and long-term follow-up protocols.

Another consideration is the variation in MUFA levels in the articles reviewed. Use of different MUFA doses is a relevant factor that may have influenced the results. Most dietary guidelines for MUFA consumption are based on the subtraction of recommended saturated and polyunsaturated fat intakes from the total fat intake rather than on evidence for the optimal level of MUFA intake (Liu et al., 2017). A few guidelines have specified quantitative recommendations for MUFA intake, ranging from 10 to 25% of the total caloric value of the diet (Schwingshackl et al., 2021; Sociedade Brasileira de Cardiologia, 2017). Thus, when considering an average requirement of 2000 kcal/day, the minimum recommendation of 10% is equivalent to 22 g of MUFA. On a daily basis, this MUFA content can be achieved by consuming approximately 27 mL of extra virgin olive oil (Jimenez-Lopez et al., 2020), 67 g of almonds (NEPA, 2011), or 37 g of macadamia nuts (Kris-Etherton, 1999), regardless of food sources.

5. CONCLUSIONS

Our systematic review showed that some improvement in IR-related parameters was observed in most of the evaluated studies, despite the diversity of MUFA interventions, doses, and outcomes. Therefore, individuals with IR may benefit from the consumption of extra virgin olive oil, nuts, a MUFA-rich diet including different sources of vegetable oils, or a Mediterranean diet. However, further studies are necessary to establish dose recommendations.

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DISCLOSURE

All authors declare no conflicts of interest regarding the contents of this article.

REFERENCES


Kris-Etherton PM. 1999. AHA Science Advisory. Monounsaturated fatty acids and risk of car-
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Qian F, Korat AA, Malik V, Hu FB. 2016. Metabolic Effects of Monounsaturated Fatty Acid-Enriched Diets Compared With Carbohydrate or Polyunsaturated Fatty Acid-Enriched Diets in Patients With Type 2 Diabetes: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Diabetes Care* **39** (8), 1448–1457. https://doi.org/10.2337/dc16-0513


