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Research Article

Does Vegetarian Diet Affect on Glycemic Control? A Systematic Review and Meta-Analysis

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Abstract: Vegetables and fruits have been recommended to diabetes patients to control blood glucose. Vegetarian diet is one of options for patients with diabetes. This paper aimed to examine the role of vegetarian diets in improving glycemic control, metabolic parameters, and body weight among patients with type 2 diabetes. Digital archives including MEDLINE, CINAHL, CENTRAL databases and hand searches from 1980 to 2013 were performed. Studies are eligible in case of randomized controlled trials [RCTs] with vegetarian diets as an intervention among patients with type 2 diabetes, as well as outcomes including glycemic control, metabolic parameters, and body weight. Meta-analyses were conducted using RevMan 5. Nine hundred eighty three potentially articles were identified from initial search. After removing illegible studies, five studies were included in the systematic review. Yet, only three studies were included in meta-analysis. The vegetarian diets had a significant effect on all of parameters, except fasting plasma glucose that is in borderline. The HbA1c was decreased on 0.20. On the metabolic parameters i.e. cholesterol, triglycerides, HDL, and LDL were declined to 0.17, 0.28, 0.13, and 0.10, respectively. Body weight was reduced approximately 1.41 among type 2 diabetes patients those consuming vegetarian diet. Vegetarian diets have significant benefits in improving glycemic index, metabolic parameters, as well as body weight. These findings suggest that vegetarian diets could be an option among diabetes patients, since it is beneficial on glycemic control, metabolic parameters, and weight loss.

Keywords: glycemic control; metabolic parameters; type 2 diabetes; vegetarian diets.

INTRODUCTION

The prevalence of diabetes mellitus (DM) is growing up rapidly in worldwide. The number of people suffering from diabetes is estimated to increase from 386 million in 2013 to 592 million in 2035 for all age-groups worldwide (Guariguata *et al*., 2014). Type 2 diabetes mellitus is the most common diabetes, which affects 90% - 95% of diabetes patients (Aschner *et al*., 2012; World Health Organization, 2013). Type 2 diabetes leads to a range of serious complications such as microangiopathy and macroangiopathy. These complications affect not only on premature mortality, but also on quality of life (Childs, 2007).

Diet plays a predominant role and is regarded as an essential component of an overall healthy lifestyle (Trapp, Barnard, & Katcher, 2010). The principal of diabetes diet management includes a balance of carbohydrate, protein, and fat that meet the individual metabolic needs and preferences (American Diabetes Association, 2014). A variety of dietary approaches have been proposed to manage diabetes, including Mediterranean diet, plant-based diet, low-carbohydrate, low-glycemic index, and high-protein (Ajala, English, & Pinkney, 2013; World Health Organization, 2013). The diet comprising of vegetables and fruits has been recommended. Moreover, vegetarian diet has been suggested to be one of dietary meal for type 2 diabetes management (American Diabetes Association, 2014; Barnard, Katcher, Jenkins, Cohen, & Turner-McGrievy, 2009).

The vegetarian diets can be either absolutely consumption of vegetable or just simply remove meat but still consuming fish or animal products, such as milk, egg and dairy (American Dietetic Association, 2009). Based on the content of food consumption, vegetarian diets can be classified as four types, including vegan that eliminates strictly all animal meats and products, lacto vegetarian that allow to consume milk and by-product, lacto-ovo-vegetarian diet that includes eggs, and partial or pecto-vegetarian diet that fish is allowed (Biase, Fernandes, Gianini, & Duarte, 2007; Tonstad, Butler, Yan, & Fraser, 2009). Vegetables as main meal of this type of diet are well known that contain a substantial amount of fiber and

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complex carbohydrates that effects on glucose metabolism (Dwyer, 1988). Undigested carbohydrates elevate colonic fermentation that produce short-chain fatty acids (SCFA), consequently, hepatic insulin sensitivity was improved (Thorburn, Muir, & Proietto, 1993).

A few meta-analyses have been conducted to investigate the effects of dietary approaches on glycemic control (Ajala *et al*., 2013; Post, Mainous, King, & Simpson, 2012). Ajala's (2013) reviewed the types of DM diets and their effects on glycemic control and metabolic parameters. The results shown that low-carbohydrate, low-glycemic index, Mediterranean, and high-protein improved glycosylated hemoglobin (Ajala *et al*., 2013). However, the Ajala's review did not explore focusing on vegetarian diet. Another review by Post *et al*. found that high fiber diet is more efficacious on HbA1c and fasting blood glucose then placebo population (Post *et al*., 2012). Nevertheless, those two reviews did not examine the effects of vegetarian diets on metabolic control for patients with T2DM. This paper aimed to conduct a systematic review and a meta-analysis to examine the role of vegetarian diets in improving glycemic control, metabolic parameters, and body weight among type 2 diabetes patients compared with conventional diabetes diet.

METHODS

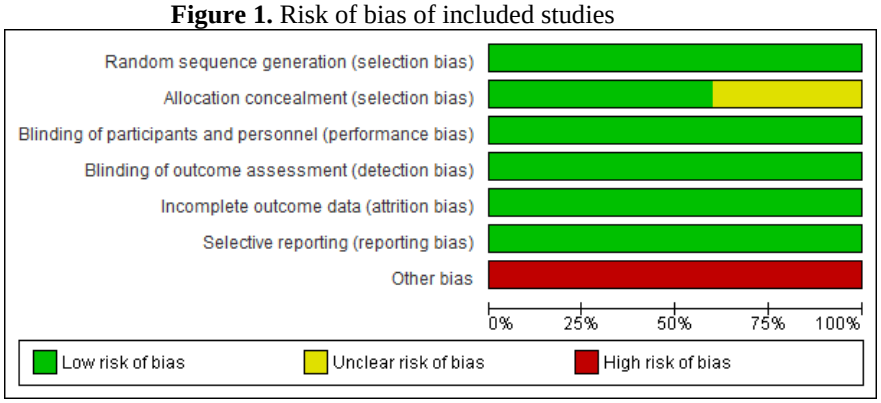
Study selection

PICOTS framework that stands for **P**opulations, **I**nterventions, **C**omparisons, **O**utcomes, **T**ime and **S**tudy design was applied to set out the inclusion criteria (The Cochrane Collaboration, 2008). Studies were eligible if they were randomized controlled trials (RCTs), undertaken in an adult population (≥ 18 years of age) with type 2 diabetes mellitus, and with vegetarian diet as an intervention that lasted ≥ 12 weeks. A 12-weeks of the minimum duration of intervention is chosen due to the consideration of HbA1c. HbA1c can reflect the level of blood sugar for the past 120 days. Vegetarian diets were referred to as either strictly consumption of vegetable or restrict from meat but still consuming fish or any animal products, such as milk, egg and dairy (American Dietetic Association, 2009). The comparison diet is conventional diabetes diet. The conventional diabetes diets were referred to as one of the following diet approaches: traditional diet containing all food resources, the diet meeting American Diabetes Association (ADA) diet 2003 guideline, or the diet meeting Diabetes and Nutrition Study Group (DNSG) diet guideline. The outcomes were evaluated through three groups of parameters comprise glycemic control (i.e. glycosylated Hemoglobin [HbA1c] and fasting plasma glucose [FPG]); metabolic parameters (i.e. cholesterol, triglyceride [TG], high density lipoprotein [HDL], and low density lipoprotein [LDL]), and body weight. Articles were searched from electronic databases including MEDLINE, CINAHL, and CENTRAL. Hand searches were performed to get the related sources. Key terms in different combinations were applied to the searching: diabetes, type 2 diabetes, vegetarian diet, vegan diet, lacto-ovo vegetarian diet, lacto vegetarian diet, plant foods, blood sugar, blood glucose, glycemic control, and metabolic control. Articles were published in English from 1980 to 2013.

Data Extraction and Quality Measures

Data in the study design, participants, variety of diet, and outcomes were extracted by SH and checked by YYH, respectively. Study appraisal was conducted by SH and YYH independently. The methodological quality of the studies was appraised using the risk of bias assessment in Review Manager (version 5.3, The Nordic Cochrane Center, Copenhagen, Denmark). The risk of bias of the studies were depicted into five domains; selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. The source of selection bias domain contents of random sequence generation and allocation concealment. In this review, all risk of bias components are in low levels except in allocation concealment domain. Yet, two of five studies are unclear in allocation concealment (Kahleova, *et al*., 2011; & Nicholson, *et al*., 1999). Small sample size, using self-report, no standard of meal serving, unrestricted energy intake and carbohydrate, no exercise alteration and giving supplement such as vitamin B12 are some confounding factors that contributed in risk of bias (see **Figure 1**).

Figure 1. Risk of bias of included studies



The author (SH) had tried to contact with the corresponding authors of the three studies (Nicholson *et al*., 1999; Barnard *et al*., 2006; & Barnard *et al*., 2009). No reply was obtained from the above studies. Because mean changes and standard deviation in Nicholson's study was absent (Nicholson *et al*., 1999) and the parameter units in Barnard's study (Barnard *et al*., 2006; Barnard *et al*., 2009) were inconsistent with unit that was used in this review. Consequently, parameters were converted manually from mg/dl to mmol/l of cholesterol, HDL, and LDL was converted by multiply by 0.0259 and triglyceride was converted by multiply by 0.0113 (Barnard *et al*., 2009). If mean changes could not obtained from those articles, those mean changes would be calculated by authors according to following formula: $mean_{final} - mean_{baseline}$. Data obtain manual calculation of standard deviation was done by applying the SD_{change} formula with a correlation coefficient 0.80 for significant parameters, and 0.30 for not significant parameters (The Cochrane Collaboration, 2008).

$$SD_{E,change} = \sqrt{SD^2_{E,baseline} + SD^2_{E,final} - \left(2 \times Corr \times SD_{E,baseline} \times SD_{E,final}\right)},$$

To ensure preciseness of data, all the data of change means and standard deviation were checked. If an error was found, a revision from the data was done by the authors. Further information related the studies' result on glycemic control and metabolic parameters were shown in **Table 1**.

Note: [a]: study involved in meta-analysis; [b]: study excluded in meta-analysis; [c]: calculated manually by the author; [d]: original data revised due to error.

Parameters	Study	Experiment Group					Control Group			
		n	**Baseline**	**Final**	**Change**[c]		***n***	**Baseline**	**Final**	**Change**[c]
HbA1c (%)	Nicholson, 1999[a]	7	8.3 ± 1.7	6.9 ± 1.1	-1.4 ± 1.73		4	8.0 ± 1.1	7.0 ± 0.6	-1.00 ± 1.15
	Barnard, 2006[a]	49	8.0 ± 1.1	7.1 ± 1.0	-0.9[d] ± 0.67		50	7.9 ± 1.0	7.4 ± 1.0	-0.5[d] ± 0.63
	Kahleova, 2011[a]	37	-	-	-0.65 ± 0.99		37	-	-	-0.21 ± 1.10
	Barnard, 2009[b]	49	8.05 ± 0.16	7.71 ± 0.19	-0.34 ± 0.11		50	7.93 ± 0.14	7.79 ± 0.18	-0.14 ± 0.17
	Mishra, 2013[b]	17	7.52 ± 0.49	6.78 ± 0.44	-0.74 ± 0.19		18	7.03 ± 0.36	7.13 ± 0.38	-0.10 ± 0.12
FSG (mmol/L)	Nicholson, 1999[a]	7	10.74 ± 2.85	7.75 ± 2.07	-2.99 ± 1.72		4	9.86 ± 1.63	8.64 ± 0.20	-1.22 ± 1.48
	Barnard, 2006[a]	49	9.08 ± 2.95	7.11 ± 1.97	-1.97 ± 1.81		50	8.90 ± 2.26	6.98 ± 1.91	-1.92[d] ± 1.36
	Kahleova, 2011[a]	37	9.51 ± 2.75	7.82 ± 1.98	-1.69[d] ± 1.67		37	9.45 ± 2.37	8.29 ± 2.17	-1.16[d] ± 1.45
	Barnard, 2009[b]	49	9.08 ± 0.42	8.00 ± 0.43	-1.08 ± 2.28		50	8.91 ± 0.32	8.13 ± 0.45	-0.78 ± 2.34
Cholesterol (mmol/L)	Nicholson, 1999[a]	7	5.26 ± 1.09	4.63 ± 1.32	-0.63 ± 1.44		4	5.56 ± 0.61	4.93 ± 0.46	-0.63 ± 0.65
	Barnard, 2006[a]	49	4.84 ± 0.97[c]	4.13 ± 0.83[c]	-0.71 ± 1.28		50	5.15 ± 1.14[c]	4.52 ± 0.94[c]	-0.63 ± 0.69
	Kahleova, 2011[a]	37	4.37 ± 0.75	4.28 ± 1.07	-0.09[d] ± 0.65		37	4.16 ± 0.87	4.14 ± 0.74	-0.02[d] ± 0.52
	Barnard, 2009[b]	49	4.84 ± 0.14 [c]	4.29 ± 0.12 [c]	-0.56 ± 0.16		50	5.15 ± 0.16 [c]	4.77 ± 0.14 [c]	-0.38 ± 0.18
	Mishra, 2013[b]	96	4.90 ± 0.11 [c]	4.56 ± 0.11 [c]	-0.34 ± 0.07		119	4.95 ± 0.09 [c]	4.90 ± 0.09 [c]	-0.05 ± 0.06
Triglycerides (mmol/L)	Nicholson, 1999[a]	7	2.12 ± 0.78	1.87 ± 0.63	-0.25 ± 0.84		4	2.29 ± 1.92	1.85 ± 1.14	-0.44 ± 1.92
	Barnard, 2006[a]	49	1.67 ± 1.27[c]	1.35 ± 0.63[c]	-0.32 ± 1.85		50	1.79 ± 1.50[c]	1.50 ± 1.29[c]	-0.29 ± 0.91
	Kahleova, 2011[a]	37	2.28 ± 1.01	2.08 ± 0.94	-0.20[d] ± 1.32		37	1.89 ± 0.79	1.83 ± 0.74	-0.06[d] ± 0.49
	Barnard, 2009[b]	49	1.67 ± 0.18 [c]	1.29 ± 0.11 [c]	-0.38 ± 0.18		50	1.79 ± 0.21 [c]	1.70 ± 0.33 [c]	-0.09 ± 0.33
	Mishra, 2013[b]	96	1.46 ± 0.08 [c]	1.62 ± 0.08 [c]	0.16 ± 0.10		119	1.44 ± 0.07 [c]	1.40 ± 0.07 [c]	-0.03 ± 0.08
HDL (mmol/L)	Nicholson, 1999[a]	7	1.15 ± 0.32	0.95 ± 0.28	-0.20 ± 0.19		4	1.12 ± 0.17	1.10 ± 0.17	-0.02 ± 0.11
	Barnard, 2006[a]	49	1.35 ± 0.51[c]	1.23 ± 0.44[c]	-0.12 ± 0.31		50	1.29 ± 0.38[c]	1.21 ± 0.31[c]	-0.08 ± 0.23
	Kahleova, 2011[a]	37	1.07 ± 0.29	1.06 ± 0.22	-0.01 ± 0.17		37	1.02 ± 0.19	1.14 ± 0.21	0.12[d] ± 0.13
	Barnard, 2009[b]	49	1.35 ± 0.07 [c]	1.33 ± 0.07 [c]	-0.03 ± 0.88		50	1.29 ± 0.05 [c]	1.26 ± 0.05 [c]	-0.03 ± 0.06
	Mishra, 2013[b]	96	1.42 ± 0.05 [c]	1.32 ± 0.04 [c]	-0.10 ± 0.03		119	1.45 ± 0.04 [c]	1.47 ± 0.03 [c]	0.02 ± 0.02
LDL (mmol/L)	Barnard, 2006[a]	49	2.70 ± 0.85[c]	2.28 ± 0.72[c]	-0.42 ± 0.51		48	3.07 ± 1.07[c]	2.67 ± 0.86[c]	-0.4 ± 0.64
	Kahleova, 2011[a]	37	2.70 ± 0.57	2.55 ± 0.89	-0.15[d] ± 0.55		37	2.65 ± 0.82	2.52 ± 0.71	-0.13[d] ± 0.50
	Barnard, 2009[b]	49	2.70 ± 0.12 [c]	2.35 ± 0.11 [c]	-0.35 ± 0.14		50	3.05 ± 0.15 [c]	2.80 ± 0.14 [c]	-0.24 ± 0.17
	Mishra, 2013[b]	96	2.82 ± 0.10 [c]	2.49 ± 0.09 [c]	-0.34 ± 0.06		119	2.85 ± 0.08 [c]	2.80 ± 0.08 [c]	-0.05 ± 0.05
Weight (kg)	Nicholson, 1999[a]	7	96.7 ± 13.3	89.5 ± 14.4	-7.2 ± 8.82		4	97.0 ± 22.9	93.2 ± 22.2	-3.8 ± 14.28
	Barnard, 2006[a]	49	97.0 ± 22.9	91.1 ± 22.4	-5.9[d] ± 14.33		50	99.3 ± 21.0	95.0 ± 20.9	-4.3 ± 13.25
	Kahleova, 2011[a]	37	102.8 ± 17.1	96.9 ± 15.9	-5.9[d] ± 10.5		37	101.6 ± 17.8	98.4 ± 18.5	-3.2 ± 11.5
	Barnard, 2009[b]	49	97.0 ± 3.3[5]	92.6 ± 3.5	-4.4 ± 0.9[6]		50	99.3 ± 3.0	96.3 ± 3.2	-3.0 ± 0.8[7]
	Mishra, 2013[b]	96	93.3 ± 2.1	89 ± 2.0	-4.3 ± 0.4		119	93.5 ± 1.9	93.4 ± 1.9	-0.08 ± 0.4

Table 1. Results of the Studies on Glycemic Control, Lipid Profile and Body Weight.

Statistical Analysis

Review Manager (version 5.3, The Nordic Cochrane Center, Copenhagen, Denmark) was used for meta-analysis. The inverse variance method was used to compute a mean difference between the experimental and control groups' while effect sizes were presented by mean differences with 95 % CI. A Random effect model was used in this study, because the studies were assumed difference in effect size (Borenstein, Hedges, Higgins, & Rothstein, 2010). The outcomes were assessed by comparing mean change of baseline and follow-up parameters between intervention and control group. Forest plots were created for each outcome measure to illustrate the strength effects of the vegetarian diets.

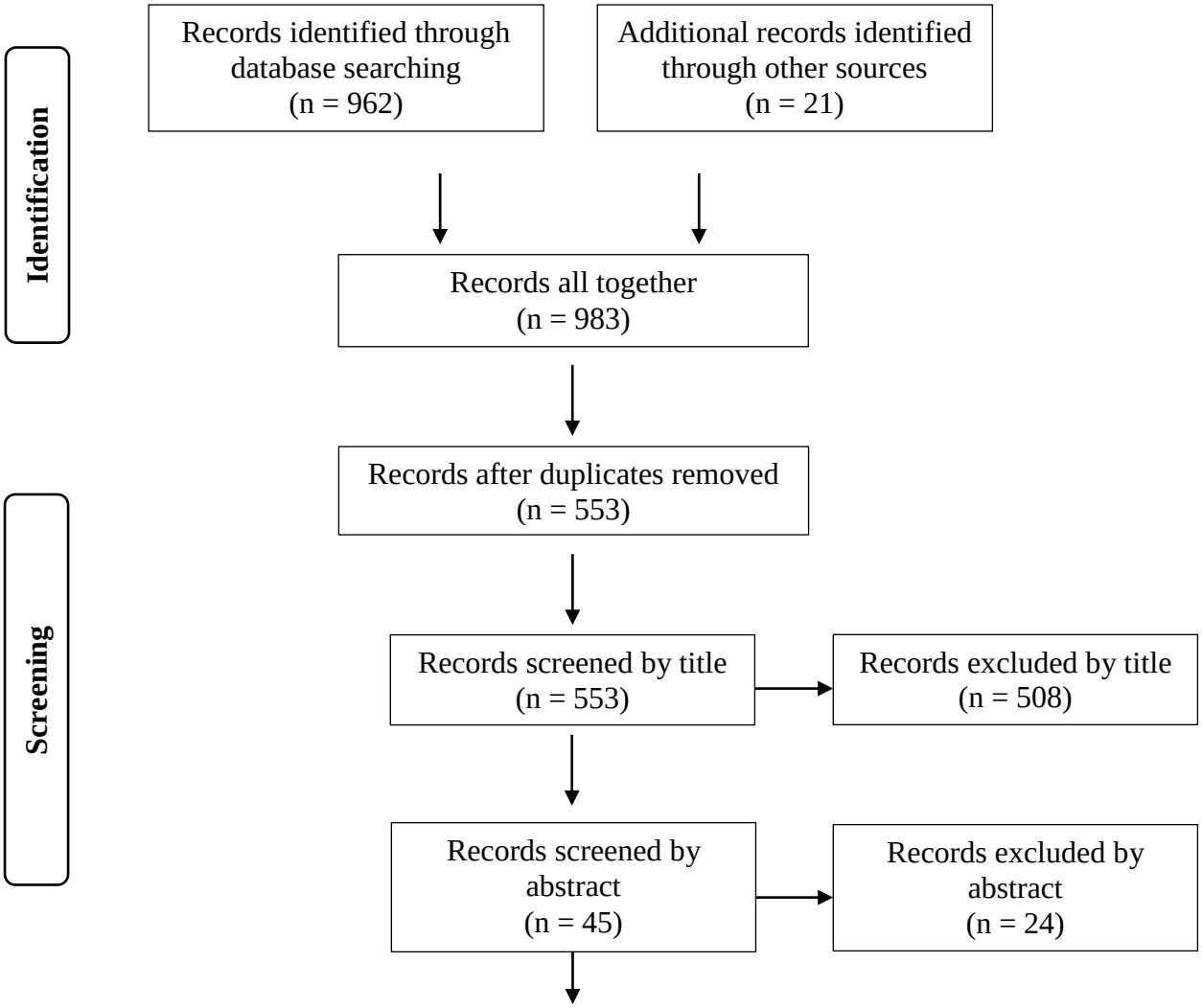
Only three of the five studies (Barnard *et al*., 2009; Kahleova *et al*., 2011; Nicholson *et al*., 1999) were included in meta-analysis. Two studies conducted by Barnard *et al*. (2006) and Mishra *et al*. (2013) were excluded in this meta-analysis. Barnard and his colleagues followed-up the effect of vegan diet on glycemic control at 22-weeks (Bernard *et al*., 2006) and 74-weeks (Bernard *et al*., 2009), respectively. Therefore, the meta-analysis only included the 74-weeks study instead of 22-weeks study. The study conducted by Mishra and the colleagues was excluded due to participant containing obesity and type 2 diabetes.

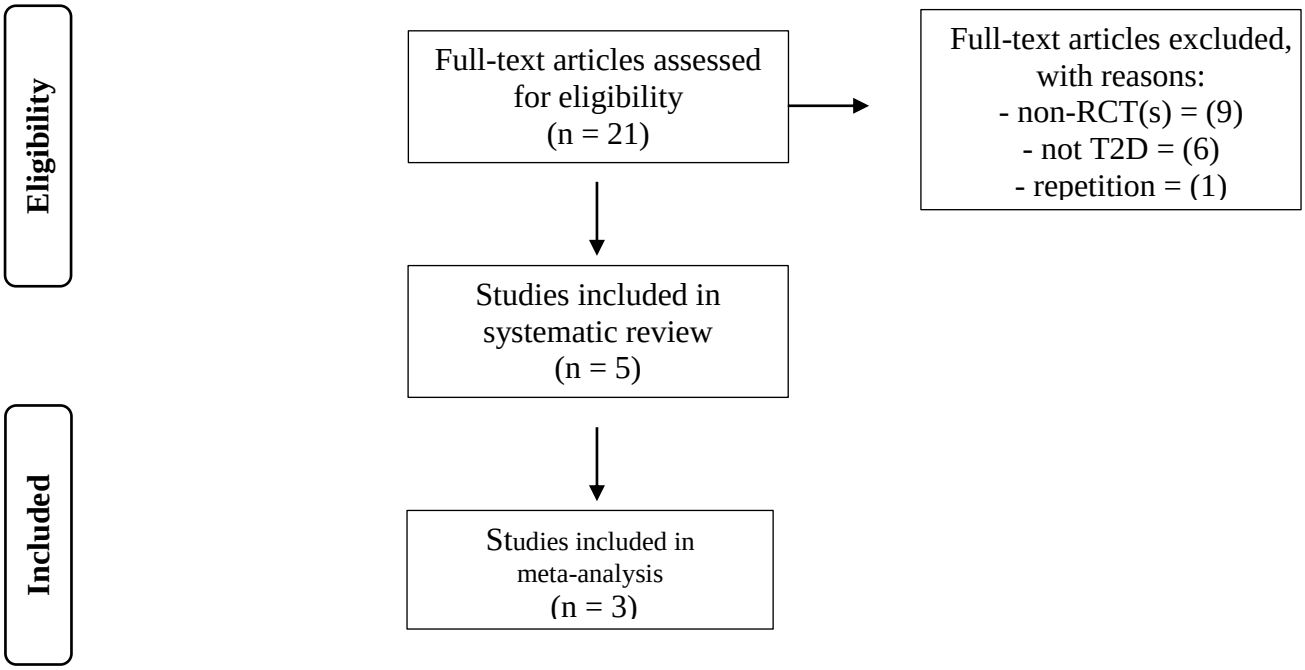
RESULTS

Searching Results

There were 983 potentially articles were identified from initial search. After removing 430 duplicated studies, and 532 illegible articles, 21 articles were left and assessed full-test for eligibility. Of the remaining 21 studies, nine were non-RCT, six were not related to T2DM and one study was same with previous study. Consequently, five articles were included in the systematic review (Barnard, Cohen, *et al*., 2009; Barnard *et al*., 2006; Kahleova *et al*., 2011; Mishra *et al*., 2013; Nicholson *et al*., 1999). Among the five articles, one article (Mishra *et al*., 2013) contained subjects who either overweight and/or type 2 diabetes, and one article (Barnard *et al*., 2006) was preliminary study of one study (**Figure 2**).

Figure 2. Flow diagram of study selection





Studies Characteristics

Table 2 presented the characteristics of the five studies. Sample size of five studies ranged from 7 to 96. The total number of participants for the vegetarian group and conventional group was 238 and 260, respectively. Mean ages for participants ranged from 44 to 60 years, and the intervention duration ranged from 12 to 74 weeks. Regarding the vegetarian diet intervention, four studies (Barnard, Cohen, et.al., 2009; Barnard, et.al., 2006; Mishra et.al., 2013; Nicholson et.al., 1999) marked the vegetarian diet as low-fat vegan diet, while the other study (Kahleova et.al., 2011) did not specify the type of vegetarian diets. In all of experimental groups, there is no any animal product consumed. The nutrient proportion of carbohydrate, protein, and fat in the vegetarian diet was 60-75 %, 10-15 %, and 10-25 %, respectively. On the other hand, the types of the conventional diet in the control group included ADA diet guideline 2003, DNSG diet, and regular conventional diets. The detailed contents of vegetarian and conventional diet were described in **table 2**. As noted, the regular conventional diets was emphasized of fish and poultry rather than red meat.

Table 2. Characteristics of the Studies

Study/year	Sample size	Duration	Experiment Group (Vegetarian diets)	Control Group (Conventional diets)	Remarkable Results
Barnard, 2006	EC 49 CG 50	22 weeks	Low-fat vegan diet (˜ 10% of energy from fat, 15% protein, and 75% carbohydrate) consisted of vegetables, fruits, grains, and legumes.	ADA diet (10-20% protein, 7% saturated fat, 60-70% carbohydrate and monounsaturated fats, and cholesterol ≤200% mg/day)	- HbA1c (S) - FPG (S) - Cholesterol (S) - Triglycerides (S) - HDL (S) - LDL (S) - Body weight (S)
Barnard, 2009[a]	EC 49 CG 50	74 weeks	Low-fat vegan diet (˜ 10% of energy from fat, 15% protein, and 75% carbohydrate) consisted of vegetables, fruits, grains, and legumes.	ADA diet (10-20% protein, 7% saturated fat, 60-70% carbohydrate and monounsaturated fats, and cholesterol ≤200% mg/day)	- HbA1c (S) - FPG (S) - Cholesterol (S) - Triglycerides (S) - HDL (↓) - LDL (S) - Body weight (S)
Kahleova, 2011	EG: 37 CG: 37	24 weeks	Vegetarian diet (˜60% of energy from carbohydrates, 15% protein and 25% fat) consisted of vegetables, grains, legumes, fruits, and nuts	DNSG diet (50% of total energy from carbohydrate, 20% protein, less than 30% fat [≤7% saturated fat, 200 mg/day of cholesterol/day])	- HbA1c (S) - HDL (↑) - LDL (↓) - Body weight (S)
Mishra, 2013[b]	EG: 96 CG: 119	18 weeks	Low-fat vegan diet (consisted of whole grain, vegetables, legumes, and fruit), low glycemic index, supplement of vitamin B12	Regular diet, no dietary changes	- HbA1c (S) - Cholesterol (S) - Triglycerides (Sc) - HDL (S) - LDL (S) - Body weight (S)
Nicholson, 1999	EG 7 CG 4	12 weeks	Low-fat vegan diet (10 – 15% of calories from protein and less than 10% of calories from fat, with the remaining calories coming from unrefined complex carbohydrates) consisted of whole grains, vegetables, legumes, and fruits.	Conventional diet (55-60% of calories from carbohydrate and less than 30% of calories from fat, with approximately 200 mg of cholesterol per day) emphasized the use of fish and poultry, rather than red meat.	- HbA1c (NS) - FPG (S) - Cholesterol (NS/Sc) - Triglycerides (NS/SC) - HDL (S) - LDL (NS/Sc) - Body weight (S)

Note:
- [a]: follow-up study; [b]: study that contained subjects with overweight and/or type 2 diabetes;
- EG: Experiment Group; CG: Control Group; ADA: American Diabetes Association; DNSG: Diabetes and Nutrition Study Group;
- HbA1c: Glycosylated Hemoglobin; FPG: Fasting Plasma Glucose; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein;
-S: Significant; NS: Non Significant; Sc: Substantial changes; ↑: increased; ↓: decreased.

Glycemic Control

The results of forest plot for the meta-analysis of glycemic control was shown in **Figure 3**. Vegetarian diets had a significant effect on HbA1c ($p < 0.05$) with an effect size Z = 7.14 and reduced by 0.20 compared to conventional diets (**Figure 3A)**. Fasting plasma glucose was in borderline ($p = 0.05$) that the vegetarian diets had a substantial impact on their effect size Z = 1.99 and reduced by 0.55 compared to conventional diets **(Figure 3B).**

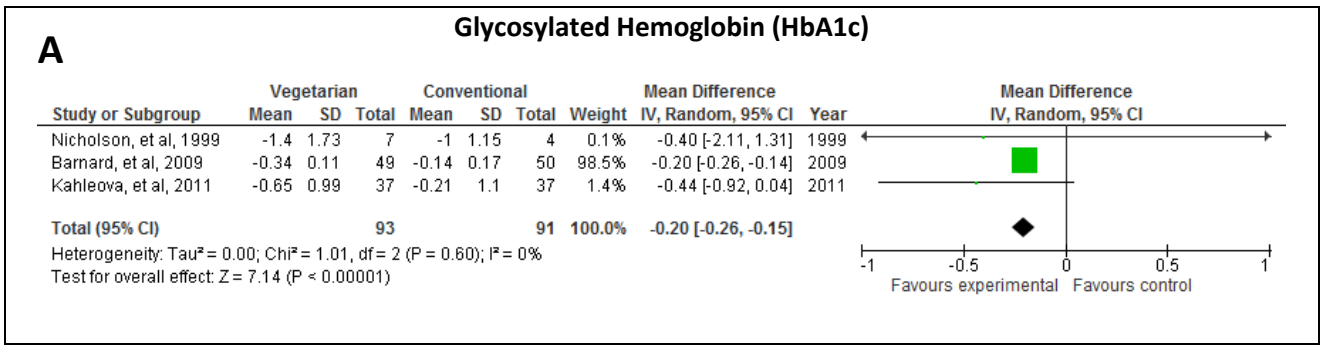
Metabolic Parameters

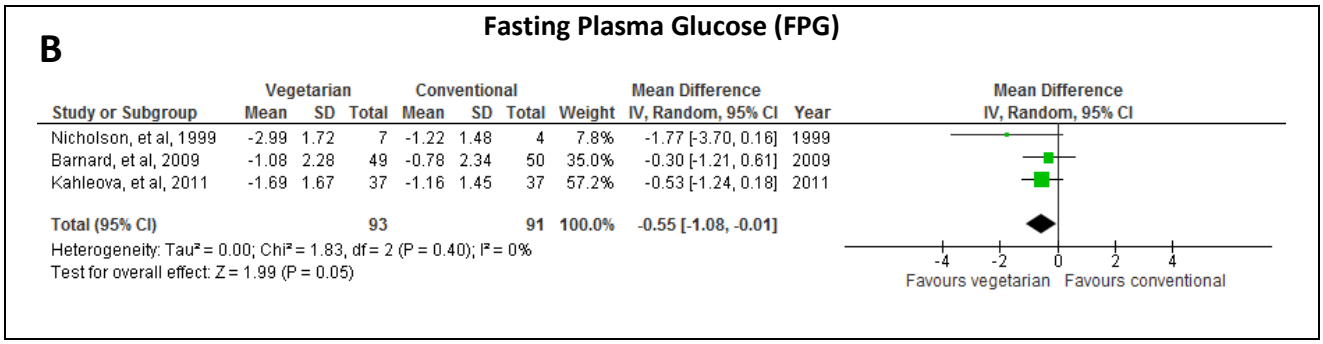
Vegetarian diets also had a significant effect ($p < 0.05$) on all lipid profiles with an effect size are 5.22 (cholesterol), 5.42 (triglyceride), 4.03 (HDL), and 3.45 (LDL). Compared with conventional diets, the reduction rate were lied on 0.17 in cholesterol, 0.28 in triglyceride, 0.13 in HDL, and 0.10 in LDL (**Figure 3C, 3D, 3E, and 3F**).

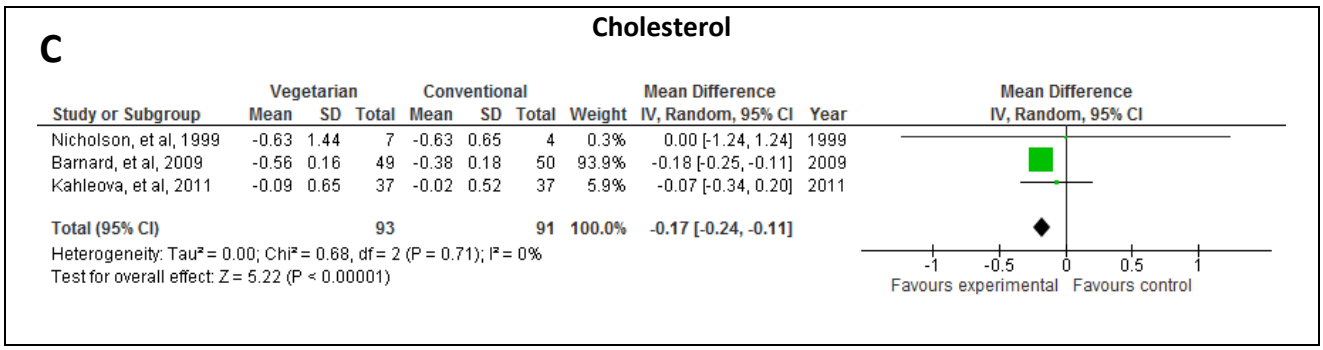
Body weight

Body weight parameter was statistically significant (effect size 8.23, $p < 0.05$) that the vegetarian diets had a valuable impact on body weight, which is reduce 1.41 compared to conventional diets **(Figure 3G).**

Figure 3. Forest Plot of Glycemic Control, Metabolic Parameters and Body Weight





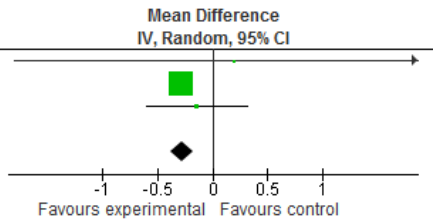


D

Tryglyceride

Study or Subgroup	Vegetarian Mean	SD	Total	Conventional Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI	Year
Nicholson, et al, 1999	-0.25	0.84	7	-0.44	1.92	4	0.3%	0.19 [-1.79, 2.17]	1999
Barnard, et al, 2009	-0.38	0.18	49	-0.09	0.33	50	94.7%	-0.29 [-0.39, -0.19]	2009
Kahleova, et al, 2011	-0.2	1.32	37	-0.06	0.49	37	5.0%	-0.14 [-0.59, 0.31]	2011
Total (95% CI)			**93**			**91**	**100.0%**	**-0.28 [-0.38, -0.18]**	

Heterogeneity: Tau² = 0.00; Chi² = 0.62, df = 2 (P = 0.73); I² = 0%
Test for overall effect: Z = 5.42 (P < 0.00001)

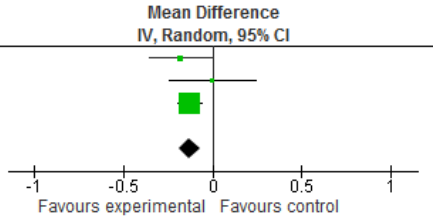


E

High Density Lipoprotein (HDL)

Study or Subgroup	Vegetarian Mean	SD	Total	Conventional Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI	Year
Nicholson, et al, 1999	-0.2	0.19	7	-0.02	0.11	4	12.3%	-0.18 [-0.36, -0.00]	1999
Barnard, et al, 2009	-0.03	0.88	49	-0.03	0.06	50	6.3%	0.00 [-0.25, 0.25]	2009
Kahleova, et al, 2011	-0.01	0.17	37	0.12	0.13	37	81.4%	-0.13 [-0.20, -0.06]	2011
Total (95% CI)			**93**			**91**	**100.0%**	**-0.13 [-0.19, -0.07]**	

Heterogeneity: Tau² = 0.00; Chi² = 1.37, df = 2 (P = 0.51); I² = 0%
Test for overall effect: Z = 4.03 (P < 0.0001)

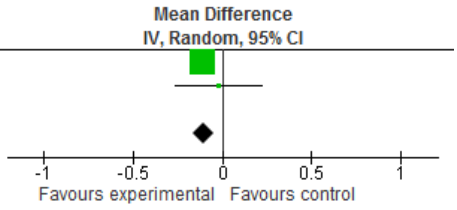


F

Low Density Lipoprotein (LDL)

Study or Subgroup	Vegetarian Mean	SD	Total	Conventional Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Barnard, et al, 2009	-0.35	0.14	49	-0.24	0.17	50	93.9%	-0.11 [-0.17, -0.05]
Kahleova, et al, 2011	-0.15	0.55	37	-0.13	0.5	37	6.1%	-0.02 [-0.26, 0.22]
Total (95% CI)			**86**			**87**	**100.0%**	**-0.10 [-0.16, -0.05]**

Heterogeneity: Tau² = 0.00; Chi² = 0.51, df = 1 (P = 0.48); I² = 0%
Test for overall effect: Z = 3.45 (P = 0.0006)

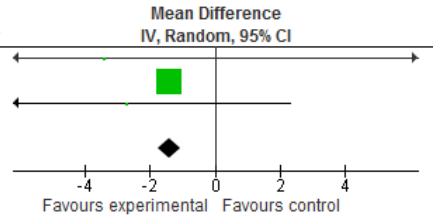


G

Body Weight

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI	Year
Nicholson, et al, 1999	-7.2	8.82	7	-3.8	14.28	4	0.0%	-3.40 [-18.84, 12.04]	1999
Barnard, et al, 2009	-4.4	0.9	49	-3	0.8	50	99.5%	-1.40 [-1.74, -1.06]	2009
Kahleova, et al, 2011	-5.9	10.5	37	-3.2	11.5	37	0.4%	-2.70 [-7.72, 2.32]	2011
Total (95% CI)			**93**			**91**	**100.0%**	**-1.41 [-1.74, -1.07]**	

Heterogeneity: Tau² = 0.00; Chi² = 0.32, df = 2 (P = 0.85); I² = 0%
Test for overall effect: Z = 8.23 (P < 0.00001)



DISCUSSION

The results of the meta-analysis show a significant effect of vegetarian diets on glycemic control and metabolic parameters compared to conventional diets. These findings suggest that vegetarian diets tend to be beneficial in glycemic control and metabolic parameters compared to a non-vegetarian diet.

The study shows significant evidence that vegetarian diets reduce glycemic control and body weight in people with type 2 diabetes. The reduction on HbA1c by vegetarian diets of 0.20 and 0.55 on fasting plasma glucose. This findings consistent with the other meta-analysis conducted by Ajala *et al.* (2013); Post *et al.* (2012) and (Pande, Krishnamoorthy, & Moulick, 2011). Ajala found that diets such as low-carbohydrate, low-glycemic index, Mediterranean, and high-protein, significant in improving glycemic control (Ajala *et al.*, 2013). Study conducted by Pande *et al.* was proved the

efficacy of Indian vegetarian mixed meals diet on glycemic control (Pande *et al*., 2011). Vegetarian diets consist of high levels of dietary fiber, which is formed into soluble and insoluble fiber (Anderson, Randles, Kendall, & Jenkins, 2004). This nutrient have been proposed a great benefit on glucose metabolism (Craig, 2010; Dwyer, 1988; Jenkins *et al*., 2003). The efficacy of fiber on glycemic control also stated by Post *et al*. (2012). Their meta-analysis found that fiber, which is contained in vegetables, has tremendous impact on glycemic control (Post *et al*., 2012). The possible explanation for the effects of dietary fiber on glycemic control is the components of dietary fiber are cellulose and hemicellulose that have biological effects such as increasing fecal bulk and shortening transit time, which influence the fermentation process in the colon. Therefore, the colonic fermentation enhances the production of short-chain fatty acid (SCFA), then, the SCFA suppresses glucose production in hepatocytes. Consequently, insulin sensitivity is increased (Turner-McGrievy *et al*., 2011; Weickert *et al*., 2005; Wong, Souza, Kendall, Emam, & Jenkins, 2006). The increasing insulin sensitivity likewise the improvement of glycemic control (Christiansen, Melholt Rasmussen, Nybo, Steenstrup, & Nybo, 2012). The SCFA also stimulate the release of peptide (Anderson, Smith, & Gustafson, 1994) that trigger the glycogenolysis process (Gao & Yue, 2012). Consequently, it affects in decreasing food intake. Moreover, glycogenolysis in these participants may related to low-fat vegetarian diet, which prompt to fat burnt to substitute the energy needs (Oparah, 2006; Mishra *et al*., 2013 & Tonstad *et al*., 2009). Eventually, it yield weight loss.

This review was shown that vegetarian diets offer the significant reduction on lipids profile such as cholesterol, triglyceride, HDL, and LDL. This findings were accordance with Brown and colleagues' study that dietary fiber was reduced lipids profile (Brown, Rosner, Willett, & Sacks, 1999). Vegetarian diets are associated with lower levels of lipoprotein (Biase *et al*., 2007; Masarei *et al*., 1984). Consuming a vegetarian diet means decreasing the intake of saturated fat and cholesterol (Jenkins *et al*., 2003). The vegetarian diets contain abundant fibers, monounsaturated fats (MUFAs) and polyunsaturated fats (PUFAs) (Ajala *et al*., 2013), which have been demonstrated to reduce the lipid profile (Masarei *et al*., 1984). Garg (1996) was explained the correlation between insulin resistance and dyslipidemia. First, insulin affects hepatic triglyceride lipase (HTGL) activity and reduces post-heparin plasma HTGL activity. When insulin resistance occurs, it will increase post-heparin plasma HTGL activity that causes decreased of lipids level. Another explanation is related to the role of lipoprotein lipase (LPL). When LPL activity was declined, the triglycerides and very low density lipoprotein (VLDL) particles will transfer excessively that impact on lipids profile changes.

Limitations

Some limitation should be considered in this review. The limited number of the studies in the current review may cause sample size bias in the results. Instead, additional studies concern in vegetarian diets and the effects on glycemic control and metabolism parameters is required. Publication bias was arisen in this review, because only English language articles were included. The variation in the vegetarian diet types and intervention duration cause the results of this review are limited in generalization. Finally, manual calculation of partial mean changes and standard deviation changes that unavailable from their original study may affect precise estimation of the effect size.

Implication for Practice

Findings from this review recommend that vegetarian diets can be an option to patients with type 2 diabetes to manage their glycemic, metabolic controls and body weight. People with T2D could select different type of vegetarian diet reviewed to meet their personal needs.

CONCLUSIONS

This review shows that the vegetarian diets have substantial effects in improving glycemic control, metabolic parameters, and body weight. It could be a dietary option in diabetes management. Based on the limitation of this review, further study in effects of vegetarian diet on T2D with large sample size, and long-term intervention is required.

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