Malnutrition and Impact on Health

Chapter 1

Malnutrition and Type 2 Diabetes

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1. Abstract

This review aimed to evaluate, through randomized controlled trials (RCTs), the dietary intake and its evolution after nutritional interventions on older adults with type 2 diabetes. An electronic search was performed in Pubmed and list of references from 2000 until May 2021 was made. Studies were eligible if 1) participants were only individuals with type 2 diabetes; 2) at least one outcome was related to dietary intake; 3) the study design was a randomized controlled trial; and 4) mean age of participants ≥ 55 years old. This review demonstrates that a high percentage of patients with type 2 diabetes had Malnutrition, through excess of total fat intake and saturated fat consumption and deficiency of fiber intake and servings of fruit and vegetables per day. In general, nutritional interventions had: 1) high efficacy rates in the reduction of total energy intake; 2) low efficacy rates in the reduction of total fat and saturated fat intake; 3) low efficacy rates in the increase of polyunsaturated fat, monounsaturated fat and fiber intake and servings of fruit and vegetables per day.

Keywords: Malnutrition; Randomized Controlled Trials; Dietary Intake; Nutritional Interventions; Older Adults; Type 2 Diabetes.

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2. Introduction

Type 2 diabetes (T2D) is recognized as a public health concern, that is rising rapidly worldwide with a considerable impact on human life and enormous socioeconomic and health challenge [1]. Type 2 diabetes is characterized by relative insulin deficiency caused by pancreatic B-cell dysfunction and insulin resistance in target organ [2]. The complications of diabetes are divided into microvascular, that include neuropathy, nephropathy, and retinopathy, and macrovascular, such as cardiovascular disease, stroke and peripheral artery disease [3].

The adoption of unhealthy diet and physical inactivity has resulted in an unparalleled increase in the number of individuals with T2D. The number of individuals with diabetes is estimated to further increase to 642 million by 2040, more than 90% of whom had T2D [4]. The rate of T2D has substantially increased in older people [5] and remains a major cause of excess morbidity and mortality [6, 7]. Aging is thought to be associated with reduced capacity to regenerate B-cells, as well as the insulin secretion rate in response to glucose was significantly decreased in older individuals [8].

One of the main pillars of T2D management is the adoption of a healthy diet due to its importance on weigh and metabolic control. Also, the adoption of a healthy diet is associated with a lower risk of cardiovascular diseases, the major cause of death in T2D patients [9]. Beyond recommendations for dietary intake for general population [10], there are specific recommendations for T2D individuals stated by American Diabetes Association (ADA) and International Diabetes Federation (IDF) [4, 11]. Dietary guidelines for the management of diabetes have evolved from a focus on a low-fat diet to the recognition that more important considerations are macronutrient quality, avoidance of processed foods and overall dietary patterns [12]. Adherence to the nutritional recommendations is an extremely difficult task for T2D individuals because of several reasons: 1) food cost; 2) small portion sizes; 3) support and family issues; 4) quality of life and lifestyle issues [13]. In consequence, it occurs an imbalance (deficiency or excess) of one or more nutrients, named by Saunders et al. (2020) [14] as Malnutrition, leading to adverse effects on human health [13]. According to Vijan et al. (2005) [13], there is the need for high-quality interventions with the purpose of improving T2D patients' ability to change their diet. According to Hariton & Locascio (2018) [15], randomized controlled trials (RCTs) are the gold standard for effectiveness research. Thus, the aim of this study is to evaluate, through RCTs, the dietary intake and its evolution after nutritional interventions on older adults with type 2 diabetes.

3. Methods

3.1. Search strategy

A search was carried out by two independent authors [CV and CS] in the electronic database "PubMed", from the year of 2000 until May 2021, to identify articles assessing the effects of a nutritional intervention in dietary outcome(s) in individuals with type 2 diabetes. For database search, the following keywords were used: ((diabetes[Title]) AND (eating[Title] OR food [Title] OR nutrient [Title] OR nutrition[Title] OR nutritional[Title] OR dietary[Title] OR diet[Title])) AND (randomized controlled trial [Title/Abstract] OR randomly[Title/Abstract]).

3.2. Selection of the studies

Two authors [CV and CS] independently reviewed the search results and screened publications provided by database (Pubmed), according to the following steps: 1) articles were selected by the information from title and abstract; 2) full text analysis of potentially relevant articles was done to determine their eligibility for this review. Disagreements between authors were resolved by consensus.

We considered studies eligible if: 1) participants were only individuals with type 2 diabetes; 2) at least one outcome was related to dietary intake; and 3) the study design was a randomized controlled trial; 4) mean age of participants ≥ 55 years old.

We excluded studies according to the following criteria: 1) studies in individuals with type 1 diabetes, gestational diabetes, or prediabetes; 2) studies with no outcomes related to dietary intake; 3) the study design was not a randomized controlled trial; and 4) mean age of participants < 55 years old.

3.3. Data extraction

Each selected article was independently evaluated by authors to extract information regarding: [1] study characteristics (first author, year of publication, country); [2] study participants (including sample size and mean age ± standard deviation of intervention and control group); [3] evaluation method of dietary outcome(s); [4] intervention and control groups (description of interventions); [5] outcomes measured (due to the subject of this review, authors only presented nutritional outcomes); [6] main results of the outcomes measured. If there were disagreements in data extraction, authors discussed until consensus.

3.4. Data analysis

For each study, we analysed nutritional outcomes according to 1) specific recommendations for type 2 diabetes patients: reduce total energy intake; consumption of at least 14g/1000 kcal of fiber per day [11]; eating up to three servings of fresh fruit per day;

choosing unsaturated fats instead of saturated fats [4] and 2) recommendations for general population [10]: total fat intake should not exceed 30% of total energy intake; saturated fat intake should be less than 10% of total energy intake; individuals should consume at least 5 portions (400g) of fruit and vegetables per day.

For each study, we analysed baseline values of dietary outcomes on intervention group and differences in the evolution of dietary outcomes between intervention and control group.

4. Results

4.1. Study selection

A total of 359 references were identified in the initial search. After screening for title and abstract, 330 papers were excluded. After full-text reading, 16 more papers were removed. Thus, in final analysis 13 studies were included in this review.

4.2. Study characteristics

The characteristics of the studies included in this review are presented in **Table 1**.

Table 1: Main characteristics of each study that met the inclusion and exclusion criteria.

Authors / Country	Objective	Participants (N); mean age (years ± SD)	Evaluation method	Intervention group	Control group	Evaluations (related to dietary outcomes)
Vasconcelos et al. (2021) [16] / Portugal	Analyze the effects of a 16-week food education program on dietary pattern of patients with type 2 diabetes	N = 33 INT: 67.6 ± 5.4 years old CON: 62.8 ± 5.5 years old	3-day food record	Combined exercise intervention during 9 months plus 16-week food education program Food education program included two different sessions a week: a) 15-minute theoretical session through active learning; b) dual-task strategy integrated in one exercise session (analysis of food label information, responses with the use of traffic light system during walking exercise)	Combined exercise intervention for 9 months	At baseline and 9-months, total energy, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, fiber intake, servings of fruit and servings of vegetables per day were evaluated.
Cade et al. (2009) [17]/ United Kingdom	Assess the effectiveness of a 7-week Nutritional Program on the adoption of a healthy eating pattern of individuals with type 2 diabetes	N = 317 INT: 65.4 ± 11.6 years old CON: 66.2 ± 11.5 years old	3-day food record	Subjects attended a 2-h session, once a week, for 7 weeks. The first six sessions covered aspects of learning to cope with long-term health problems, and improved eating, relaxation and exercise patterns. The seventh session was related to the identification of common problems for people with diabetes; monitoring diabetes and self-management of diabetes.	Standard care plus an Individual appointment with a dietitian, lasting between 15–30 minutes.	At baseline, and 12-months, total energy, total fat and saturated fat intake were evaluated.

Muchiri et al. (2015) [18] / South Africa	Analys the effects of 8-week nutrition education program on dietary behaviours in patients with type 2 diabetes	N = 82 INT: 59.4 ± 6.9 years old CON: 58.2 ± 8.0 years old	Three face-to-face 24 hour dietary recall	8-week nutrition education program consisted of 8 weekly sessions (2-2.5 hours each) regarding different subjects related to nutritional aspects of Diabetes. Besides these classes, participants received education materials related to nutrition aspects.	Received education materials regarding nutritional aspects	At baseline, 6 and 12-months, total energy, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, fiber intake, servings of fruit and servings of vegetables per day were evaluated.
Weinstein et al. (2014) [19] / USA	Analyse the impact of distributing coupons at farmers markets plus a 1-hour educational intervention on fruit and vegetable intake on patients with type 2 diabetes.	N = 78 INT: 55.6 ± 10.7 years old CON: 55.4 ± 11.1 years old	Responses to 9 questions from the 2011 Centers for Disease Control Behavioral Risk Factor Surveillance System	Nutritional intervention consisted in a single hour group education session, based on the national standards for Diabetes Self-Management	Standard of care including physician visits and education by a certified diabetes educator and/or dietitian.	At baseline and 3-months, servings of fruit and vegetables per day were evaluated.
Yang et al. (2016) [20] / Korea	Compare the effects of personalized nutrition education with a general instruction for diabetes in patients with type 2 diabetes.	N = 56 INT: 63.9 ± 8.7 years old CON: 65.6 ± 8.6 years old	24-hour dietary recall	Education involving meal selection according to the caloric needs, comparison of food selections with typical meals, and evaluation of meals to establish self-management skills for appropriate meal choices in the future.	General nutrition information for diabetes according to the guidelines for diabetes nutrition therapy	At baseline and 3 months, total energy, total fat, fruit and vegetables intake were evaluated.
Yannakoulia et al. (2007) [21] / Greece	Compare the effects of a nutritional intervention with usual care conditions on, lifestyle changes in patients with type 2 diabetes	N = 30 INT: 56.3 ± 8.8 years old CON: 56.9 ± 10.0 years old	Food frequency questionnaire	Goal-oriented consultations sessions (N = 5; every 2 weeks) for 2 months.	Dietary goals were discussed in one consultation at baseline	At baseline and 2 months, servings of fruit and vegetables per day were evaluated.
Chee et al. (2017) [22]/ Malaysia	Evaluate the effectiveness of a nutritional program versus usual diabetes care in type 2 diabetes patients from primary care setting	N = 230 INT 1: 55.0 ± 8.0 years old INT 2: 55.0 ± 8.0 years old CON: 55.0 ± 8.0 years old	3 day food record	Structured low-calorie meal plan (1200 or 1500 kcal/day) plus monthly consultations with a nutrition expert (for 6 months). The difference between the two intervention groups was the type of counseling.	Advice to follow a conventional low-calorie diet plan (1200 or 1500 kcal/day).	At baseline and 6 months, total energy and fat intake were evaluated
Coppell et al. (2010) [23] / New Zealand	Determine the effects of a dietary intervention on cardiovascular risk factors in patients with type 2 diabetes	N = 93 INT: 56.6 ± 8.8 years old CON: 58.4 ± 8.8 years old	3 day food record	Based on recommendations of the Diabetes and Nutrition Study Group of the European Association for the Study of Diabetes, participants had: - Two individual sessions with dietitian (within the first month) - monthly individual sessions with dietitian for 5 months - one group education session within the first two months. Participants'family members were encouraged to attend dietary education sessions.	Usual care plus advice on physical activity (to reach at least 30 minutes of physical activity of moderate intensity	At baseline and 6 months, total energy, total fat, polyunsaturated fat and fiber intake were evaluated

Glasgow et al. (2006) [24] / USA	Evaluate the effectiveness of a computer-based diabetes intervention on dietary outcomes in type 2 diabetes patients	N = 335 INT: 62.0 ± 11.7 years old CON: 61.0 ± 11.0 years old	**Fat intake:** Block fat screener **Fruit and vegetable intake:** All day NCI Fruit and Vegetable Screener	Computer-assisted self-management assessment and feedback, tailored goal-setting, barrier identification, and problem-solving, followed by health counsellor interaction and follow-up calls	Usual Care	At baseline and 2 months, total fat intake and servings of fruit and vegetables per day were evaluated
Gutschall et al. (2009) [25] / USA	Evaluate the effects of a behavioral intervention on dietary outcomes in adults with type 2 diabetes.	N = 103 INT: 58.6 ± 7.7 years old CON: 59.8 ± 7.3 years old	Three 24 hours dietary recall	Nine weekly group sessions lasting 1.5 to 2 hours each, focused on selecting lower-GI foods instead of restricting carbohydrate intake	Usual care	At baseline and 9 weeks, total energy, total fat, saturated fat, monounsaturated fat, polynsaturated fat intake and fiber intake were evaluated
Huang et al. (2010) [26] / Taiwan	Evaluate the effect of diabetes management intervention on macronutrient intake in type 2 diabetes patients	N = 154 INT: 56.6 ± 8.0 years old CON: 56.9 ± 7.5 years old	Registed dietitian administered questionnaire	Individualized nutrition counseling and dietary plans every 3 months for 12 months.	Routine care	At baseline and 12 months, total energy, total fat, saturated fat, monounsaturated fat and polynsaturated fat intake were evaluated
Li et al. (2016) [27] /China	Investigate whether nutrition education program is effective in the improvement of dietary outcomes on patients with type 2 diabetes.	N = 196 INT: 59.1 ± 4.6 years old CON: 58.3 ± 4.1 years old	Food record	Nutritional lectures about diabetes for 1 month.	Health advice and diet principles for the management of diabetes in the baseline and at 1 month.	At baseline and 1 month, total energy, total fat and fiber intake were evaluated
Liu et al. (2015) [28] / China		N = 117 INT: 63.3 ± 6.4 years old CON: 62.0 ± 7.4 years old	24-hours dietary recall	Nutrition education program that consisted of 3 phases: 1) 6-hour nutrition education program with one training session per month over a 3-month period; 2) it was provided one time per month the traffic light diet guide over a 3-month period; 3) individualized nutrition counseling every 2 months over a 6-month period.	Routine care	At baseline and 12 months, total energy and total fat intake were evaluated

In the study of Vasconcelos et al. (2021) [16], authors analyzed the effects of a 16-week food education program, integrated in a community-based exercise program, on dietary pattern of 33 patients with type 2 diabetes. On intervention group, participants integrated a 9-month combined exercise program (three 75 minutes sessions per week) plus a 16-week food education program, based on IDF nutrition teaching modules [29] and ADA recommendations for dietary intake [11]. On each week, a different nutrition-related content was addressed through two sessions: (a) a theoretical session of 15 min, through active learning, performed before one exercise session; and (b) dual-task strategies integrated in another exercise session: during walking exercise. Participants in control group integrated a 9-month combined exercise program (three 75 minutes sessions per week). No significant changes between control group (9-month exercise program) and intervention group (9-month exercise program plus 16-week food education program) were found on total energy intake ($p = 0.056$), saturated fat ($p =$

0.946), monounsaturated fat (p = 0.094), fiber intake (p = 0.173) and servings of fruit per day (p = 0.143). Compared with control group, intervention group significantly increased total fat intake (p = 0.022), through a significant increase of polyunsaturated fat intake (p = 0.003) and servings of vegetables per day (p = 0.037).

In the study of Cade et al. (2009) [17] authors aimed to assess the effectiveness of a 7-week Nutrition Program to promote healthy eating in 317 patients with type 2 diabetes. On intervention group, participants attended a group session for 2 h once per week for 7 weeks. The first six sessions focused on the acquisition of competencies related to self-management of long-term health problem, relaxation, eating and exercise patterns. In addition, a seventh week 2-h session was specific related to issues concerning diabetes (identifying common problems for people with diabetes; monitoring diabetes; self-managing diabetes in terms of food intake, physical activity, blood glucose and blood pressure; goal setting). On control group, participants continued standard care plus na individual appointment with a dietitian lasting 15 to 30 minutes. At 12 months, there was no significant difference between the groups in total energy intake, fat intake and saturated fat intake. Significance values were not presented in the paper.

In the study of Muchiri et al. (2015) [18], authors analyzed the effects of 8-week nutrition education program on dietary behaviors in 82 patients with type 2 diabetes. On intervention group, the 8-week nutrition education program consisted on 8 weekly sessions (2-2.5 hours each) regarding the following subjects: concept of Diabetes, treatment of Diabetes, healthy eating, dietary guidelines (fats, salt, sugar and water), improvement of vegetable supply, meal planning (portions and meal frequency), meal planning (principles) and meal preparation. Besides classes, participants received education materials (pamphlet and wall/fridge poster) regarding the subjects presented. On control group, participants received materials with nutritional information. At 6 months, no significant differences were noticed between intervention and control group on total energy intake (p = 0.09), total fat intake (p= 0.96), saturated fat intake (p = 0.51), monounsaturated fat intake (p=0.47), polyunsaturated fat intake (p = 0.26), fiber intake (p = 0.72) and servings of vegetables and fruit per day (p = 0.15). At 12 months, no significant differences were noticed between intervention and control group on total fat intake (p = 0.89), saturated fat intake (p = 0.42), monounsaturated fat intake (p = 0.18), polyunsaturated fat intake (p = 0.47), fiber intake (p = 0.39) and servings of vegetables and fruit per day (p = 0.53). Compared with control group, the intervention group had a significantly lower median energy intake and 12 months (p = 0.017).

Weinstein et al. (2014) [19] had the purpose to test the impact of distributing coupons at farmers markets plus a 1-hour educational intervention on fruit and vegetable intake on 78 patients with type 2 diabetes. On intervention group, nutritional intervention consisted in a single hour group education session, based on the national standards for Diabetes Self-Management and regarding the following subjects: identification of myths that limit fruit and vegetable con-

sumption; educational facts regarding fruit and vegetables consumption; and the creation of a Healthy Plate. Besides, participants received $6 in Health Bucks to spend at Green Markets for the purchase of fruits and vegetables. Participants from control group continued to follow standard of care. At 12 weeks, servings of fruit per day significantly increase in intervention group compared to control group ($p = 0.04$). Regarding servings of vegetables per day, no significant differences were noticed between groups (p value non stated).

The purpose of the study of Yang et al. (2016) [20] was to compare the effects of personalized nutrition education with a general instruction for diabetes in 70 patients with type 2 diabetes. Patients from intervention group received education involving meal selection according to the caloric needs, comparison of food selections with typical meals, and evaluation of meals to establish self-management skills for appropriate meal choices in the future. Participants from control group received general nutrition information for diabetes according to the guidelines for diabetes nutrition therapy. At 3 months, no significant differences were found between groups on total energy intake (*p* value non stated). Participants from intervention group significantly increased total fat intake ($p < 0.05$) and decreased fruit intake per day ($p = 0.013$). On intervention group, no significant differences were found on vegetables intake per day ($p = 0.143$).

The purpose of the study of Yannakoulia et al. (2017) [21] was to compare the effects of a nutritional intervention with usual care conditions on lifestyle changes in 30 patients with type 2 diabetes. Participants from intervention group received five individual goal-oriented consultation sessions for 2 months. Individuals from control group discussed dietary goals in one consultation at baseline. No significant differences were noticed between groups in servings of fruit and vegetables per day (data not presented).

In the study of Chee et al. (2017) [22], these authors aimed to evaluate the effectiveness of a 6-month diabetes lifestyle program in 230 patients with T2D from primary care settings. In a randomized controlled trial, this study has two intervention groups (IG), both receiving a structured low-calorie meal plan (1200 or 1500 kcal/day) and a physical activity prescription of at least 150 min per week. These participants were also followed up monthly by the dietitian and physician, during the 6 months. The difference between the two intervention groups was that in one group the counseling was done through motivational interviewing principles (IG1) and the other group received convention counseling techniques that focused on empathetic listening, education, persuasion, and encouragement (IG2). Control group (CG) received advice to follow a conventional low-calorie diet plan (1200 or 1500 kcal/day). Authors found that at 6 months, participants from interventions groups significantly decreased total energy intake $p < 0.001$). and total fat intake $p < 0.001$). comparing with participants from control group.

The purpose of the study of Coppell et al. (2010) [23] was to determine the effects of

a dietary intervention on cardiovascular risk factors in 93 patients with type 2 diabetes. For 6 months, participants from intervention group received by a registered dietitian: two individual sessions (during the first month); monthly individual sessions (between month 1 and 6); and one group education session within the first two months. These sessions were based on recommendations of the Diabetes and Nutrition Study Group of the European Association for the Study of Diabetes. Participants 'family members were encouraged to attend nutritional classes. In control group, participants continued usual care plus advice on physical activity (to reach at least 30 minutes of physical activity of moderate intensity. At 6 months, no significant differences between groups were found in total energy intake ($p = 0.376$), total fat intake ($p = 0.211$), polyunsaturated fat intake ($p = 0.211$) and fiber intake ($p = 0.064$). Intervention group significantly decreased saturated fat intake compared with control group ($p = 0.006$).

In the study of Glasgow et al. (2006) [24], authors aimed to evaluate the effectiveness of a computer-based diabetes intervention on dietary outcomes in type 2 diabetes. Participants from intervention group received a CD-ROM with information related with healthy eating plus follow-up letters that had the aim of reinforcing patients' selected goals. Individuals from control group continued with usual care. At 6 months, participants from intervention group significantly reduced fat intake ($p = 0.006$) when compared with control group. No significant differences between groups were noticed in servings of fruit and vegetables per day ($p = 0.270$).

In the study of Gutschall et al. (2009) [25], these authors aimed to evaluate the change in dietary outcomes following a behavioral intervention which promoted lower-GI foods among 103 adults with type 2 diabetes. Participants from intervention group received nine weekly group sessions lasting 1.5 to 2 hours each, focused on selecting lower-GI foods instead of restricting carbohydrate intake to avoid severely restricting food groups with a low-carbohydrate diet. Participants from control group continued usual care. At 9 weeks, participants from intervention group significantly reduced fat intake ($p = 0.003$), saturated fat intake ($p = 0.03$), monounsaturated fat intake ($p = 0.006$) when compared with control group. Total fiber intake significantly increased in intervention group compared with control group ($p = 0.002$). No significant differences were noticed between groups in total energy intake ($p = 0.34$) and polyunsaturated fat intake ($p = 0.17$).

In the study of Huang et al. (2010) [26], authors aimed to evaluate the effect of diabetes management intervention on macronutrient intake in 154 patients with type 2 diabetes. Participants from intervention group received individualized nutrition counseling and dietary plans to reinforce the concepts of controlling portion sizes every 3 months for 12 months. Participants from control group continued to follow usual care. At 12 months, participants from intervention group significantly reduced total energy intake ($p < 0.001$) and saturated fat intake ($p = 0.01$). No significant differences were found between groups on total fat intake (p

= 0.793), polyunsaturated fat intake ($p = 0.500$) and monounsaturated fat intake ($p = 0.596$).

In the study of Li et al. (2016) [27], these authors had the purpose of investigate whether nutrition education program is effective in the improvement of dietary outcomes on 196 middle-aged patients with type 2 diabetes. Participants from intervention group lived together for 1 month and received nutritional lectures about diabetes in that period. The contents of education included basic knowledge of diabetes, nutrition equilibrium, nutrition diet design, exercise techniques, blood sugar monitoring, and medication treatment of diabetes. Control group received health advice and diet principles for the management of diabetes in the baseline and at 1 month. At 1 month, participants from intervention group significantly reduced total energy intake ($p < 0.001$) and increased fiber intake ($p < 0.01$) when compared to control group. No results were provided regarding total fat intake

In the study of Liu et al. (2015) [28], these authors aimed to identify the effectiveness of nutrition intervention on dietary outcomes in a community setting of 117 type 2 diabetes patients. The intervention group received nutrition education program in three phases: 1) 6-hour nutrition education program with one training session per month over a 3-month period; 2) it was provided one time per month the traffic light diet guide over a 3-month period; 3) individualized nutrition counseling every 2 months over a 6-month period. Control group received standard care at the community health centers, which included basic dietary principles given by dietitians. At 12 months, participants from intervention group significantly reduced total energy intake ($p = 0.001$) and total fat intake ($p < 0.002$) when compared with control group.

4.3. Dietary Outcomes

Table 2 described the detailed data regarding dietary outcomes.

Table 2: Detailed data regarding dietary outcomes.

RCT / Country	Total calories	Total fat	Saturated fat	Polyunsaturated fat	Monounsaturated fat	Fibre	Fruit	Vegetables
Vasconcelos et al. (2021) [16] / Portugal	**Baseline:** 1.488 ± 363 kcal/day **9 months:** 1581 ± 444 kcal/day	**Baseline:** 30.9 ± 5.2% **9 months:** 32.6 ± 5.3%	**Baseline** 7.7 ± 2.0% **9 months** 8.0 ± 1.9%	**Baseline:** 4.5 ± 1.0% **9 months:** 5.1 ± 1.3%	**Baseline:** 14.1 ± 3.0% **9 months:** 14.6 ± 3.2%	**Baseline:** 11.4 ± 3.6 g/1000kcal **9 months:** 10.9 ± 3.0 g/1000kcal	**Baseline:** 1.4 ± 0.7 daily servings **9 months:** 2.0 ± 0.9 daily servings	**Baseline:** 1.4 ± 0.6 daily servings **9 months:** 1.5 ± 0.6 daily servings
Cade et al. (2009) [17]/ UK	**Baseline:** 1.886 ± 444 kcal/day **9 months:** 1668 ± 443 kcal/day	**Baseline:** 33.4% **9 months:** 30.9%	**Baseline:** 11.9% **9 months:** 10.8%	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated

Muchiri et al. (2015) [18]/ South Africa*	**Baseline:** 1722.6 kcal/day **6 months:** 1418.7 kcal/day **12 months:** 1430.2 kcal/day	**Baseline:** 16.4% **6 months:** 16.0% **12 months:** 16.4%	**Baseline:** 4.3% **6 months:** 4.3% **12 months:** 4.4%	**Baseline:** 5.0% **6 months:** 4.6% **12 months:** 4.5%	**Baseline:** 5.3% **6 months:** 4.6% **12 months:** 4.4%	**Baseline:** 11.6 g/1000kcal **6 months:** 12.7 g/1000 kcal **12 months:** 14.7 g/1000 kcal	**Results of Fruit and vegetables together** **Baseline:** 1.3 daily servings **6 months:** 2.1 daily servings **12 months:** 2.2 daily servings	
Weinstein et al. (2014) [19]/ USA*	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated	**Baseline:** 0.5 daily servings **3 months:** 0.7 daily servings	Evaluated but data not presented
Yang et al. (2016) [20]/ Korea	Evaluated but data not presented	**Baseline:** 20% **6 months:** 21.8%	Not evaluated	Not evaluated	Not evaluated	Not evaluated	**Baseline:** 154.9 ± 152.1 g/ day **3 months:** 101.2 ± 111.4 g/ day	**Baseline:** 402.6 ± 166.6 g/day **3 months:** 431.4 ± 167.9 g/day
Yannakoulia et al. (2007) [21]/ Greece	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated	**Baseline:** 1.7 ± 1.8 daily servings **2 months:** 2.5 ± 1.3 daily servings	**Baseline:** 2.8 ± 2.6 daily servings **2 months:** 3.5 ± 1.7 daily servings
Chee et al. (2017) [22]/ Malaysia	**INT 1: Baseline:** 1665 ± 53 kcal/day **6 months:** 1091 ± 29 kcal/day **INT 2: Baseline:** 1588 ± 40 kcal/day **6 months:** 1130 ± 37 kcal/day	**INT 1: Baseline:** 28.6% **6 months:** 25.6% **INT 2: Baseline:** 28.6% **6 months:** 26.0%	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated
Coppell et al. (2010) [23]/ New Zealand	**Baseline:** 1915.4 ± 453.6 kcal/day **6 months:** 1637.3 ± 422.8 kcal/day	**Baseline:** 30.9 ± 6.1% **6 months:** 28.7 ± 5.3%	**Baseline:** 11.2 ± 3.2% **6 months:** 9.7 ± 2.5%	**Baseline:** 5.2 ± 1.6% **6 months:** 5.6 ± 1.8%	Not evaluated	**Baseline:** 13.5 g/1000 kcal **6 months:** 16.1 g/1000 kcal	Not evaluated	Not evaluated
Glasgow et al. (2006) [24]/ USA	Not evaluated	**Baseline:** 27.6 ± 17.9% **6 months:** 22.4 ± 15.2%	Not evaluated	Not evaluated	Not evaluated	Not evaluated	**Results of Fruit and vegetables together** **Baseline:** 5.5 ± 3.8 daily servings **2 months:** 5.7 ± 4.8 daily servings	

Gutschall et al. (2009) [25]/ USA	**Baseline:** 1780 Kcal/ day **9 weeks:** 1686 kcal/ day	**Baseline:** 38.4% **9 weeks:** 35.9%	**Baseline:** 12.3% **9 weeks:** 11.3%	**Baseline:** 8.6% **9 weeks:** 8.0%	**Baseline:** 14.5% **9 weeks:** 13.7%	**Baseline:** 11 g/1000 kcal **9 weeks:** 13 g/1000 kcal	Not evaluated
Huang et al. (2010) [26]/ Taiwan	**Baseline:** 1899 ± 399.8 Kcal/day **12 months:** 1670 ± 309.2 Kcal/day	**Baseline:** 30.6 ± 6.7% **6 months:** 31.1 ± 7.9%	**Baseline:** 8.7 ± 3.1% **6 months:** 7.7 ± 3.4%	**Baseline:** 10.9 ± 3.0% **6 months:** 10.9 ± 4.5%	**Baseline:** 9.7 ± 3.0% **6 months:** 10.3 ± 3.9%	Not evaluated	Not evaluated
Li et al. (2016) [27]/ China	**Baseline:** 2452 ± 253 kcal/ day **1 month:** 2112 ± 274 kcal/ day	**Baseline:** 37% **1 month:** 22%	Not evaluated	Not evaluated	Not evaluated	**Baseline:** 8.6 g/1000 kcal **1 month:** 14.7 g/1000 kcal	Not evaluated
Liu et al. (2015) [28]/ China	**Baseline:** 1832 ± 322 kcal/ day **12 months:** 1708 ± 170 kcal/ day	**Baseline:** 32.3 ± 6.3% **12 months:** 29.9 ± 5.0%	Not evaluated	Not evaluated	Not evaluated	Not evaluated	Not evaluated

*Median was used for all dietary outcomes

5. Discussion

This study summarizes the effects of nutritional interventions on dietary outcomes in individuals with type 2 diabetes. The main results of this review were:

1) Total energy intake decreased in 89% of studies (8 out of 9 studies).

2) A high percentage of RCTs (64%) had baseline values of total fat intake above 30% of total energy intake. Only in 1 out of 7 studies, nutritional intervention was effective in the reduction of total fat intake to values below 30% of total energy intake.

3) In half RCTs (3 out of 6 studies) that evaluated saturated fat intake, intervention group had baseline values above 10% of total energy intake. On 1 out of 3 studies (33%), nutritional intervention was effective in the significant reduction of saturated fat intake below 10% of total energy intake.

4) Nutritional interventions allowed a significant increase of polyunsaturated fat intake in only 1 out of 5 studies (20%).

5) Nutritional interventions allowed a significant increase of monounsaturated fat intake in

only 1 out of 4 studies (25%).

6) In all 5 RCTs that evaluated fiber intake, intervention group had baseline values below the recommended 14g/1000kcal Nutritional interventions allowed a significant increase of fiber intake in only 1 out of 5 studies (20%).

7) In 3 out of 5 RCT, servings of fruit and vegetables on intervention group are below the recommendations for its intake. No nutritional interventions were effective in the significant increase of servings of fruit and vegetables per day.

5.1. Duration of interventions

Studies presented in this review varied widely in what concerns the duration of interventions, ranging from 1 to 18 hours of intervention and delivered through 7 weeks to 6 months.

Steinsbeck et al. (2012) [30], in a systematic review of self-management education in T2D patients, concluded that interventions held between 6 and 10 months and with 19 to 52h of duration give the best results in self-management skills.

Loveman et al. (2008) [31] adds that longer-interventions with a shorter duration between the end of the intervention and the follow-up evaluation had higher benefits. According to Minet et al. (2010) [32], compact nutritional programs with sessions grouped in a short time span are related to better results in diabetes outcomes.

5.2. Evaluation method

In this review, we found a heterogeneity of dietary assessment methods used: food record; 24-hours dietary recall; food frequency questionnaire and specific questionnaires used for the study. The majority of studies used food records (5 studies) or dietary recalls (4 studies) to assess dietary pattern. Food records provides dietary information by individuals' self-record at the time the food is eaten, reducing dependence on subjects' memory [33]. Besides, no interviewers are required and, thus, no risk of bias is presented [33]. In all studies presented in this review that used this dietary assessment method, a 3-day food record was used. In what concerns 24-hours dietary recall, it is an open-ended survey conducted through an interview, in which people interviewed recall dietary intake information during the last 24 hours. This evaluation method imposed minimal burden to respondents. However, the information is dependent on individuals' memory and i tis of crucial importance the presence of a well-trained interviewer to minimize recall bias [33].

5.3. Methods to provide nutritional intervention

Regarding methods to provide nutritional intervention, in more than half studies (8 out of

13 studies), nutritional intervention was delivered in a group setting. Nutritional interventions of 3 studies were individualized and in 2 studies there existed a mix between group and individual nutritional education sessions. According to ADA [11], nutritional interventions may integrate diabetes education in group or individualized setting. Two meta-analyses [30, 34] showed the benefits of group-based education on self-management skill in comparison with individual education. According to Odgers et al. (2017) [35], nutrition education in a group setting makes it possible discussions about several subjects through patients'interaction. Besides, it allows participants to feel integrated in a group context that have similar difficulties in the management of the same disease.

5.4. Total energy intake

In this review, total energy intake decreased in intervention group in 8 of the 9 studies that examined this dietary outcome. These results are according to recommendation of ADA [11] that stated that overweight individuals with T2D should reduce energy intake, as higher values of total energy intake are associated with insulin resistance in type 2 diabetes patients.

Only in the study of Vasconcelos et al. (2021) [16], there was a small increase in total energy intake on intervention group, despite non-significant results between intervention and control group ($p = 0.056$).

5.5. Total fat intake

According to WHO, to avoid unhealthy weight increase, total fat intake should not exceed than 30% of the total energy intake [10]. Dietary fat may affect glucose tolerance and insulin sensitivity [36]. A high fat content in the diet may result in deterioration of glucose tolerance by several mechanisms including decreased binding of insulin to its receptors, impaired glucose transport, reduced proportion of glycogen synthase and accumulation of stored triglycerides in skeletal muscle [37].

In this review, of the eleven studies that evaluated total fat intake, 7 studies (64%) had baseline values above 30% of total energy intake. On 3 of these 7 studies [23, 27, 28], interventions were effective in the reduction of this macronutrient consumption to values under 30% of total energy intake. However, only in one study [28], significant decrease on total fat intake on intervention group when compared to control group was found ($p < 0.002$). On 4 studies [18, 20, 22, 24], baseline values of total fat intake were already below 30%. In these studies, interventions allowed the maintenance of these values under the upper value recommended by WHO to this macronutriente intake.

5.6. Saturated fat intake

The intake of saturated fats should not reach 10% of total energy intake [10]. Higher

consumption of saturated fatty acids have been associated with higher fasting insulin levels, lower insulin sensitivity [37] and cardiovascular disease in T2D patients [38].

From the 6 studies that evaluated saturated fat intake, half of the studies [16, 18, 26] presented baseline values of this type of fat below 10% of total energy intake. After intervention, saturated fat intake remained below 10% of total energy intake.

On the other 3 studies [17, 23, 25], baseline values of saturated fat intake were above 10% of total energy intake. Only in the study of Coppell et al. (2010) [23], nutritional intervention had efficacy in the decrease of this type of fat below the upper limit of 10% of total energy intake recommended by WHO (2020) [10]. It is also important to highlight that in this RCT, intervention group significantly decreased saturated fat intake compared with control group ($p = 0.006$). Dietary intervention of this study was based on recommendations from Diabetes and Nutrition Study Group of the European Association for the study of Diabetes. One of the recommendations referred that study' participants should reduce their saturated fat intake to less than 10% of the total energy intake, fact that was achieved on intervention group.

5.7. Polyunsaturated fat intake

High consumption of polyunsaturated fats is associated with lower levels of of fasting glucose, trygliceridies and LDL cholesterol [39] and improvements on insulin resistance and insulin secretion capacity [40].

Only 5 from 13 studies of this review evaluated the intake of polyunsaturated fat. The results of nutritional interventions were mixed. Two studies [16, 23] reported an increase on polyunsaturated fat intake. However only in the study of Vasconcelos et al. (2021) [16] it was noticed significant differences between intervention and control group ($p = 0.003$). In this RCT [16], the fact that two contents of nutritional intervention were related to fats and cooking methods could explain the significant increase of polyunsaturated fat intake on intervention group. On the contrary, two studies found a descrease on the consumption of this fatty acid [18, 25] though no significant differences were found between intervention ands control group. In the study of Huang et al. (2010) [26], values of polyunsaturated fat remains the same after nutritional intervention.

5.8. Monounsaturated fat intake

A high intake of monounsaturated fat benefits glycaemic control and cardiovascular risk factors reduction [11].

Only 4 from 13 studies that compose this review evaluated the intake of this type of fat. Like polyunsaturated fat, results were mixed, with increase of monounsaturated fat intake on 2 studies [16, 26] and decrease of its consumption on 2 studies [18, 25]. A fact to emphasize

is that in the study of Gutschall et al. (2009) [25] the decrease of monounsaturated fat intake after nutritional intervention reach significant differences when compared with control group ($p = 0.006$).

5.9. Fiber intake

According to Post et al. (2012) [41], the increase of dietary fibre in the diet of T2D patients leads to a reduction on fasting blood glucose and HbA1c, which is a explained by the the positive association of fibre intake and insulin sensitivity [42].

Regarding fiber intake, from the 5 studies presented in this review, baseline fiber intake values of all studies were below 14g/1000kcal per day. After nutritional intervention, on 3 studies [18, 23, 27], participants achieved the consumption of 14g/1000kcal per day. However, significant increase of fiber intake after nutritional intervention (on intervention group) when compared with control group were only found in the study of Li et al. (2016) [27] ($p < 0.01$). The fact that one of the nutritional education contents was related to the importance of eating vegetables, fruit and whole grains could explain results from this study.

5.10. Servings of fruit and vegetables per day

Higher intake of fruits and vegetables has an inverse association with mortality by cardiovascular diseases, a macrovascular complication of type 2 diabetes and the leading cause of mortality wordlwide [43].

In the 5 studies that evaluated servings of fruit and vegetable per day, in 2 studies [20, 24], its consumption on intervention group was above 5 servings a day at baseline and increased after nutritional intervention. Other 2 studies found the opposite [16, 18], as neither baseline values nor after nutritional intervention values reach the 5 servings a day of fruit and vegetables. In 1 study [21], the intervention group had baseline values of servings of fruit and vegetables per day below 5 servings a day and after intervention this value increased above this recommendation. Despite this relevant increase, results were non significant when compared to control group. Finally, the study of Weinstein et al. (2014) [19] only presented data of servings of fruit per day despite the evaluation of servings of vegetables per day (data not presented). Participants from intervention group followed IDF recommendations for servings of fruit per day. Other important constatation of this study is that after nutritional intervention, intervention group significantly increase fruit consumprion when compared to control group.

5.11. Strengths

As strengths of this review we can refer the compilation of studies from 5 continents with completely distintc dietary habits; presence of only randomized controlled trials; studies that target the most prevalent age of type 2 diabetes.

5.12. Limitations

The main limitations of this review were: the search was made in only one Database, few number of studies that meet the inclusion criteria, heterogeneity of the characetristics of nutritional interventions and heterogeneity of dietary intake assessment methods.

6. Conclusions

In conclusion, this review demonstrates that a high percentagem of patients with type 2 diabetes had Malnutrition, through excess of total fat intake and saturated fat consumption and deficiency of fiber intake and servings of fruit and vegetables per day. In general, nutritional interventions had 1) high efficacy rates in the reduction of total energy intake; 2) low efficacy rates in the reduction of total fat and saturated fat intake; 3) low efficacy rates in the increase of polyunsaturated fat, monounsaturated fat and fiber intake and servings of fruit and vegetables per day.

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