SYSTEMATIC REVIEW/META ANALYSIS

Effect of Low/Very Low-Calorie and Other Special Diets on Anthropometric and Cardio-Metabolic Parameters of Diabetes Mellitus Patients: A Systematic Review and Meta-Analysis

Bhupesh Gupta[1*], Rajdeep Singh[2], Nikita Verma[3], Kirtika Gupta[4], Ginni Datta[5], Anshu Mittal[6]

[1,6]Department of Community Medicine, Maharishi Markandeshwar Institute of Medical Sciences & Research, Haryana, India
[2,4,5]Department of Otorhinolaryngology, Maharishi Markandeshwar Institute of Medical Sciences & Research, Haryana, India
[3]Guru Gobind Singh Medical College, Faridkot, Punjab, Faridkot, India

DOI: 10.55489/njcm.161020255875

ABSTRACT

Introduction and Methodology: This systematic review and meta-analysis, following PRISMA guidelines and registered in PROSPERO (CRD42025645593), searched Embase, Scopus, PubMed, Web of Sciences and Google Scholar for studies on low-calorie or very-low-calorie or other special diets (VLC/KD) in diabetes mellitus (DM) patients.

Results: From 16 RCTs involving 1232 patients, the meta-analysis found reductions with standardised mean difference in weight (-0.59; 95% CI, -1.05: -0.13), waist (-0.72; 95% CI, -1.80: 0.37), BMI (-0.93; 95% CI, -1.56; -0.29), Hba1c (-0.67; 95% CI, -0.94: -0.40), fasting (-0.82; 95% CI, -1.35: -0.29) and post-prandial blood sugar (-0.45; 95% CI, -4.06: 3.16), Total cholesterol (-0.37; 95% CI, -0.76: 0.03), LDL cholesterol (-0.16; 95% CI, -0.45: 0.14), HDL cholesterol (0.19; 95% CI, -0.03: 0.41), systolic blood pressure (-0.55; 95% CI, -0.89: -0.22), and diastolic blood pressure (-0.52; 95% CI, -0.92: -0.13) after a long-term intake of low/very-low calorie or other special diets. High heterogeneity (I^2 >50%) was observed in most outcomes, warranting cautious interpretation.

Conclusions: These results support incorporating high-fibre, low-glycemic index foods and Monounsaturated Fatty Acids (MUFA) over Saturated Fatty Acids in energy-balanced diets for DM management.

Keywords: Non-communicable disease, VLCD, Diabetes mellitus, Cardiovascular disease, Lipid metabolism

ARTICLE INFO

Financial Support: None declared
Conflict of Interest: The authors have declared that no conflict of interests exists.
Received: 01-08-2025, **Accepted**: 09-09-2025, **Published**: 01-10-2025
***Correspondence:** Dr. Bhupesh Gupta (Email: bhupeshgupta1992@gmail.com)

How to cite this article: Gupta B, Singh R, Verma N, Gupta K, Datta G, Mittal A. Effect of Low/Very Low-Calorie and Other Special Diets on Anthropometric and Cardio-Metabolic Parameters of Diabetes Mellitus Patients: A Systematic Review and Meta-Analysis. Natl J Community Med 2025;16(10):1021-1036. DOI: 10.55489/njcm.161020255875

www.njcmindia.com │ pISSN: 0976-3325 │ eISSN: 2229-6816 │ Published by Medsci Publications

INTRODUCTION

Diabetes mellitus (DM) is a leading cause of morbidity and mortality in developed countries.[1] Type II diabetes mellitus (T2DM), which is characterised by insulin resistance (IR) and hyperglycemia, accounts for 90% of all cases of diabetes. The International Diabetes Society guidelines state that, in addition to medication, lifestyle modifications are necessary for the treatment of type 2 diabetes mellitus (T2D).[2]

The undesirable effects and potential risks of pharmaceuticals still cause individuals to pay a significant amount of attention to the efficacy of this therapy, despite the recent advancements in drug therapy. As a result, non-pharmacological therapeutic approaches, like the very low-carbohydrate ketogenic (VLCK) dietary regimen made up of foods high in fat, low in carbohydrates, and moderate in protein, are more often used.[3]

The diet called the ketogenic diet is noted for its high-fat and low-carbohydrate content. By ingesting more calories from fats and less from carbohydrates, a ketogenic diet aims to substitute glucose as the human body's main means of energy generation with ketone bodies created from fat breakdown. According to one participant, improved glycemic control, weight loss, and satiety seemed to outweigh the diet's disadvantages, including the absence of support from a doctor and reliable information sources.[4] The ketogenic diet, which has been demonstrated to lower cholesterol levels, increase fasting glucose and insulin levels, and eliminate or lower the need for diabetic medication, can significantly help patients with diabetes.[1]

Numerous systematic reviews and meta-analyses have looked at the effectiveness of different dietary strategies for obese persons looking to lose weight. While many meta-analyses and literature reviews[5-9] have been conducted on low-carb diets, no research has examined how the low-calorie ketogenic diet and other such specialised diets affect blood sugar regulation, weight, lipid metabolism, neurological disorders, cardiovascular disease risk, or renal disease risk in individuals with pre-diabetes, diabetes mellitus, and obesity. It is therefore unknown if VLC/KD and other such specialised diets are beneficial for glycaemic control, metabolism of lipids, Cardiovascular disorders (CVD) risk, and renal disease risk in these populations.

Similar to LCD/VLCKD, there are other specialised diets also, which claim to improve anthropometric and cardiometabolic parameters in diabetes mellitus patients. One of them is the Mediterranean diet. The eating customs of the people who live surrounding the Mediterranean Sea are referred to as the "Mediterranean diet." It is distinguished by a limited intake of red or processed meats, a moderate intake of dairy products, fish, and red wine, and a high intake of vegetables, fruits, whole grains, legumes, and monounsaturated fatty acids (mostly from olive oil).[10]

It was hypothesized that specialized diets such as low-calorie/very low-calorie diets, or ketogenic or Mediterranean diets, etc., would improve anthropometric and cardiometabolic parameters of diabetes mellitus patients. This review aims to meta-analyse the effects of such diets on HbA1c, body weight, blood glucose, lipids, and blood pressure in DM patients.

METHODOLOGY

The study was listed in PROSPERO (CRD420 25645593). PRISMA standards for meta-analysis and systematic review were followed in the conduct of this study.[11] Table 1 mentions PICOS criteria for study inclusion and exclusion.

Table 1: PICOS Criteria for Inclusion and Exclusion of Studies

Specifications	Inclusion Criteria	Exclusion Criteria
Population	Diabetes Mellitus patients	Non-DM patients
Intervention	Low-calorie or very low-calorie ketogenic or special diets for DM	Regular diets
Comparison	Baseline values	No comparison to baseline
Outcomes	Anthropometric and Cardiometabolic parameters	No Anthropometric and Cardiometabolic parameters
Study Design	Randomized Controlled Trials	Non-RCTs

Eligibility criteria

Inclusion Criteria: The researchers included trials that satisfied the following criteria in their study: (a) they had to be controlled clinical studies or RCTs in English; (b) the participants had to be adults ≥18 years with diabetes mellitus; and (c) the study had to compare the effects of low-calorie (<1200 kcal/day) or very-low-calorie ketogenic meals (<800 kcal/day) or other special diet interventions before and following they initiated with or without conventional treatment.

Exclusion Criteria: (a) Individuals with end-stage illnesses or hospice patients were not the focus of the research. (a) Articles published before 1994, or more than thirty years ago, were likewise not included. (c) Research of an observational type was excluded.

Information sources: To find papers published between 1994 and 2024, we used the PRISMA guidelines and searched databases like Embase, Scopus, PubMed, Web of Science, and Google Scholar.

Search methodology: The English-language papers published between 1994 and 2024 were found using a variety of search phrases in databases, as mentioned in Table 2. In order to find further papers, we also looked through the bibliographies of pertinent articles.

Table 2: Search Strategy and search terms used in various databases

Database	Search Strategy
PubMed	((“low-calorie diet” OR “very low-calorie diet” OR “special diet” OR “VLC/KD” OR “low carbohydrate-high protein diet”) AND (“diabetes mellitus” OR “T2DM”) AND (“metabolic parameters” OR “cardiometabolic parameters”))
Scopus	TITLE-ABS-KEY ((“low-calorie diet” OR “very low-calorie diet” OR “special diet” OR “VLC/KD” OR “low carbohydrate-high protein diet”) AND (“diabetes mellitus” OR “T2DM”) AND (“metabolic parameters” OR “cardiometabolic parameters”))
Web of Science	TS= (“low-calorie diet” OR “very low-calorie diet” OR “special diet” OR “VLC/KD” OR “low carbohydrate-high protein diet”) AND TS= (“diabetes mellitus” OR “T2DM”) AND TS= (“metabolic parameters” OR “cardiometabolic parameters”)
Embase	‘low-calorie diet’ OR ‘very low-calorie diet’ OR ‘special diet’ OR ‘VLC/KD’ OR ‘low carbohydrate-high protein diet’ AND ‘diabetes mellitus' OR 'T2DM’ AND ‘metabolic parameters’ OR ‘cardiometabolic parameters’
Google Scholar	“low-calorie diet” OR “very low-calorie diet” OR “special diet” OR “VLC/KD” OR “low carbohydrate-high protein diet” AND “diabetes mellitus” OR “T2DM” AND “metabolic parameters” OR “cardiometabolic parameters”

Selection procedure: Once the studies were found in the databases, each author independently assessed each one's eligibility. In order to settle any disagreements, the authors held a comprehensive discussion.

Data collection process: Titles and abstracts were used to establish each study's eligibility. To verify their eligibility, the authors then went over all trial materials that were judged eligible or possibly eligible (see Figure 1). Each trial's eligibility was evaluated by paired reviewers, who also collected data on the trial's features and the intervention's effect on results. Conflicts among the reviewers were resolved by discussion or by including a third reviewer. To resolve any ambiguities or obtain any information they required, the authors got in touch with the author of the original study.

Data items and Data Extraction: To handle and maintain citations and expedite the review process, the literature was entered into EndNote (version X9). A standardised form was used to collect the first researcher's label, publishing year, research nation, sample size, and main findings from the retrieved papers (Table 3). Data was extracted using MS Excel, including means, SDs, and sample sizes for pre-/post-intervention. R software was used for forest plots and funnel plots. Before discrepant items were corrected, the total agreement rate was 0.90, which is regarded as nearly perfect according to Cohen's kappa statistic.

Study Quality and Bias Risk: Cochrane's ROB tool 2.0 was used to evaluate the quality of randomised controlled trials. Five criteria are used to evaluate the quality: There is a risk of bias in the following areas: (1) the randomisation process; (2) deviation from targeted interventions; (3) missing outcomes data; (4) the estimation process; and (5) the reporting process. A set of signalling questions is used to assess each domain, and responses are used to determine whether the risk of bias is low, some concerns, or High. Bias is low risk if all domains met criteria and high if ≥1 domain was high risk.

Effect measures: The meta-analysis was performed using standardised mean difference (SMD) and the standard deviation in the physical and cardiometabolic parameters for diabetic individuals from baseline to follow-up. A random effects model was used due to expected heterogeneity from varying diet durations. The effects before and after interventions were compared using standardised mean differences (SMD) with a confidence interval of 95%. The chi-square value and the I^2 statistic were used to evaluate heterogeneity. For data analysis, the statistical software R (version 4.3) was utilised. Significant heterogeneity was defined as pooled analyses with I^2 >50%. For each result, a funnel plot was used to visually evaluate publication bias. To explore heterogeneity, a subgroup analysis was performed according to diet type (low vs. very-low-calorie), duration (<6 vs. ≥6 months), and geography (Continents).

Synthesis methods: When suitable, trial data with no discernible clinical differences were merged into a meta-analysis. The authors used the latest version of R 4.3.0 to aggregate all of the included studies in a random-effects meta-analysis and calculate the standardised mean differences (SMD) and the 95% confidence intervals (CI) of the impact of the intervention estimate. A meta-analysis was conducted for each measurement method and follow-up period because the trial's results were shown as a change in score from benchmarks to follow-up data.

Reporting bias assessment: In order to illustrate publication bias, funnel plots were created. To assess publication bias for continuous variables, Egger's regression analysis for funnel plots (Sterne and Egger, 2006) was employed, whilst the trim and fill technique (Duval and Tweedie, 2000a, 2000b) was only utilised to adjust effect size for missing publications.

RESULTS

Study selection: 843 items were found after applying keywords; 209 were removed for being copies, 65 were removed for being unavailable in languages other than English, and 208 were removed for not meeting the inclusion requirements. 111 papers were judged to be sufficiently outdated (over 30 years) for inclusion in the research, but 39 studies lacked an abstract. 16 publications were chosen by the authors for the meta-analysis after careful evaluation and discussion. The thorough selection process is shown in Figure 1's PRISMA flow chart.

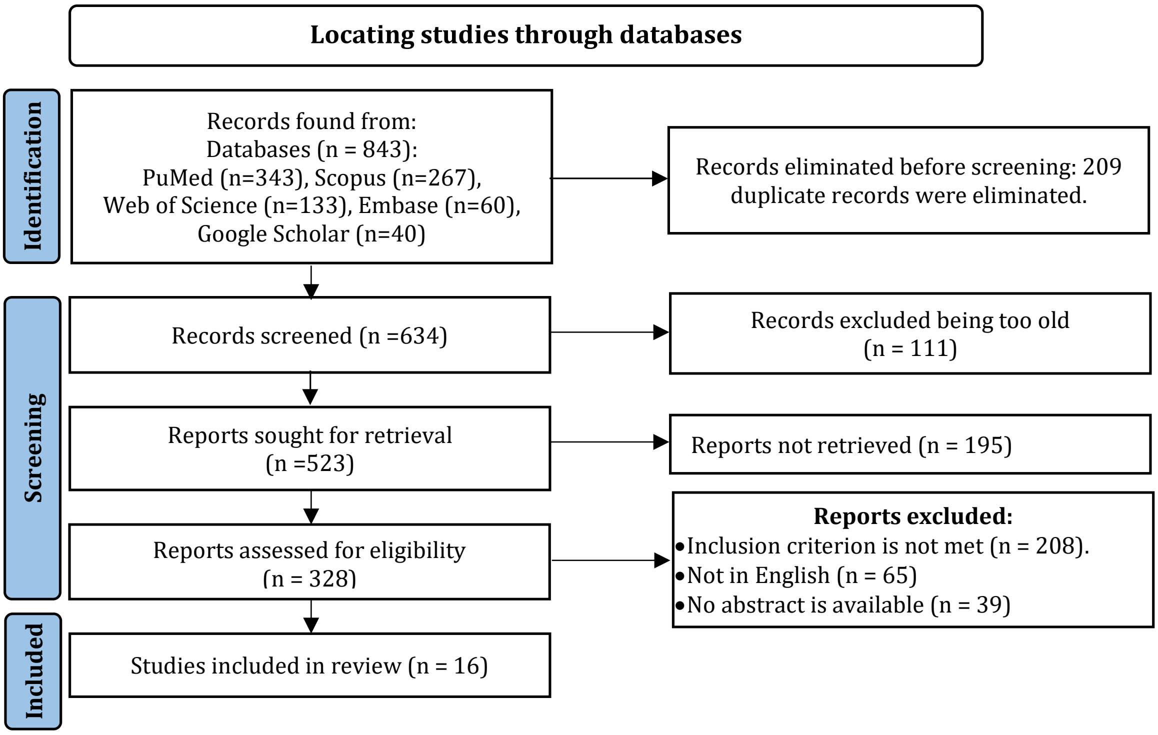

Fig 1: PRISMA Workflow Chart illustrating the process for choosing studies

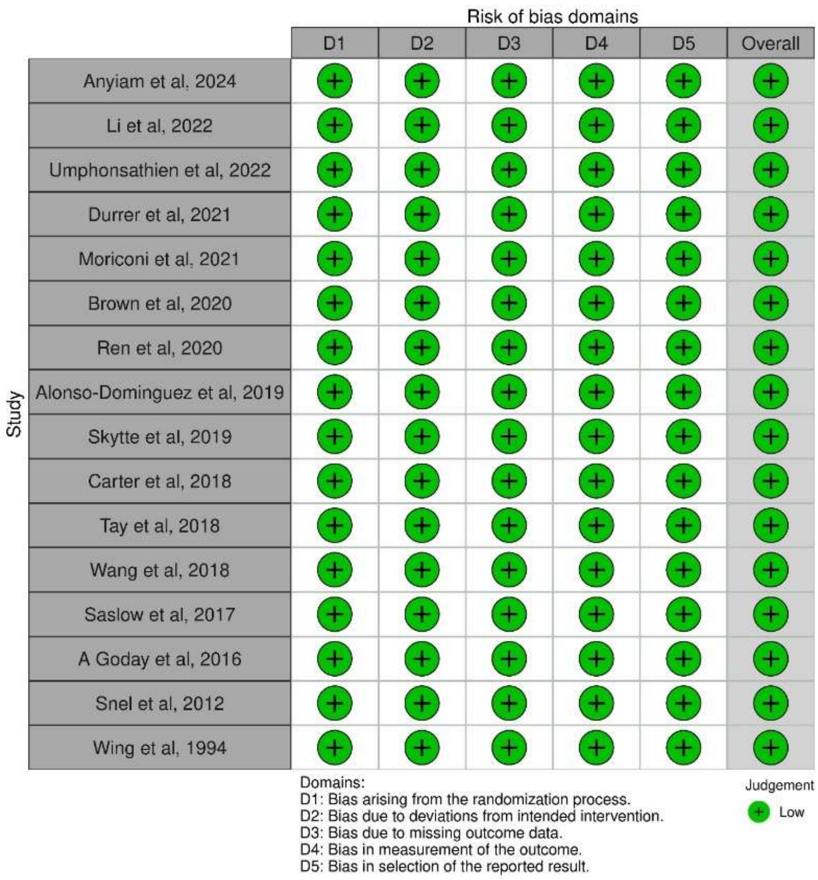

Fig 2: A traffic plot illustrating the possibility of bias evaluation

Study characteristics: In the meta-analyses, 1232 In sixteen randomised controlled trials, people with Type 2 diabetes were evaluated. Most of the research was conducted in China (n=3). Conversely, the remaining investigations were conducted in the following countries: Australia (n = 2), Spain (n = 2), the Kingdom of England (n = 2), the United States of America (n = 2), Canada (n = 1), Denmark (n = 1), Italy (n = 1), the Netherlands (n = 1), and Thailand (n=1).

Table 3: Features of the research included

Author and year of publication	Country, total sample size and type of study	Intervention Duration and Diet calories (kcal/day)	Macros in Intervention Diet	Major findings
Anyiam et al,[12] 2024	United Kingdom, 30, RCT	12 weeks, 800	-	Semaglutide plus VLCD promoted more weight loss than semaglutide by itself.
Li et al,[13] 2022	China, 60, RCT	12 weeks, 1500±50	carbohydrate 30-50 g, protein 60 g, fat 130 g	A regular ketogenic diet can help people with type 2 diabetes who are overweight or obese maintain their body weight as well as their blood sugar and cholesterol levels.
Umphonsathien et al,[14] 2022	Thailand, 40, RCT	20 weeks, 600	55% carbohydrate, 15% protein and 30% fat.	Achieving ideal glycaemic control was made possible by the Intermittent Very Low-Calorie Diet. Intermittent VLCD for two days per week and four days per week had comparable benefits on diabetic remission.
Durrer et al,[15] 2021	Canada, 188, RCT	12 weeks, 850-1100	<50 g carbohydrates, ~35-45 g fat, and ~110-120 g protein	Through total medication cessation and a lower medication effect score than TAU, the low-carbohydrate-energy-restricted diet treatment was successful in lowering the requirement for glucose-lowering drugs. These decreases happened at the same time that anthropometrics, blood pressure, lipids, and haemoglobin A1C all showed clinically significant improvements.
Moriconi et al,[16] 2021	Italy, 30, RCT	12 months, 800	-	The study demonstrates the beneficial therapeutic impact of a very low-calorie ketogenic meal plan in the long-term treatment of Type 2 diabetes mellitus and obesity.
Brown et al,[17] 2020	United Kingdom, 90, RCT	12 months, 800	57% carbohydrate, 14% fat, 26% protein and 3% fibre	A low-calorie Whole Diet Substitution intervention helped patients with severe type 2 diabetes as well as obesity.
Ren et al,[18] 2020	China, 45, RCT	3 months, 1686.34	Carbohydrate 40%, Proteins 38%, Fats 22%	A Low-Calorie Diet could exert a beneficial effect on depression and glycometabolism in patients with T2DM.
Alonso-Dominguez et al,[10] 2019	Spain, 204, RCT	12 months	Mediterranean diet: Vegetables, monounsaturated fatty acids (mainly from olive oil), fruits, whole grains, legumes and fish; moderate consumption of dairy products, fish and red wine; and low consumption of red or processed meats	Improvements in postprandial glucose, waist circumference, and BMI were noted at the 3-month follow-up visit in comparison to the baseline visit, but there were no appreciable changes in the use of antidiabetic medications.
Skytte et al,[19] 2019	Denmark, 28, RCT	6 weeks	30 E% carbohydrate, 30 E% protein and 40 E% fat	During six weeks of food availability and stable body weight settings, a high-protein, low-carb diet reduced hepatic and pancreatic lipid levels and increased glycaemic control in persons with type 2 diabetes under control.
Carter et al,[20] 2018	Australia, 137, RCT	12 months, 500-600	Minimum of 50 g of protein per day	For individuals with type 2 diabetes, intermittent calorie restriction is a comparable alternative diet plan to constant calorie restriction in terms of lowering HbA1c.
Tay et al,[21]	Australia, 115, RCT	104 weeks, 1357-	14% carbohydrate (< 50 g/day), 28%	With no negative effects on the kidneys, the low-calorie diet maintained higher

Author and year of publication	Country, total sample size and type of study	Intervention Duration and Diet calories (kcal/day)	Macros in Intervention Diet	Major findings
2018		2143	protein and 58% total fat (35% monounsaturated fat and 13% polyunsaturated fat)	reductions in the need for diabetes medication and improvements in blood lipid profile and diurnal blood glucose stability, indicating better T2D management.
Wang et al,[22] 2018	China, 56, RCT	3 months, 1796	39% carbohydrate, 19 % protein and 42 % fat	For Chinese individuals with type 2 diabetes, a low-calorie diet may increase blood glucose levels in addition to a low-fat diet. In individuals with type 2 diabetes, it can also lower BMI, control blood lipids, and lower insulin dosage.
Saslow et al,[23] 2017	USA, 25, RCT	32 weeks, 1768	163g carbohydrate, 83g protein and 77g fat	Randomisation into a very low-carb keto diet and lifestyle program via the internet instead of a traditional, low-fat diabetes diet program resulted in improved glycaemic control and more weight loss for those with type 2 diabetes.
A Goday et al,[24] 2016	Spain, 89, RCT	4 months, 600-800	Carbohydrates <50 g and lipids 10 g, proteins between 0.8 and 1.2 g per kg of ideal body weight	Patients with type 2 diabetes can safely and well tolerate a normal hypocaloric diet, but the intervention weight loss program using a very low-calorie Ketogenic eating plan is more efficient in lowering their body weight and maintaining glycaemic control.
Snel et al,[25] 2012	Netherlands, 27, RCT	16 weeks, 450	50g protein, 50-60g carbohydrate, 7-9 g lipid, and 10g of dietary fiber	More fat is lost when exercise is added to a 16-week VLCD.
Wing et al,[26] 1994	USA, 93, RCT	50 weeks, 400-500		Although glycaemic control and weight loss were enhanced by intermittent VLCD, these benefits were quite minor and do not seem to support the practical application of intermittent VLCD.

The earliest and newest papers were those published in 1994 and 2024, respectively. According to Cochrane's ROB 2.0 regulations, the quality of each study was evaluated and classified as "Low," "Medium," or "High." The specifics of the investigations that appear on the list are given in Table 3.

Evaluation of study quality: As illustrated in Figure 2, every included study showed a low risk of bias based on Cochrane's Risk of Bias tool 2.0. There were five domains, as the image illustrates, and each study had a minimal risk of bias.

Synthesis and individual study results: Each analysis's standardised mean difference is shown by the total length of the line over the black square, which shows the 95% confidence interval. The impact of low-calorie or very low-calorie special diets on the cardio-metabolic parameters of diabetic patients is depicted by the rhombus. For forest plots, see Figure 3-13.

The study found that the Body weight of patients after intervention was reduced with a significant standardised mean difference of -0.59 (95%CI: -1.05; -0.13, p<0.01, I^2 =77%) (Fig.3)(Fig 5)

The study found that the waists of patients after intervention were reduced with a significant standardised mean difference of -0.72 (95%CI: -1.80; -0.37, p<0.01, I^2 =92%). (Fig 4)

The study found that the BMI of patients after intervention was reduced with a significant standardised mean difference of -0.93 (95%CI: -1.56; -0.29, p<0.01, I^2 =88%).

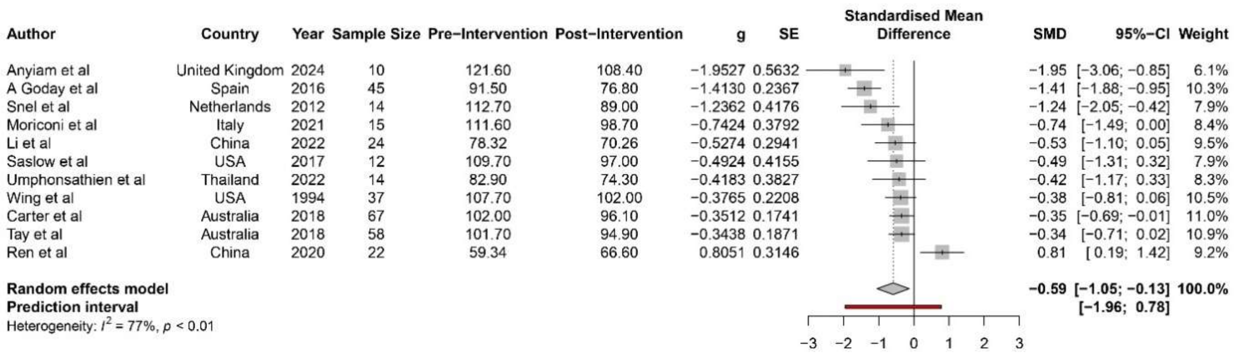

Fig 3: Effect of Low/Very Low-Calorie and Special Diet on Body Weight of Diabetes Patients

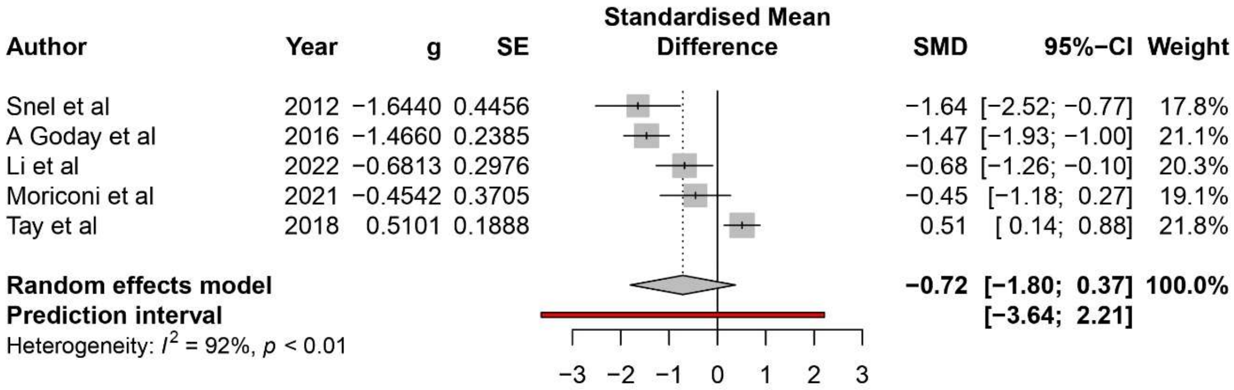

Fig 4: Impact of a Special and Low/Very Low-Calorie Diet on Diabetes Patients' Waists

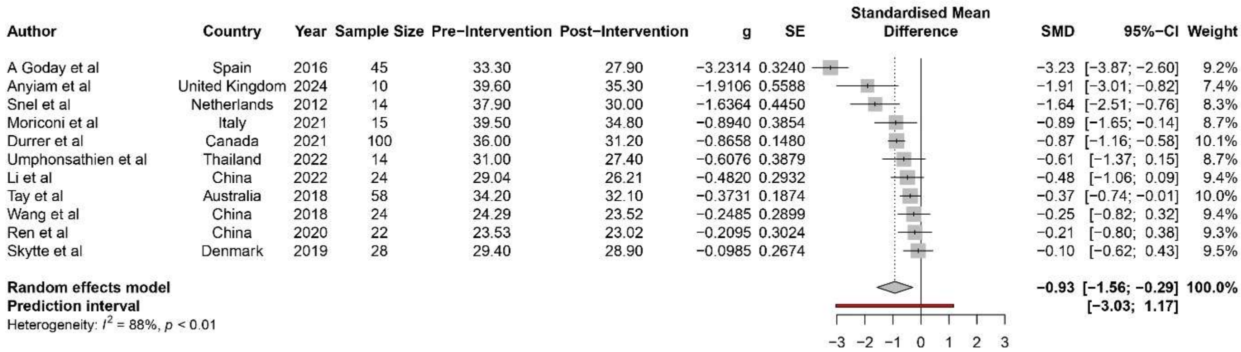

Fig 5: Impact of a Special and Low/Very Low-Calorie Diet on Diabetes Patients' BMI

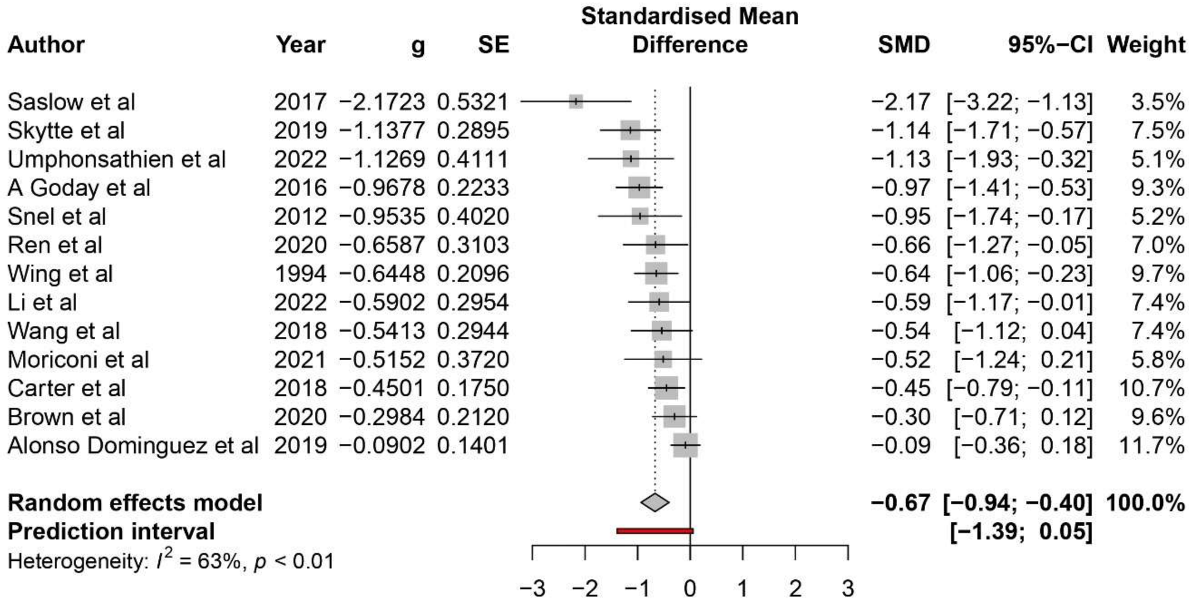

Fig 6: Impact of a special and Low/Very Low-Calorie Diet on Diabetes Patients' HBA1C

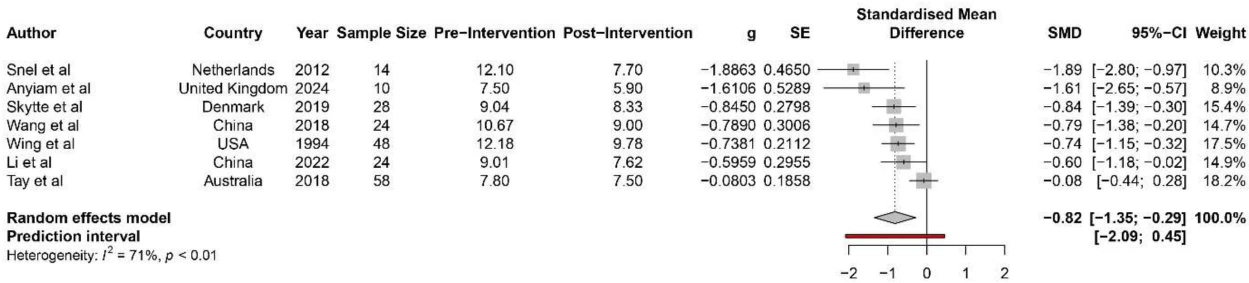

Fig 7: The impact of a Low/Very Low-Calorie and special eating plan on diabetic patients' fasting blood sugar levels

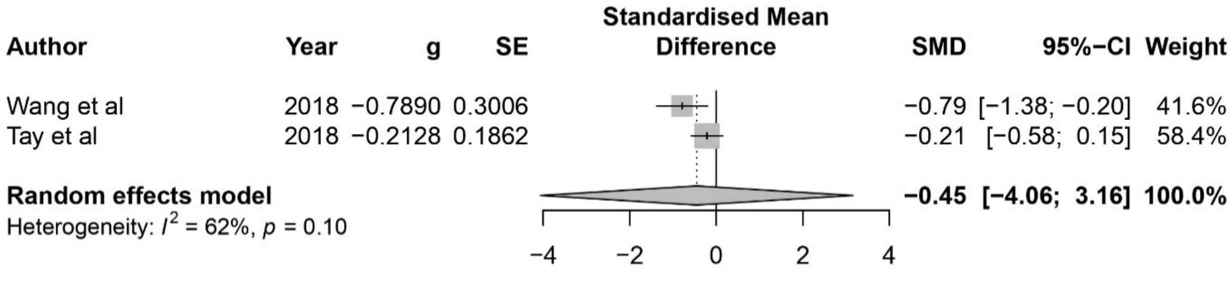

Fig 8: Impact of Special and Low/Very Low-Calorie Diets on Diabetes Patients' Postprandial Blood Sugar

The study found that the HbA1c of patients after intervention was reduced with a significant standardised mean difference of -0.67 (95%CI: -0.94; -0.40, p<0.01, I^2 =63%). (Fig 6)

The study found that the fasting blood sugar levels of patients after intervention were reduced with a significant standardised mean difference of -0.82 (95%CI: -1.35; -0.29, p<0.01, I^2 =71%). (Fig 7)

The study found that the post-prandial blood sugar levels of patients after intervention were reduced with a non-significant standardised mean difference of -0.45 (95%CI: -4.06; 3.16, p=0.1, I^2 =62%). The range of the confidence interval is high due to a smaller number of studies found for the required forest plot. (Fig 8)

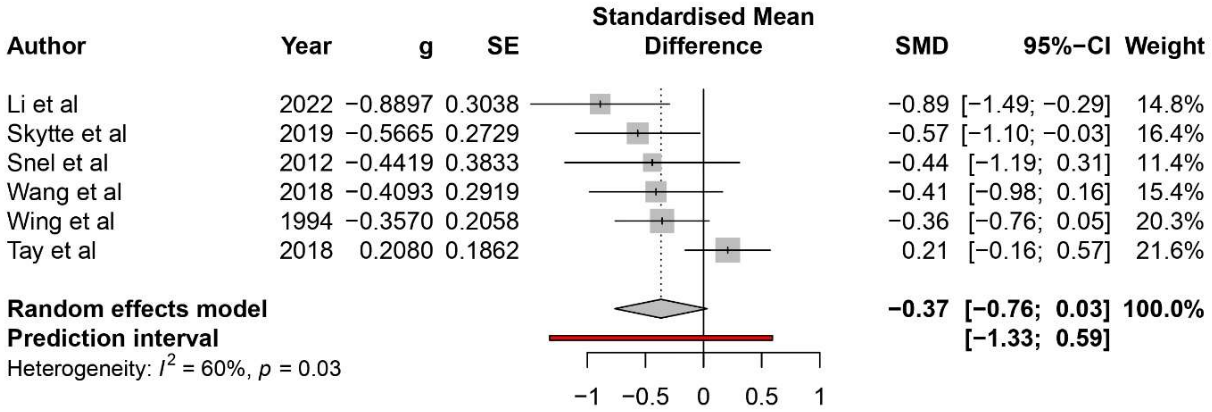

Fig 9: Impact of a Special and Low/Very Low-Calorie Diet on Diabetes Patients' Total Cholesterol Levels

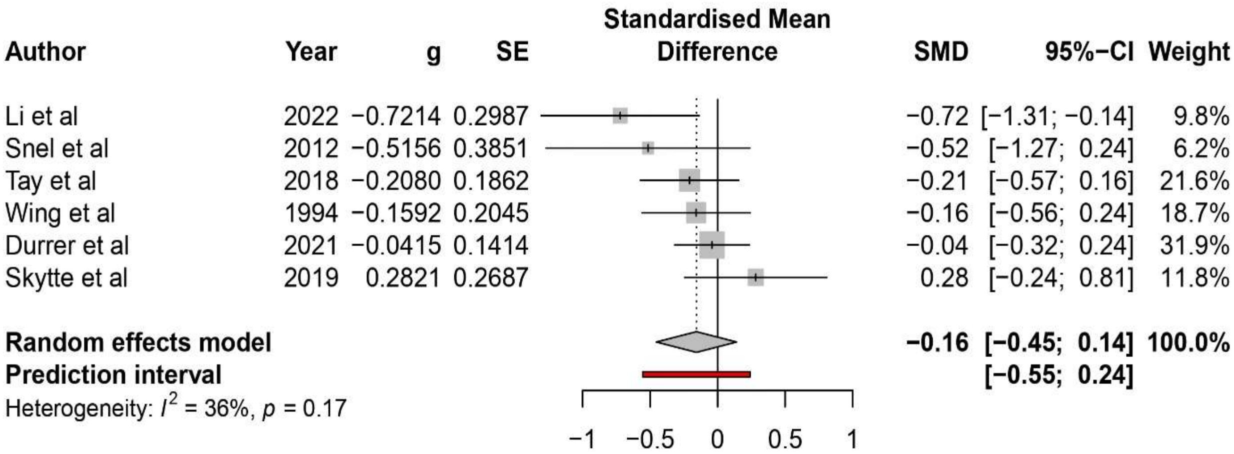

Fig 10: Effect of Low/Very Low-Calorie and Special Diets on LDL Cholesterol Levels of Diabetes Patients

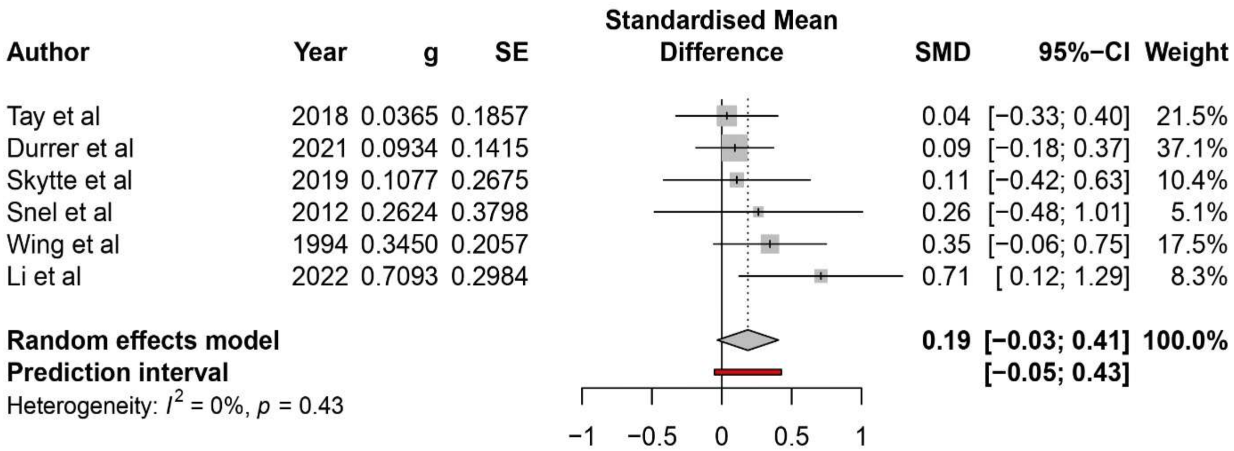

Fig 11: Effect of Low/Very Low-Calorie and Special Diet on HDL Cholesterol Levels of Diabetes Patients

The study found that the total cholesterol levels of patients after intervention were reduced with a non-significant standardised mean difference of -0.37 (95%CI: -0.76; 0.03, p=0.03, I^2 =60%) (Fig 9).

The study found that the LDL cholesterol levels of patients after intervention were reduced with a non-significant standardised mean difference of -0.16 (95%CI: -0.45; 0.14, p=0.17, I^2 =36%) (Fig 10).

The study found that the HDL cholesterol levels of patients after intervention were improved with a non-significant standardised mean difference of 0.19 (95%CI: -0.03; 0.41, p=0.43, I^2 =0%) (Fig 11).

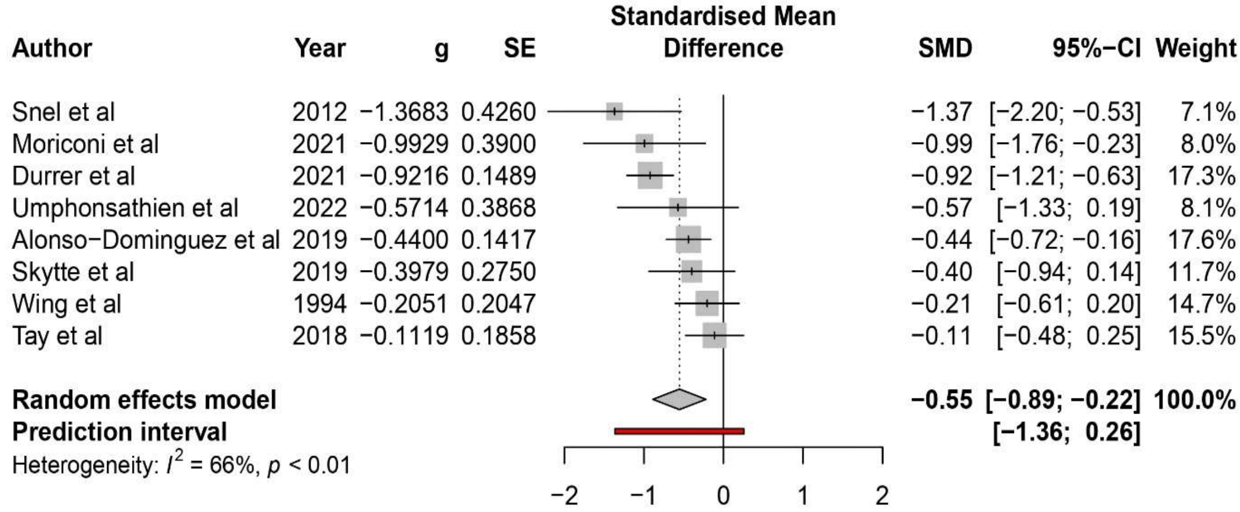

Fig 12: Effect of Low/Very Low-Calorie and special diet on Systolic Blood Pressure of Diabetes patients

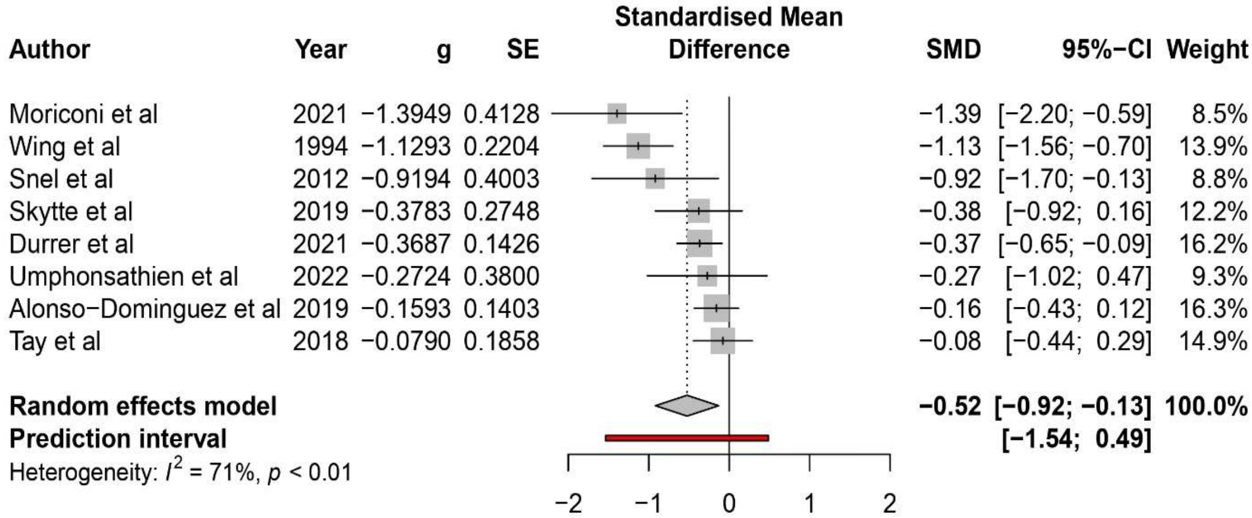

Fig 13: Effect of Low/Very Low-Calorie and special diet on Diastolic Blood Pressure of Diabetes patients

The study found that the Systolic Blood Pressure levels of patients after intervention were reduced with a significant standardised mean difference of -0.55 (95%CI: -0.89; -0.22, p<0.01, I^2 =66%) (Fig 12).

The study found that the Diastolic Blood Pressure levels of patients after intervention were reduced with a significant standardised mean difference of -0.52 (95%CI: -0.92; -0.13, p<0.01, I^2 =71%) (Fig 13).

No studies reported serious adverse effects, but 6 studies noted mild adverse effects such as constipation, hypoglycemia, asthenia, muscular weakness, and postural hypotension, which all resolved after termination of intervention.[12,15,17,20,24,26]

Reporting biases: The funnel plots, as shown in Figure 8, were found to be symmetrical, which indicates the absence of any publication bias. Egger's Regression test for the effect of intervention on weight found the Bias estimate to be -1.5553 (SE = 1.9097) with p-value = 0.4364. Similarly, there was no bias in Egger's regression test for the other mentioned parameters in the given funnel plots.

Sub-group Analysis: Sub-group analysis was performed to explore heterogeneity sources by diet type (low vs. very-low-calorie), duration (<6 vs. ≥6 months), and geography (Continent type) as shown in Figures 15, 16, and 17. The study found that VLCKD had more reduction in weight (-0.93 [-1.32; -0.55]) as compared to LCD (-0.11 [-0.62; 0.40]). However, it was found that patients undergoing the dietary intervention for less than 6 months showed a higher reduction in weight (-0.75 [-1.52; 0.01]) as compared to more than 6 months (-0.39 [-0.59; -0.19]). Sub-group analysis found the highest effect on weight in the European subcontinent (-1.29 [-1.65; -0.93]) and lowest in the Asian subcontinent (-0.04 [-0.89; 0.81]) after intervention.

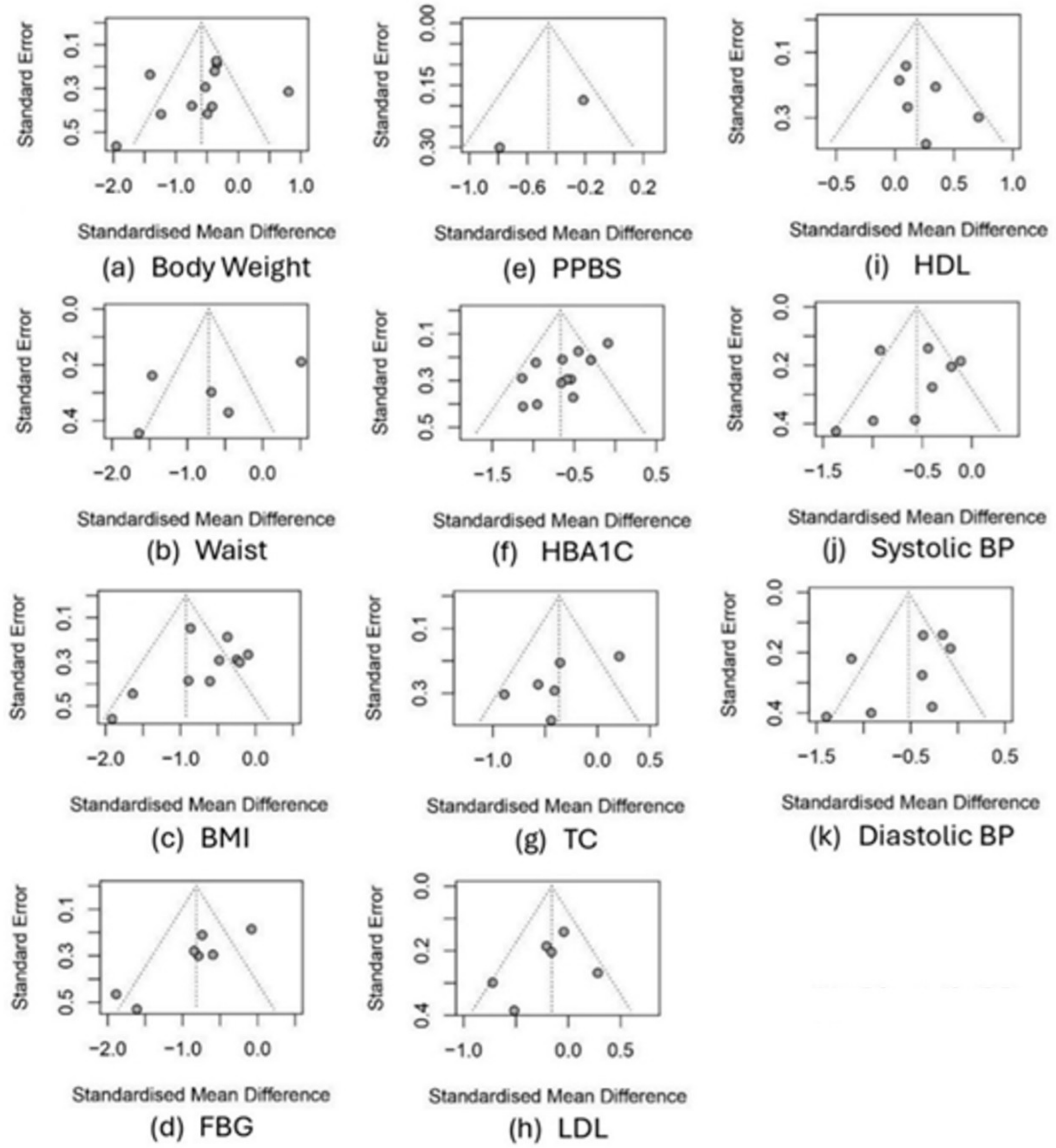

Fig 14: Funnel chart illustrating how a low-calorie and special diet affects diabetes patients' weight (a), the waist (b), body mass index (c), HBA1C levels (d), fasting blood sugar levels (e), postprandial glucose levels (f), total cholesterol levels (g), LDL cholesterol level (h), HDL cholesterol level (i), systolic blood pressure (j), and diastolic blood pressure (k).

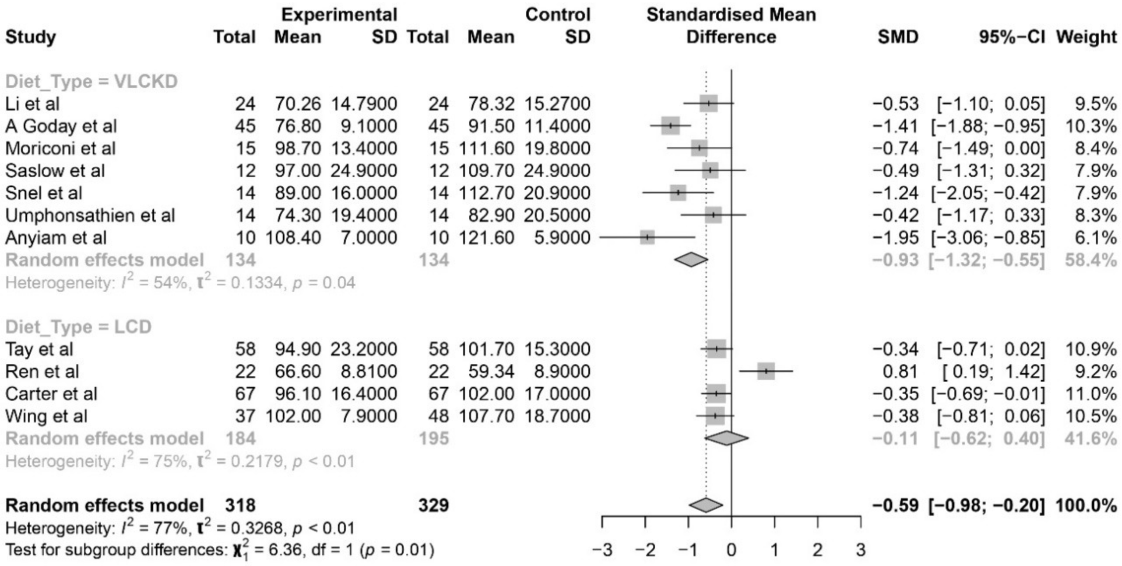

Fig 15: Sub-group analysis of the Effect of LCD/VLCD and special diet on Weight according to Diet Type

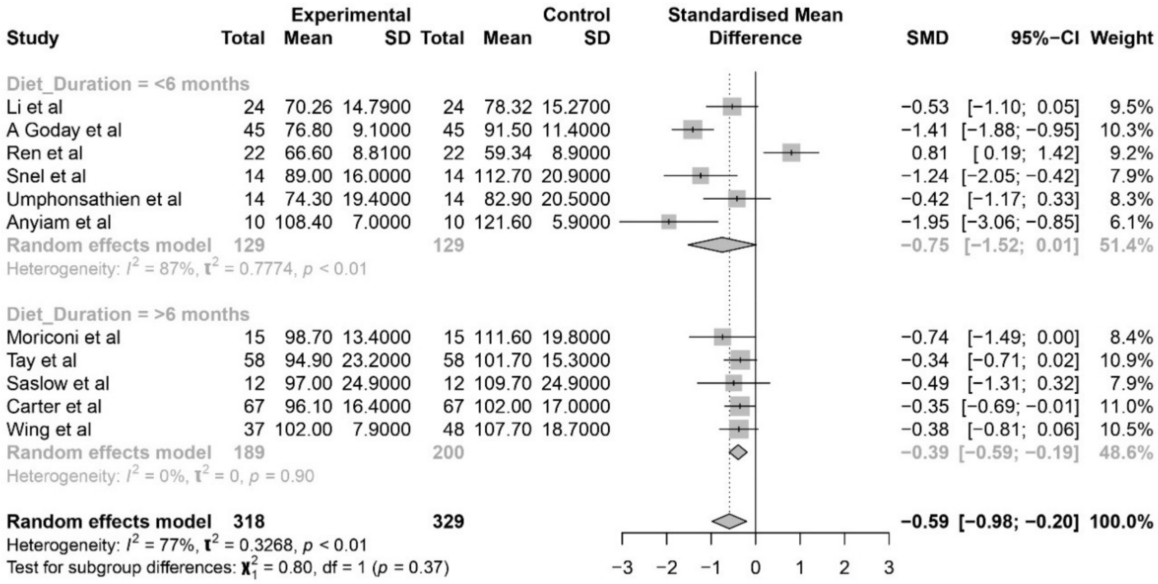

Fig 16: Sub-group analysis of the Effect of LCD/VLCD special diet on Weight according to Diet Duration

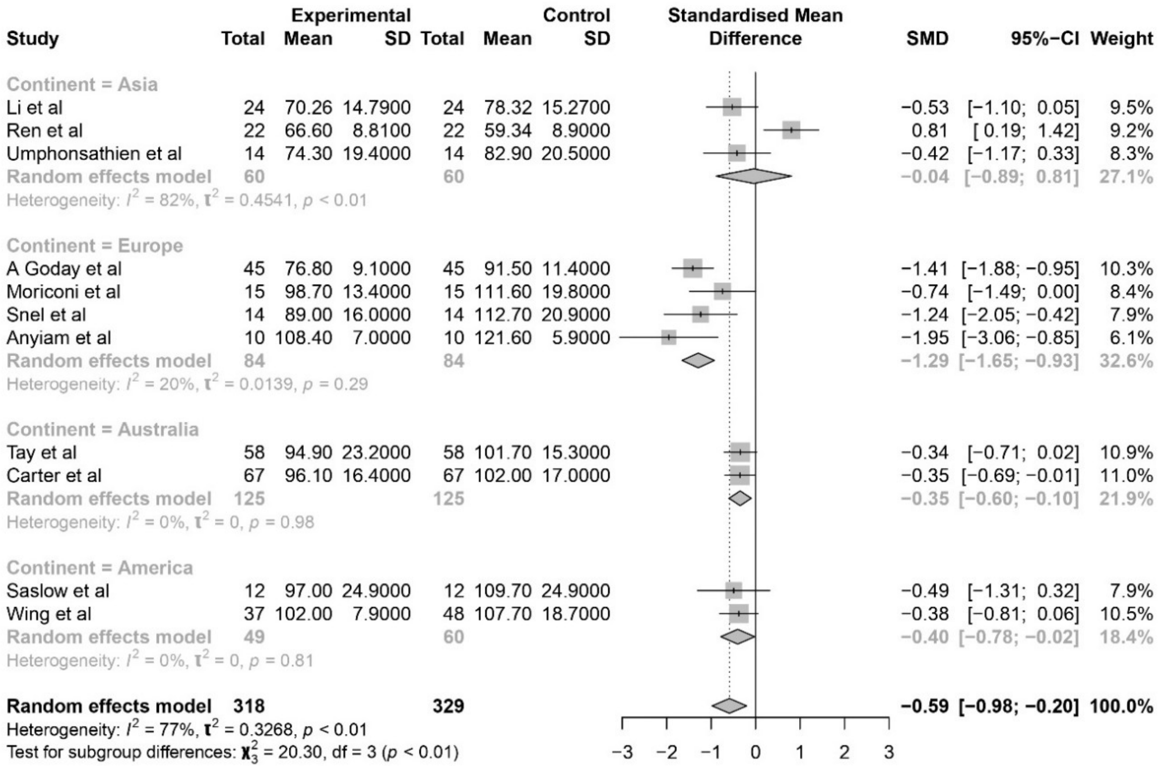

Fig 17: Sub-group analysis of the Effect of LCD/VLCD special diet on Weight according to Continents

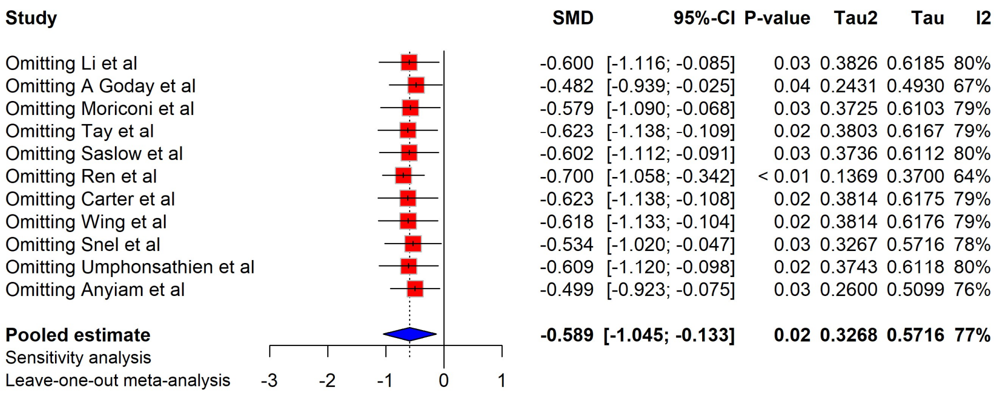

Fig 18: Sensitivity analysis of Effect of LCD/VLCD special diet on Weight using Leave-one-out method

Sensitivity Analysis: Sensitivity analysis was performed using the Leave-one-out method as shown in Figure 18. The results showed that eliminating every study did not significantly alter the conclusions.

Discussion

The beneficial effects of low-calorie as well as special diets on the cardio-metabolic variables of people with diabetes mellitus were thoroughly examined. Results from 1232 participants and 16 publications showed that LCD/VLCD and other specialised diets improved the general health of diabetics.

According to research conducted by Alarim et al., a ketogenic diet is better than placebos at controlling blood sugar levels and altering lipid profiles. The findings are strong enough to support the diet as an additional treatment for type 2 diabetes.[1]

Freshly identified overweight or obese individuals with type 2 diabetes might profit from weight loss while achieving short-term, sufficient blood sugar control without medication, according to research conducted by Raksa Karolina et al.[2] The keto diet may control blood sugar and lipid levels in the blood in addition to weight in persons with overweight or obese T2DM. On this diet, diabetic patients should be regularly watched by a physician, who should also be able to adjust their medication as needed.[3]

Participants in the study by Wong et al. reported benefits of the diet, such as improved glucose management, decreased weight, and satiety, which appeared to outweigh drawbacks, such as a lack of sources of information and support from a health care professional.[4]

Our SMD -0.67 for HbA1c aligns with Sainsbury et al.[7] but focuses specifically on ketogenic variants. According to Li et al., people who have overweight or obese type 2 diabetes may be able to control their weight, blood sugar, and lipid levels in their blood by following a phased-ketogenic diet. But maintaining tenacity over the long run is hard.[13]

An LCD considerably reduced depression and HbA1c, according to Ren et al. Meanwhile, Roseburia, Ruminococcus, and Eubacterium, bacteria that produce short-chain fatty acids (SCFA), greatly increased in response to a-LCD. The GLP-1 level was higher in the a-LCD category compared to the LFD arm. In T2DM patients, an A-LCD may benefit depression and glycometabolism. According to the author, the impact of a-LCD in alleviating depression in people with T2DM may be connected to how it stimulates SCFA synthesis and GPR43 activation, further maintains GLP-1 secretion, and encourages the development of bacteria that create SCFA.[18]

In their investigation, Tay et al. found that the LC maintained higher drops in the quantity of diabetic medicine needed, rises in lipid levels in the blood, and diurnal blood sugar balance, and no adverse renal effects, indicating improved T2D therapy optimization.[21] In 12-month research by Saslow et al., people with high weight and HbA1c levels who were put on an LCK diet saw better weight loss, HbA1c reductions, and medication cessation.[23]

In their study, Goday et al. discovered that a VLCK diet-based interventional weight-loss programme is safer and more tolerable for T2DM patients than a typical hypocaloric diet to decrease body weight and improve glycaemic control.[24] According to Dashti et al., LCKD lowers the need for insulin and oral antidiabetic medications in people with type 2 diabetes. [27]

According to studies by Rafiullah M. et al., the VLCK diet seems to reduce body weight and regulate glycemia in individuals with diabetes and obesity for a maximum period of six months.[28] The VLCK group continued to benefit from decreased blood triglyceride and high-density lipoprotein cholesterol levels for a full year. Additionally, they took fewer diabetes drugs.[28]

After 4 months of transitioning to KD paired with IF, Lichtash C et al. found that she was able to achieve glycaemic control off of medication, with a HbA1c of 6.4. Starting with 24 hours three times a week, workweeks would progress to 42 hours three times a week, 42 hours twice a week, and finally 16 hours once a week. The continuation phase started eight months later. IF was lowered to 16 hours per day, with 24 hours happening three times per month, and metformin was reinstated. At 14 months, the body mass index remained barely altered, and the HbA1c level remained 5.8%. [29]

According to Suzanne Schneider et al, it makes sense that some of these people could profit from a lower-carbohydrate diet, given the substantial role that hyperglycemia plays in the aetiology of CKD. It is challenging for clinicians to offer risk analyses and advice due to the lack of consensus regarding isocaloric comparisons that suggest a certain carbohydrate diet for people with type 1 diabetes (T1D). [30]

According to Zhou et al.'s research, the ketogenic diet could represent a promising nutritional strategy for helping overweight people with type 2 diabetes maintain their body weight and manage their blood sugar levels while also improving their lipid levels. To treat T2DM in overweight patients, a ketogenic diet might be advised.[31]

Versha et al. claim that the low-carb ketogenic eating regimen has shown some preliminary promise in the treatment of Type 2 diabetes.[32] In their study, S. Kumar et al. discovered that the KD controls insulin and glucose levels, making it a viable diabetic treatment option. KD can therefore also serve as proof of a therapeutic gap between obesity and diabetes.[33]

The Choi YJ et al. study found that ketogenic diets were better than a low-fat diet at managing metabolic parameters related to weight, lipid, and glycaemic management in overweight and obese individuals, particularly in those with pre-existing diabetes.[34]

In their study, Myette-Côté É et al. found that an LC diet increased fasting proinsulin levels and improved 4-day glycaemic management compared to GL, with additional benefits in decreasing blood sugar when LC was paired with post-meal walking.[35]

Lee Y-M et al. discovered that both diets reduced HbA1c levels; however, the vegan diet had superior glycaemic management than the traditional diet. Therefore, a vegan diet should be included in the dietary recommendations for T2D patients for better control and therapy.[36]

The results of a study by Vitale et al. support the idea that the synergy between different nutrients and foods in the Mediterranean diet, rather than on any one of its components, is what gives the diet its positive health effects and makes it a good model for type 2 diabetes. [37]

In their study, Gardner CD et al. discovered that although the WFKD had a bigger reduction in triglycerides, it was less maintainable and had unfavourable effects due to increased LDL cholesterol and decreased nutritional intakes from excluding fruits, legumes, and whole, intact grains.[38]

The study found the majority of research articles were from Asian/Western countries; however, there was limited data found from Africa/South America. VLC/KD and other such diets may reduce medication needs, but require monitoring for hypokalemia, constipation, hypotension, and other such mild effects along with them.

Limitations

The meta-analysis had certain limitations, including high heterogeneity in certain factors, which may be due to varying compliance or co-interventions. Future studies need standardized monitoring to avoid this. Certain other limitations include a smaller number of studies in some parameters, like post-prandial glucose levels (n=2), which occurred due to the lesser availability of articles on the concerned topic. English-only studies may introduce language bias.

Conclusion and Recommendations

These results highlight the need to emphasise the significance of higher fibre foods with a low glycemic index, like legumes, vegetables, and fruits, and entire grain cereals, as well as the replacement of monounsaturated fat sources for the consumption of saturated fat sources of information, in energy-balanced conditions, among individuals with diabetes. The study recommends long-term RCTs (>1 year), which are needed to assess sustainability and renal safety in diabetes patients with the discussed interventions.

Authority for Registration: PROSPERO registered this study (CRD42025645593).

Individual Authors' Contributions: **BG**, **NV**, and **KG**: the article's idea, layout, and typological reasoning. **BG**, **GD**, and **KG**: data collection and literature selection. **BG**, **KG**, and **AM**: data interpretation and analysis; article editing. **BG**, **GD**, and **KG**: supervision of the study and paper revision. The submitted version of the article was approved by all authors who contributed to it.

Availability of Data: Available on reasonable request to the corresponding author.

Declaration of Non-use of Generative AI Tools: The authors affirm that no generative artificial intelligence tools were utilized in the design, analysis, interpretation of data, or preparation of this manuscript. All content is the result of the authors' original work.

References

1. Alarim RA, Alasmre FA, Alotaibi HA, Alshehri MA, Hussain SA. Effects of the Ketogenic Diet on Glycemic Control in Diabetic Patients: Meta-Analysis of Clinical Trials. Cureus. 2020 Oct 5;12(10):e10796. DOI: https://doi.org/10.7759/cureus.10796 PMid:33163300 PMCid:PMC7641470
2. Raksa Karolina, Pawlina Mateusz, Ziętara Karolina, Lewkowicz Martyna, Nowakowska Katarzyna, Raczkiewicz Przemysław. The ketogenic diet in the treatment of diabetes type 2. Journal of Education, Health and Sport. 2022;12(7):92-98. DOI: https://doi.org/10.12775/JEHS.2022.12.07.009
3. Tinguely D, Gross J, Kosinski C. Efficacy of Ketogenic Diets on Type 2 Diabetes: a Systematic Review. Curr Diab Rep. 2021 Aug 27;21(9):32. DOI: https://doi.org/10.1007/s11892-021-01399-z PMid:34448957 PMCid:PMC8397683
4. Wong K, Raffray M, Roy-Fleming A, Blunden S, Brazeau AS. Ketogenic Diet as a Normal Way of Eating in Adults With Type 1 and Type 2 Diabetes: A Qualitative Study. Can J Diabetes. 2021 Mar;45(2):137-143.e1. DOI: https://doi.org/10.1016/j.jcjd.2020.06.016 PMid:33039330
5. Huntriss R, Campbell M, Bedwell C. The interpretation and effect of a low-carbohydrate diet in the management of type 2 diabetes: a systematic review and meta-analysis of randomised controlled trials. Eur J Clin Nutr. 2018;72(3):311-325. DOI: https://doi.org/10.1038/s41430-017-0019-4
6. Van Zuuren EJ, Fedorowicz Z, Kuijpers T, Pijl H. Effects of low-carbohydrate- compared with low-fat-diet interventions on metabolic control in people with type 2 diabetes: a systematic review including GRADE assessments. Am J Clin Nutr. 2018;108(2):300-331. DOI: https://doi.org/10.1093/ajcn/nqy096 PMid:30007275
7. Sainsbury E, Kizirian NV, Partridge SR, Gill T, Colagiuri S, Gibson AA. Effect of dietary carbohydrate restriction on glycemic control in adults with diabetes: A systematic review and meta-analysis. Diabetes Res Clin Pract. 2018 May;139:239-252. DOI: https://doi.org/10.1016/j.diabres.2018.02.026
8. Snorgaard O, Poulsen GM, Andersen HK, Astrup A. Systematic review and meta-analysis of dietary carbohydrate restriction in patients with type 2 diabetes. BMJ Open Diabetes Res Care. 2017;5(1):e000354. DOI: https://doi.org/10.1136/bmjdrc-2016-000354 PMid:28316796 PMCid:PMC5337734
9. Singh M, Hung ES, Cullum A, et al. Lower-carbohydrate diets for adults with type 2 diabetes. Br J Nutr. 2021;127(9):1352-1357. DOI: https://doi.org/10.1017/S0007114521002373 PMid:34719409
10. Alonso-Domínguez R, García-Ortiz L, Patino-Alonso MC, Sánchez-Aguadero N, Gómez-Marcos MA, Recio-Rodríguez JI.

Effectiveness of a multifactorial intervention in increasing adherence to the Mediterranean diet among patients with diabetes mellitus type 2: a controlled and randomized study (EMID study). Nutrients. 2019 Jan 14;11(1):162. DOI: https://doi.org/10.3390/nu11010162 PMid:30646500

11. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021 Mar 29;372:n71. DOI: https://doi.org/10.1136/bmj.n71 PMid:33782057

12. Anyiam O, Phillips B, Quinn K, Wilkinson D, Smith K, Atherton P, Idris I. Metabolic effects of very-low-calorie diet, Semaglutide, or combination of the two, in individuals with type 2 diabetes mellitus. Clinical Nutrition. 2024 Aug 1;43(8):1907-1913. DOI: https://doi.org/10.1016/j.clnu.2024.06.034

13. Li S, Lin G, Chen J, Chen Z, Xu F, Zhu F, Zhang J, Yuan S. The effect of periodic ketogenic diet on newly diagnosed overweight or obese patients with type 2 diabetes. BMC Endocr Disord. 2022 Feb 3;22(1):34. DOI: https://doi.org/10.1186/s12902-022-00947-2 PMid:35115003 PMCid:PMC8811985

14. Umphonsathien M, Rattanasian P, Lokattachariya S, Suansawang W, Boonyasuppayakorn K, Khovidhunkit W. Effects of intermittent very-low-calorie diet on glycemic control and cardiovascular risk factors in obese patients with type 2 diabetes mellitus: A randomized controlled trial. Journal of diabetes investigation. 2022 Jan;13(1):156-166. DOI: https://doi.org/10.1111/jdi.13619 PMid:34176234 PMCid:PMC8756303

15. Durrer C, McKelvey S, Singer J, Batterham AM, Johnson JD, Gudmundson K, Wortman J, Little JP. A randomized controlled trial of pharmacist-led therapeutic carbohydrate and energy restriction in type 2 diabetes. Nature Communications. 2021 Sep 10;12(1):5367. DOI: https://doi.org/10.1038/s41467-021-25667-4 PMid:34508090 PMCid:PMC8433183

16. Moriconi E, Camajani E, Fabbri A, Lenzi A, Caprio M. Very-low-calorie ketogenic diet as a safe and valuable tool for long-term glycemic management in patients with obesity and type 2 diabetes. Nutrients. 2021 Feb 26;13(3):758. DOI: https://doi.org/10.3390/nu13030758 PMid:33652834 PMCid:PMC7996853

17. Brown A, Dornhorst A, McGowan B, Omar O, Leeds AR, Taheri S, Frost GS. Low-energy total diet replacement intervention in patients with type 2 diabetes mellitus and obesity treated with insulin: a randomized trial. BMJ Open Diabetes Research and Care. 2020 Jan 1;8(1):e001012. DOI: https://doi.org/10.1136/bmjdrc-2019-001012 PMid:32049634 PMCid:PMC7039597

18. Ren M, Zhang H, Qi J, Hu A, Jiang Q, Hou Y, Feng Q, Ojo O, Wang X. An almond-based low carbohydrate diet improves depression and glycometabolism in patients with type 2 diabetes through modulating gut microbiota and GLP-1: a randomized controlled trial. Nutrients. 2020 Oct 3;12(10):3036. DOI: https://doi.org/10.3390/nu12103036 PMid:33022991

19. Skytte MJ, Samkani A, Petersen AD, Thomsen MN, Astrup A, et al. A carbohydrate-reduced high-protein diet improves HbA1c and liver fat content in weight stable participants with type 2 diabetes: a randomised controlled trial. Diabetologia. 2019 Nov;62(11):2066-2078. DOI: https://doi.org/10.1007/s00125-019-4956-4 PMid:31338545

20. Carter S, Clifton PM, Keogh JB. Effect of intermittent compared with continuous energy-restricted diet on glycemic control in patients with type 2 diabetes: a randomized noninferiority trial. JAMA Network Open. 2018 Jul 6;1(3): e180756-e180756. DOI: https://doi.org/10.1001/jamanetworkopen.2018.0756 PMid:30646030 PMCid:PMC6324303

21. Tay J, Thompson CH, Luscombe-Marsh ND, Wycherley TP, et al. Effects of an energy-restricted low-carbohydrate, high unsaturated fat/low saturated fat diet versus a high-carbohydrate, low-fat diet in type 2 diabetes: a 2-year randomized clinical trial. Diabetes, Obesity and Metabolism. 2018 Apr;20(4):858-871. DOI: https://doi.org/10.1111/dom.13164 PMid:29178536

22. Wang LL, Wang Q, Hong Y, Ojo O, Jiang Q, Hou YY, Huang YH, Wang XH. The effect of a low-carbohydrate diet on glycemic control in patients with type 2 diabetes mellitus. nutrients. 2018 May 23;10(6):661. DOI: https://doi.org/10.3390/nu10060661 PMid:29882884 PMCid:PMC6024764

23. Saslow LR, Mason AE, Kim S, Goldman V, Ploutz-Snyder R, et al. An online intervention comparing a very low-carbohydrate ketogenic diet and lifestyle recommendations versus a plate method diet in overweight individuals with type 2 diabetes: a randomized controlled trial. J Med Internet Res. 2017 Feb 13; 19(2):e36. DOI: https://doi.org/10.2196/jmir.5806

24. Goday A, Bellido D, Sajoux I, Crujeiras AB, et al. Short-term safety, tolerability and efficacy of a very low-calorie-ketogenic diet interventional weight loss program versus hypocaloric diet in patients with type 2 diabetes mellitus. Nutrition & diabetes. 2016 Sep;6(9):e230. DOI: https://doi.org/10.1038/nutd.2016.36 PMid:27643725 PMCid:PMC5048014

25. Snel M, Gastaldelli A, Ouwens DM, Hesselink MK, Schaart G, et al. Effects of adding exercise to a 16-week very low-calorie diet in obese, insulin-dependent type 2 diabetes mellitus patients. J Clin Endocrinol Metab. 2012 Jul 1;97(7):2512-2520. DOI: https://doi.org/10.1210/jc.2011-3178 PMid:22569236

26. Wing RR, Blair E, Marcus M, Epstein LH, Harvey J. Year-long weight loss treatment for obese patients with type II diabetes: does including an intermittent very-low-calorie diet improve outcome? Am J Med. 1994 Oct 1;97(4):354-362. DOI: https://doi.org/10.1016/0002-9343(94)90302-6 PMid:7942937

27. Dashti HM, Mathew TC, Al-Zaid NS. Efficacy of low-carbohydrate ketogenic diet in the treatment of type 2 diabetes. Med Princ Pract. 2021 Jun 30;30(3):223-235. DOI: https://doi.org/10.1159/000512142 PMid:33040057

28. Rafiullah M, Musambil M, David SK. Effect of a very low-carbohydrate ketogenic diet vs recommended diets in patients with type 2 diabetes: a meta-analysis. Nutrition Reviews. 2022 Mar;80(3):488-502. DOI: https://doi.org/10.1093/nutrit/ nuab040 PMid:34338787

29. Lichtash C, Fung J, Ostoich KC, Ramos M. Therapeutic use of intermittent fasting and ketogenic diet as an alternative treatment for type 2 diabetes in a normal weight woman: a 14-month case study. BMJ Case Rep. 2020 Jul 7;13(7): e234223. DOI: https://doi.org/10.1136/bcr-2019-234223 PMid:32641437 PMCid:PMC7342268

30. Schneider S, Biggerstaff DL, Barber TM. Helpful or harmful? The impact of the ketogenic diet on eating disorder outcomes in type 1 diabetes mellitus. Expert Rev Endocrinol Metab. 2022 Jul;17(4):319-331. DOI: https://doi.org/10.1080/17446651.2022.2089112 PMid:35748612

31. Zhou C, Wang M, Liang J, He G, Chen N. Ketogenic Diet Benefits to Weight Loss, Glycemic Control, and Lipid Profiles in Overweight Patients with Type 2 Diabetes Mellitus: A Meta-Analysis of Randomized Controlled trials. Int J Environ Res Public Health. 2022 Aug 22;19(16):10429. DOI: https://doi.org/10.3390/ijerph191610429 PMid:36012064

32. Versha, Jangra Y, Sharma L, Meher A, Tare H. The Role of Ketogenic Diet in the Management of Diabetes and Overcome its Effect: A Review. Int J Pharm Qual Assur. 2023;14(1):220-225. DOI: https://doi.org/10.25258/ijpqa.14.1.38

33. Kumar S, Behl T, Sachdeva M, Sehgal A, Kumari S, Kumar A, Kaur G, Yadav HN, Bungau S. Implicating the effect of the ketogenic diet as a preventive measure to obesity and diabetes mellitus. Life sciences. 2021 Jan 1;264:118661. DOI: https://doi.org/10.1016/j.lfs.2020.118661 PMid:33121986

34. Choi YJ, Jeon SM, Shin S. Impact of a ketogenic diet on metabolic parameters in patients with obesity or overweight and with or without type 2 diabetes: a meta-analysis of randomized controlled trials. Nutrients. 2020 Jul 6;12(7):2005. DOI: https://doi.org/10.3390/nu12072005 PMid:32640608

35. Myette-Côté É, Durrer C, Neudorf H, Bammert TD, Botezelli JD, Johnson JD, DeSouza CA, Little JP. The effect of a short-term low-carbohydrate, high-fat diet with or without postmeal walks on glycemic control and inflammation in type 2 diabe-

tes: a randomized trial. Am J Physiol Regul Integr Comp Physiol. 2018 Dec 1;315(6):R1210-R1219. DOI: https://doi.org/10.1152/ajpregu.00240.2018 PMid:30303707

36. Lee YM, Kim SA, Lee IK, Kim JG, Park KG, Jeong JY, Jeon JH, Shin JY, Lee DH. Effect of brown rice based vegan diet and conventional diabetic diet on glycemic control of patients with type 2 diabetes: a 12-week randomized clinical trial. PloS one. 2016 Jun 2;11(6):e0155918. DOI: https://doi.org/10.1371/journal.pone.0155918 PMid:27253526 PMCid:PMC4890770

37. Vitale M, Masulli M, Calabrese I, Rivellese AA, et al. Impact of a Mediterranean dietary pattern and its components on cardiovascular risk factors, glucose control, and body weight in people with type 2 diabetes: a real-life study. Nutrients. 2018 Aug 10;10(8):1067. DOI: https://doi.org/10.3390/nu10081067 PMid:30103444 PMCid:PMC6115857

38. Gardner CD, Landry MJ, Perelman D, Petlura C, et al. Effect of a ketogenic diet versus Mediterranean diet on glycated hemoglobin in individuals with prediabetes and type 2 diabetes mellitus: The interventional Keto-Med randomized crossover trial. Am J Clin Nutr. 2022 Sep 2;116(3):640-652. DOI: https://doi.org/10.1093/ajcn/nqac154. Erratum in: Am J Clin Nutr. 2022 Dec 19;116(6):1904. DOI: https://doi.org/10.1093/ajcn/nqac279. PMID: 35641199; PMCID: PMC9437985