Association of a Vegetarian Diet with Decreased Risk of Type 2 Diabetes

Kayla Nikc

I pledge on my honor that I have not given nor received any unauthorized assistance on this term paper, nor have I read or included any previously published meta-analysis on my research topic.

Name: Kayla Nikc Signature: Kayla Nikc Date: 12/14/2020

Introduction:

Type 2 diabetes is a chronic medical condition that results from excess blood glucose levels. Insulin is a hormone which moves blood sugar from the blood and into cells to be used as energy. Unlike type 1 diabetes, in which high blood sugar levels arise from the inability of a person's pancreas to produce insulin, type 2 diabetes occurs when cells fail to respond normally to insulin and sugar levels in the blood continue to increase. According to the CDC, 90-95% of the estimated 34 million Americans diagnosed with diabetes fall into this latter category (CDC, 2019). Though the exact causes of type 2 diabetes are unknown, risk factors such as genetics, body weight, and lack of physical activity are thought to be contributing features.

Recent research has investigated diet as an alternative protective or risk factor for type 2 diabetes. In 2014, the World Health Organization announced 422 million cases of diabetes worldwide, and linked high intake of saturated fatty acids, high total fat intake, and high intake of sweetened beverages with an increased risk for type 2 diabetes (WHO, 2016). Recent research hypothesizes that individuals following a vegetarian or vegan diet will be less likely to develop type 2 diabetes due to their eliminated consumption of red and processed meats. Overall increased consumption of fruit, salads, and cooked vegetables might also contribute to healthier lifestyle behaviors, reducing the risk of being overweight and developing diabetes.

In this paper, I seek to understand the connection between vegetarian diets and the associated risk of developing type 2 diabetes. If there is a significant protective effect of a plant-based diet against type 2 diabetes, policies addressing the increasing prevalence of type 2 diabetes can be informed by this research, and programs encouraging a plant-based diet can be promoted.

Methods:

To complete this study, I completed several database searches in PubMed, in addition to a search in Google Scholar. I ran a total of 6 searches in PubMed, limiting results to the last 20 years and using variations of the following MeSH terms: incidence, "type 2 diabetes", "diabetes mellitus", vegetarianism, "vegetarian diet", and "plant-based diet". I also completed an additional search in Google Scholar using incidence, "type 2 diabetes", and vegetarianism as search terms. I gathered a total of 266 sources from these searches, 246 from PubMed and an additional 20 from the first two relevant pages of Google Scholar results.

In order to narrow down these papers, I followed the PRISMA diagram, seen in **Figure 1** below. I first eliminated any duplicates from my multiple PubMed searches and the Google Scholar results. After the 156 duplicates were removed, I was left with 110 articles published in the last 20 years whose MeSH terms indicated a relation to my topic. I removed a single study for being written in German, and then began combing through the remaining papers, removing meta-analyses and reviews, those studies with a different study focus, and papers that weren't case-control or cohort studies. After this process, I was left with 8 articles published between 2000 and 2020 with a focused research on vegetarian diets and type 2 diabetes incidence. Seven of these articles used data from prospective cohort studies and one article was a case-control analysis.

To assess the data from these studies, I used Microsoft Excel to create several forest plots. In addition to analyzing the assorted hazard ratios to investigate my main research question, I also completed several subgroup analyses: one comparing the protective effects of a vegetarian diet to those from a vegan diet, and the other comparing vegetarianism as a protective factor in male and female populations.

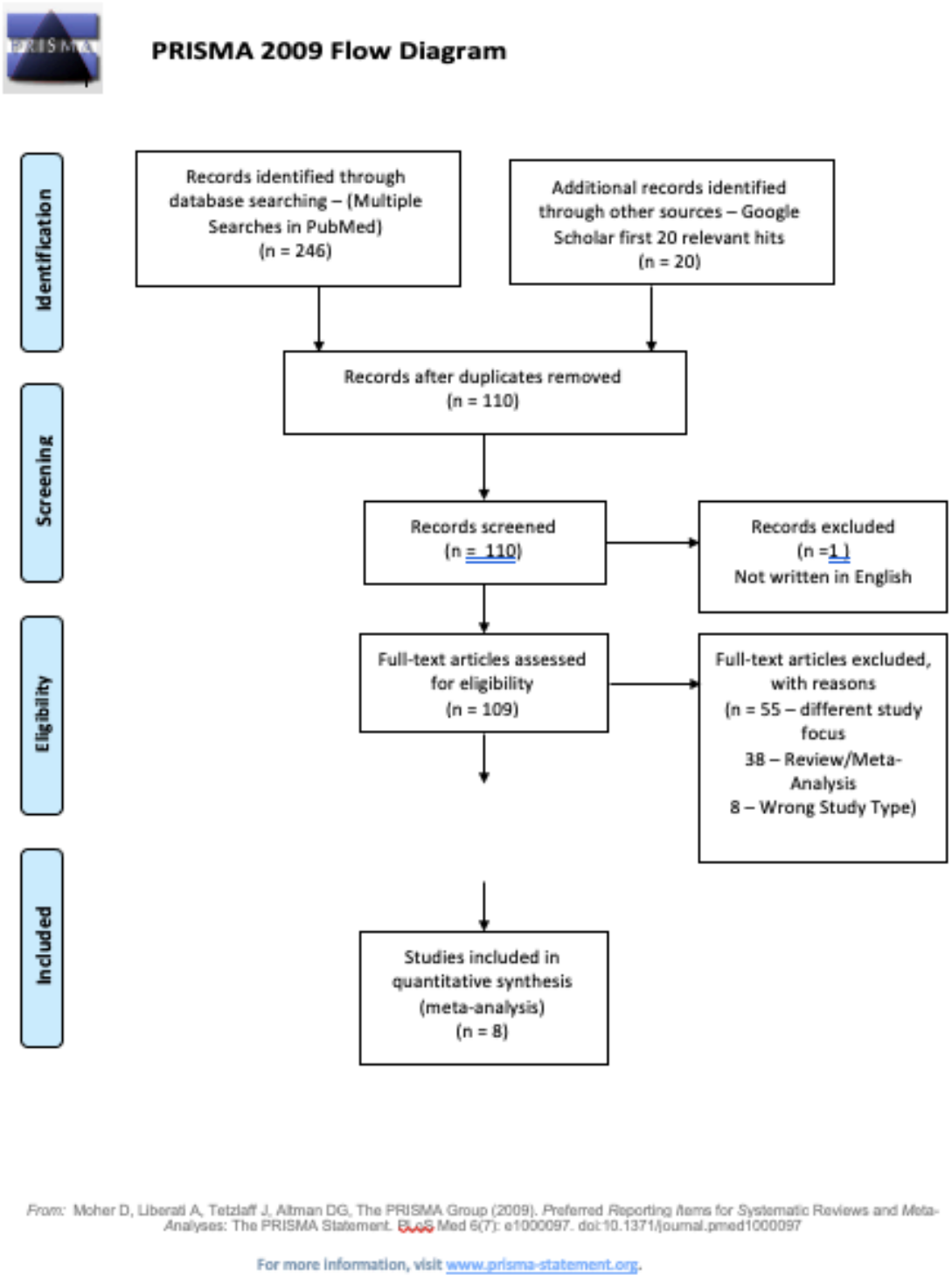

Figure 1: PRISMA 2009 flow diagram used to process papers for this investigation.

Results:

I have summarized the main features of the 8 papers I explored in **Table 1**. The majority of the papers I examined were prospective cohort studies, which provide good evidence for causality as cases develop years after the initial recruitment into the study. Half the studies I examined were completed in either the United States or Canada, with the other studies being completed in Asia and Europe. While I thought it might be interesting to compare results from the U.S. to results gathered from other countries, I decided against it because of the increased variability between the Netherlands, the United Kingdom, Iran, and Taiwan.

Despite this bias towards countries in North America, many of the studies were able to garner considerable sample sizes, decreasing the risk of incurring a type II error. All of these studies also used similar methods for assessment of diabetes and vegetarianism, though there were some minor differences in the questionnaires given. All of the studies used an official diagnosis from a medical professional as an indicator of development of type 2 diabetes, however, Chiu (2018), additionally defined a diagnosis if the participant indicated an HbA1C of above or equal to 6.5%. Similarly, to assess vegetarianism, all studies used some variety of a food frequency questionnaire in which participants were asked to indicate how often they ate certain foods on a weekly or daily basis in the previous year(s). From this, the studies were able to define vegetarian individuals as those that did not indicate consuming meat or fish in their questionnaire. Some studies increased their distinction of vegetarian diets. For example, Zamani (2019) and Satija (2016) used a Plant Based Diet Index to create subsets of a “healthy” plant-based diet, defined as one with larger consumption levels of fresh fruit and leafy greens, and an “unhealthy” plant-based diet as one which focused on pasta or other processed foods. Others, like Tonstad (2009; 2013)

and Papier (2019), differentiated vegan from vegetarian diets, which I used for further sub-group analyses.

Author	Year	Location	Study Type	Sample Size	Method of Assessment of Diabetes	Method of Assessment of Vegetarianism	Unadjusted Stats	Adjusted Stats	Subgroups
Zamani	2019	Isfashan, Iran	Case Control	460	Diagnosis of GDM by hospital	Dietary intake taken with use of three-day food diaries between the 25th and 28th week of pregnancy. Three indexes were calculated: overall Plant-based Diet Index (PDI), healthful PDI (hPDI), and unhealthful PDI (uPDI).	OR: PDI: 0.50 (0.31-0.80); hPDI: 1.07 (0.68-1.67); uPDI: 1.41 (0.89-2.23)	PDI: 0.47 (0.28-0.78); hPDI: 1.03 (0.64-1.65); uPDI: 1.65 (0.98-2.78) - Adjusted for age, energy intake, smoking status, number of children, and BMI	PDI; hPDI; uPDI; women
Vang	2008	California, USA	Prospective Cohort	8,401	Cases defined based on answers to disease history criteria in follow-up questionnaire (given after 16 years)	Food frequency intake questionnaire with specifics about animal products eaten per week/per day.	OR: Self-Calculated: 0.86 (0.72-1.03)	Study provided Age and Sex Adjusted Statistics - I could not do so as I calculated this OR myself from the data	looked at consumption of all meats, processed meats, and long-term adherence to a certain diet – Baseline BMI by weight change
Chen	2018	Rotterdam, The Netherlands	Prospective Cohort	6,770	Diagnosis of Diabetes in followup (every 3-5 years)	Food frequency questionnaire and plant-based diet index score.	Not provided - First model is adjusted for energy intake, sex, age, and RS sub-cohort: HR: 0.82 (0.73-0.92)	HR: 0.87 (0.79-0.99) - Adjusted for energy intake, sex, age, RS study cohort, education, smoking status, family history of diabetes, physical activity, food supplement use, and BMI	
Satija	2016	USA	Prospective Cohort	200,727	Indication of diabetes diagnosis in follow up; Participants who self-reported physician-diagnoses diabetes were sent a supplementary questionnaire with established validity to confirm diagnosis.	Food frequency questionnaire and plant-based diet index score.	Not - provided - Age adjusted HR per decile: 0.76 (0.74-0.79)	Adjusted for age, smoking status, physical activity, alcohol intake, multivitamin use, family history of diabetes, margarine intake, energy intake, baseline hypertension, baseline hypercholesterolemia, menopausal status in	pDI; hPDI; uPDI – Age, family history of T2D, physical activity, BMI

								women, and BMI - HR: 0.88 (0.86-0.91)	
Tonstad	2009	USA and Canada	Prospective Cohort	60,903	Self-reporting of diabetes in follow-up	Food frequency questionnaire.	Self-calculated OR: vegans: 0.36 (0.29, 0.45); lacto-ovo vegetarians: 0.40 (0.37, 0.44); pesco-vegetarians: 0.61 (0.54, 0.69); semivegetarians: 0.79 (0.68, 0.92)	Adjusted for a number of socioeconomic and lifestyle factors - HR - vegan: 0.51 (0.40-0.66); lacto-ovo vegetarian: 0.54 (0.49-0.60); pesco-vegetarian: 0.70 (0.61-0.80); semi-vegetarian: 0.76 (0.65-0.90)	Subgroups depending on intensity of vegetarian/vegan diet
Chiu	2018	Taiwan	Prospective Cohort	2,918	Cases defined if participants reported diabetes diagnosis at follow-up questionnaires or if their HbA1C was greater or equal to 6.5%	Food frequency questionnaire	HR: 0.59 (0.42-0.82)	Adjusted for age, gender, education, leisure time physical activities, family history of diabetes, follow-up methods, lipid medication, and BMI - HR: 0.65 (0.46-0.92)	Subgroup analysis by gender; BMI, metabolic syndrome, fatty liver,
Tonstad	2013	USA and Canada	Prospective Cohort	41, 387	Self-reporting of diabetes in follow-up	Food frequency questionnaire.	Self-calculated OR vegans: 0.25 (0.157-0.397); lacto-ovo vegetarian 0.497 (0.411, 0.601); pesco-vegetarian 0.60 (0.44, 0.81); semi-vegetarian: 0.43 (0.28, 0.66)	Adjusted for a number of socioeconomic and lifestyle factors - OR - vegan: 0.381 (0.236-0.617); lacto-ovo vegetarian: 0.618 (0.503-0.760); pesco-vegetarian: 0.790 (0.575-1.08); semi-vegetarian: 0.486 (0.312-0.755)	Black, Non-black; different varieties of vegetarian diet.
Papier	2019	United Kingdom	Prospective Cohort	65,411	Diabetes status ascertained through health status linkage	Food frequency questionnaire.	Self-Calculated - OR: 0.354 (0.31- 0.41)	Stratified by sex, method of recruitment, region of residence and adjusted for age, education, Townsend deprivation index, ethnicity, smoking, alcohol intake, and physical activity. HR: 0.63 (0.54-0.74)	Subgroup analysis by gender, age, BMI, smoking status, education level and diet type - vegans and vegetarians combined in this study due to small numbers but vegans also analyzed separately.

In addition to reviewing the major trends in the papers I identified in **Table 1**, I also created a forest plot (**Figure 2**) of the hazard ratios (HRs) evaluating the effect of vegetarian diets on the risk of type 2 diabetes. In order to analyze the data in this way, some of the data had to be modified from its original version. Vang et al. (2008), specifically, examined the relationship of meat consumption to type 2 diabetes incidence. Instead of using a diet with meat as the control, the control for the study's odds ratio was vegetarianism. Thus, in order to effectively include this paper in my study, I needed to self-calculate the odds ratio using a vegetarian diet as the exposure instead. Furthermore, the two Tonstad papers (2009; 2013), used several sub-groups related to vegetarianism, including lacto-ovo vegetarianism, pesco-vegetarianism, and semi-vegetarianism. For the overall forest plot, I used the statistics related to lacto-ovo vegetarianism, as I believe that diet to ascribe most closely to the definitions of vegetarianism in the other studies I examined. Finally, in the papers that used a plant-based diet index (PDI) (Satija et. al, 2016; Zamani et. al, 2019), I used the hazard ratios associated with the overall PDI rather than those associated with a "healthy" or "unhealthy" plant-based diet.

Nearly all the papers I examined in this study were able to reject the null hypothesis that there is no relation between a vegetarian diet and the incidence of type 2 diabetes. Vang et. al (2008) is the only paper to violate this pattern. Of these significant studies, all of them show vegetarianism as a protective factor against the risk of developing type 2 diabetes, though to varying degrees. While there is some variability in the hazard ratios, individuals following a vegetarian diet seem to be about 25% less likely to develop type 2 diabetes than individuals who follow a traditional diet. With such agreement in these results, a protective relationship of vegetarianism in relation to type 2 diabetes is supported.

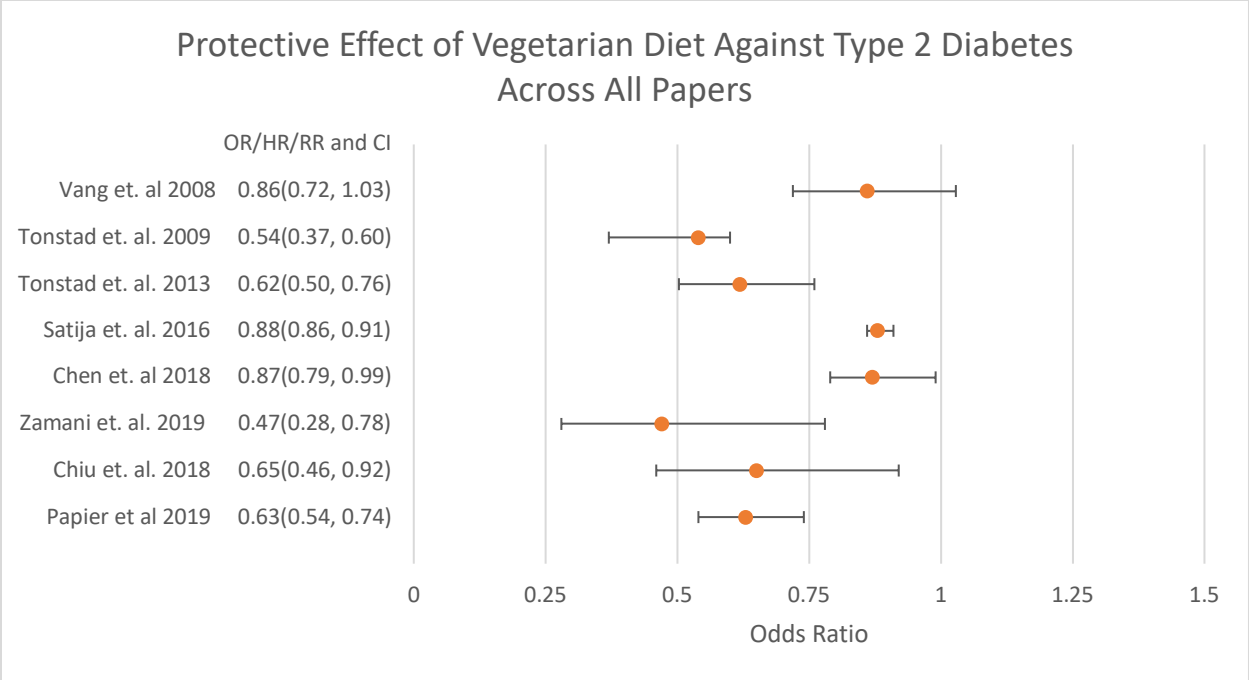

Figure 2: Protective Effect of a Vegetarian Diet Against the Incidence of Type 2 Diabetes Across All Papers. Seven of the eight papers examined found a significant relationship between vegetarianism and a reduced incidence of type 2 diabetes. Though there was variability between the papers examined, generally, vegetarianism seems to reduce the risk of developing type two diabetes by about 25%.

In addition to my primary analysis of vegetarianism as a protective factor against type 2 diabetes, I also completed additional subgroup analyses, the first of which being a comparison of the protection offered by a vegan diet to that provided by a vegetarian diet (**Figure 3**). Though vegan and vegetarian diets both exclude meat and fish, vegan diets also restrict the intake of other animal products, such as milk, cheese, and eggs. These foods, some varieties of which can be high in fat and salt, may also contribute to an increase in incidence of diabetes in the populations that consume them. Additionally, comparing the protective effects of these two diets could help narrow down associations between diet and diabetes incidence.

As expected, both vegetarian diets (shown in orange) and vegan diets (shown in blue) had a significant protective effect against type 2 diabetes incidence in the studies that analyzed them. Based on the distribution of the data points, vegan diets do seem to offer an increased protective

effect against type 2 diabetes than vegetarian diets. Overall, it seems that those following a vegan diet are 10% less likely to develop type 2 diabetes than those following a vegetarian diet. From this graph, it seems that the consumption of any meat products somewhat increases the risk for developing type 2 diabetes and, conversely, the restriction of these animal-based products will reduce the risk of developing type 2 diabetes.

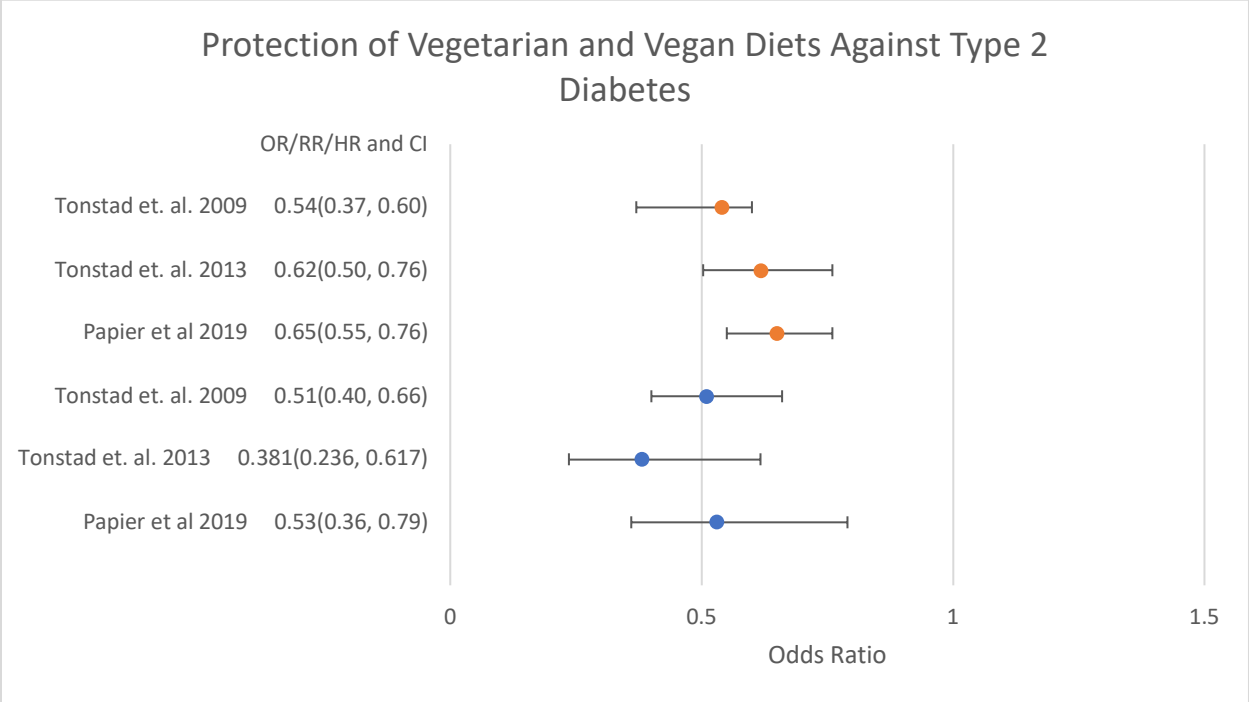

Figure 3: Comparison of the Protection Offered by Vegetarian and Vegan Diets Against Type 2 Diabetes. Three studies completed subgroup analyses of the separate protective effects offered by vegetarian and vegan diets. In order to compare the influence of each diet, I created a forest plot mapping the hazard ratios and associated confidence intervals of solely vegetarian diets (shown in orange) and vegan diets (shown in blue). From the plot, people following vegan diets are about 10% less likely to be diagnosed with type 2 diabetes that people following vegetarian diets.

Finally, I examined gender as another possible subgroup for diabetes incidence associated with diet. This forest plot is shown in **Figure 4.** From this analysis, I sought to determine whether the protection offered by a vegetarian diet was limited to a specific gender. While I did not expect to see a difference associated with gender, examining this association remains informative. The vast majority of individuals who choose to follow a vegetarian diet are female, which has been

theorized to be associated with the hyper-masculinization of meat in pop culture and social media (Brady and Ventresca, 2014). As a result of these social influences, which encourage men to ascribe "manliness" to activities such as appreciating a steak dinner or knowing how to grill a burger, men may be less likely to pursue a vegetarian diet. However, if diabetes incidence in men following a vegetarian diet (shown in orange) decreases as much as it does for women on the same diet (shown in blue), men may be more likely to reduce their consumption of meat as a preventative means despite these social pressures.

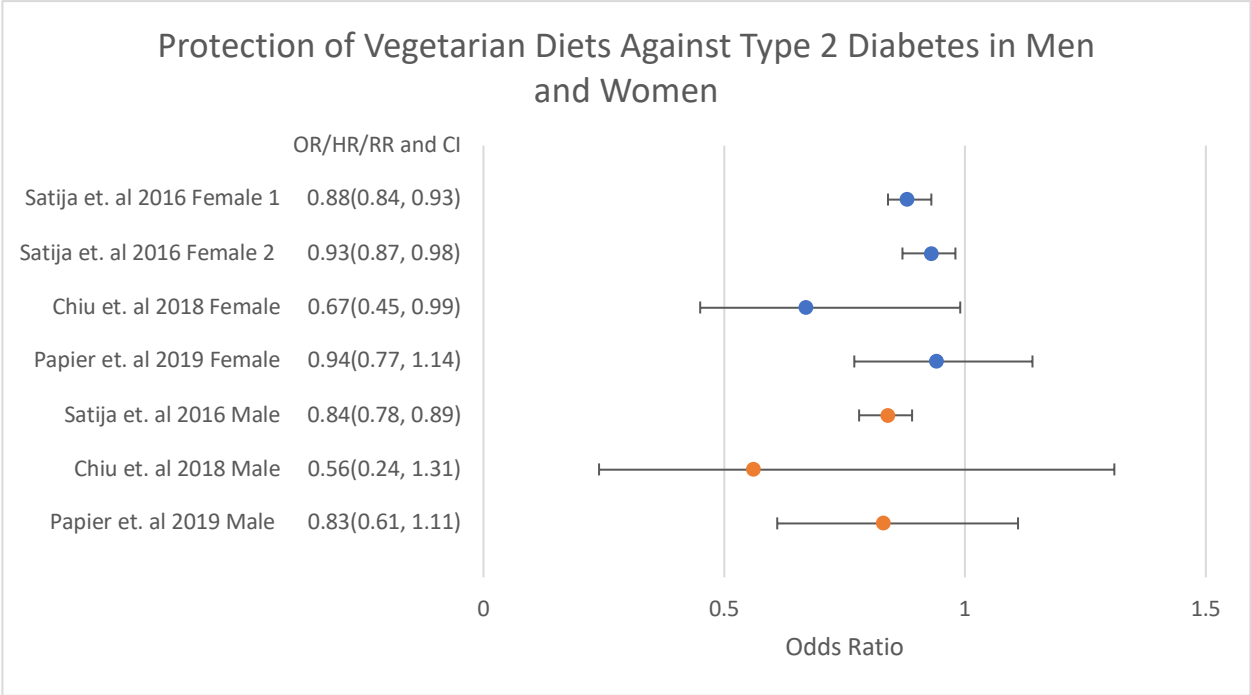

Figure 4: Comparison of the protection offered by vegetarian diets against the incidence of type 2 diabetes in men and women. Three studies completed sub-group analyses by gender in their assessment of the protection offered by a vegetarian diet against type 2 diabetes. Satija et. al (2016) is included twice in this plot because the two different all-female cohorts were analyzed separately in the study. Statistics associated with female participants are shown in clue while statistics associated with male participants are shown in orange. Four of the studies were able to find a significant association between vegetarian diet and protection against the incidence of type 2 diabetes. There is an increase in variability in the male studies, which may result from the relatively fewer numbers of vegetarian males compared to vegetarian females. From the significant results shown in this plot, however, men and women seem to be offered similar protective effects against type 2 diabetes when adhering to a vegetarian diet.

Three of the seven studies I examined related to gender were unable to reject the null hypothesis that there is no relation between vegetarianism and the risk of developing type 2 diabetes. It is worth noting that 7 subgroups were included in the comparison rather than 6 because

the 2 female cohorts in Satija et. al. (2016) were analyzed separately in the study. This being said, however, the 4 remaining studies showed that vegetarian diets did have a protective effect against the incidence of type 2 diabetes in men and women. From these significant results, the protective effect in men seems to be about the same in men and women, though it is difficult to tell with only one significant result in the male group. From these studies, I would conclude that vegetarian diets seem to offer the same protective effect against the incidence of type 2 diabetes in men and women, I encourage additional investigations to further elucidate this relationship.

Summary and Conclusion:

From my examination of these studies, I found an overwhelmingly significant protective benefit of vegetarianism against type 2 diabetes. Almost all of the 8 studies I examined found that a vegetarian diet offered a statistically significant level of protection against developing type 2 diabetes. This protection was given at about the same level to both male and female populations, but there was a slight increase in protection offered by vegan diets compared to vegetarian diets, which suggests that all animal-based products, and not just meat itself, might contribute to the risk of developing type 2 diabetes.

Though these results seem fairly conclusive, there are some issues with my current investigation. As I indicated in my results section, half the studies I examined were focused on populations in North America. Though the information gathered from these studies remains valuable, it is unclear whether these patterns are applicable to other areas outside this study. Countries in the Southern Hemisphere were completely missing from this study, and while some results may be transcribed onto populations in those regions, the relationship between

vegetarianism and diabetes in those countries remains unclear, and additional studies investigating this relationship should be completed in those countries to avoid possible selection bias.

There may also be a factor of confounding in this study. Obesity is a known risk factor for diabetes, and individuals on a vegetarian or vegan diet might inherently be at less risk for becoming obese, which would, in turn, decrease their risk for developing type 2 diabetes. Though some of the studies I investigated controlled for factors like physical activity and BMI, there were others which failed to do so or which I was unable to complete because I calculated the odds ratio myself. Additionally, though these studies controlled for BMI, not all of them provided subgroups with associations by BMI levels. This being said, however, of the studies that did control for BMI and physical activity as possible confounders, the protective relationship of vegetarianism against type 2 diabetes was still statistically significant.

A further avenue for future study could explore the differing effects of additional varieties of vegetarian diets. While Tonstad et. al (2009; 2013) was able to divide their investigation into groups of vegans, lacto-ovo vegetarians, pesco vegetarians, and semi-vegetarians, not all studies offered this level of specificity and, because there was a slight difference in the protective effect offered by vegan and vegetarian diets, it may be insightful to explore these other variations of plant-based diets. Additionally, studies could further explore the differences between "healthy" and "unhealthy" plant-based diets, as Zamani (2019) and Satija (2016) did. Though not specifically analyzed in my study due to the infrequency of its analysis, it would be worthwhile to explore more literature on this association to determine an overall assessment.

Though there may have been some selection bias and confounding present in my study, I am still confident in my conclusion that vegetarianism provides a protective benefit against the incidence of type 2 diabetes. The majority of the papers I examined were prospective cohort

studies. These are studies in which a specific population is followed from the time of exposure to a given variable to the time of development of some condition. In cohort studies, temporality is clear, which allows researchers to infer effects from certain exposures rather than mere correlations. In addition to cohort studies, I examined one case-control study. Case-control studies, unlike cohort studies, follow in logic from effect to potential cause and the odds of being exposed to a certain risk factor is estimated. Because the majority of studies I examined were prospective cohort studies, I am confident in my assessment of vegetarianism as a preventative factor against the incidence of type 2 diabetes.

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Appendix:

1. PLoS Med. 2016 Jun 14;13(6):e1002039. doi: 10.1371/journal.pmed.1002039. eCollection 2016 Jun.

   Plant-Based Dietary Patterns and Incidence of Type 2 Diabetes in US Men and Women: Results from Three Prospective Cohort Studies.
   Satija A(1)(2), Bhupathiraju SN(1), Rimm EB(1)(2)(3), Spiegelman D(1)(2)(3)(4)(5), Chiuve SE(1)(2)(6), Borgi L(7), Willett WC(1)(2)(3), Manson JE(2)(6)(8), Sun Q(1)(3), Hu FB(1)(2)(3).
   Author information:
   (1)Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, United States of America.

(2)Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, United States of America.
(3)Channing Division of Network Medicine, Department of Medicine, Brigham and Women's Hospital, Boston, Massachusetts, United States of America.
(4)Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, United States of America.
(5)Department of Global Health, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, United States of America.
(6)Division of Preventive Medicine, Department of Medicine, Brigham and Women's Hospital, Boston, Massachusetts, United States of America.
(7)Renal Division, Brigham and Women's Hospital, Boston, Massachusetts, United States of America.
(8)Harvard Medical School, Boston, Massachusetts, United States of America.

BACKGROUND: Plant-based diets have been recommended to reduce the risk of type 2 diabetes (T2D). However, not all plant foods are necessarily beneficial. We examined the association of an overall plant-based diet and hypothesized healthful and unhealthful versions of a plant-based diet with T2D incidence in three prospective cohort studies in the US.
METHODS AND FINDINGS: We included 69,949 women from the Nurses' Health Study (1984-2012), 90,239 women from the Nurses' Health Study 2 (1991-2011), and 40,539 men from the Health Professionals Follow-Up Study (1986-2010), free of chronic diseases at baseline. Dietary data were collected every 2-4 y using a semi-quantitative food frequency questionnaire. Using these data, we created an overall plant-based diet index (PDI), where plant foods received positive scores, while animal foods (animal fats, dairy, eggs, fish/seafood, poultry/red meat, miscellaneous animal-based foods) received reverse scores. We also created a healthful plant-based diet index (hPDI), where healthy plant foods (whole grains, fruits, vegetables, nuts, legumes, vegetable oils, tea/coffee) received positive scores, while less healthy plant foods (fruit juices, sweetened beverages, refined grains, potatoes, sweets/desserts) and animal foods received reverse scores. Lastly, we created an unhealthful plant-based diet index (uPDI) by assigning positive scores to less healthy plant foods and reverse scores to healthy plant foods and animal foods. We documented 16,162 incident T2D cases during 4,102,369 person-years of follow-up. In pooled multivariable-adjusted analysis, both PDI and hPDI were inversely associated with T2D (PDI: hazard ratio [HR] for extreme deciles 0.51, 95% CI 0.47-0.55, p trend < 0.001; hPDI: HR for extreme deciles 0.55, 95% CI 0.51-0.59, p trend < 0.001). The association of T2D with PDI was considerably attenuated when we additionally adjusted for body mass index (BMI) categories (HR 0.80, 95% CI 0.74-0.87, p trend < 0.001), while that with hPDI remained largely unchanged (HR 0.66, 95% CI 0.61-0.72, p trend < 0.001). uPDI was positively associated with T2D even after BMI adjustment (HR for extreme deciles 1.16, 95% CI 1.08-1.25, p trend < 0.001). Limitations of the study include self-reported diet assessment, with the possibility of measurement error, and the potential for residual or unmeasured confounding given the observational nature of the study design.
CONCLUSIONS: Our study suggests that plant-based diets, especially when rich in high-quality plant foods, are associated with substantially lower risk of developing T2D. This

supports current recommendations to shift to diets rich in healthy plant foods, with lower intake of less healthy plant and animal foods.

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PMCID: PMC4907448
PMID: 27299701 [Indexed for MEDLINE]

Conflict of interest statement: All authors have read the journal's policy and have the following competing interests: EBR received a research grant from the USDA/Blueberry Highbush Council.

2. Nutr Diet. 2019 Nov;76(5):589-596. doi: 10.1111/1747-0080.12512. Epub 2019 Jan 24.

Association of a plant-based dietary pattern in relation to gestational diabetes mellitus. Zamani B(1)(2), Milajerdi A(1), Tehrani H(3), Bellissimo N(4), Brett NR(4), Azadbakht L(1)(5)(6).

Author information:
(1)Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran.
(2)Students' Scientific Research Center (SSRC), Tehran University of Medical Sciences (TUMS), Tehran, Iran.
(3)Department of Obstetrics and Gynaecology, Isfahan University of Medical Sciences, Toronto, Isfahan, Iran.
(4)School of Nutrition, Ryerson University, Toronto, Ontario, Canada.
(5)Diabetes Research Centre, Endocrinology and Metabolism Clinical Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.
(6)Food Security Research Centre and Department of Community Nutrition, School of Nutrition and Food Science, Isfahan University of Medical Sciences, Isfahan, Iran.

AIM: The prevalence of gestational diabetes mellitus (GDM), which has adverse effects on mothers and their offspring, is increasing worldwide. The role of a plant-based dietary pattern as a determinant of GDM is not well understood. Therefore, we examined the association between plant-based dietary patterns and the risk of GDM.
METHODS: We enrolled 460 pregnant women in this case-control study, of them 200 were cases and 260 were controls. Dietary intake of participants was evaluated using three 24-hour dietary records. Adherence to the plant-based dietary patterns was scored using three indices of the overall plant-based dietary index (PDI), healthy plant-based diet (hPDI) and unhealthy plant-based diet index (uPDI). The risk of GDM was compared across tertiles of PDI, hPDI and uPDI.
RESULTS: After multivariable adjustment, we demonstrated that the high PDI score was inversely associated with risk of GDM (OR = 0.47; 95% CI: 0.28-0.78, P =

0.004), but there was no significant association between hPDI (OR = 1.03; 95% CI: 0.64-1.65, P = 0.884) or uPDI (OR = 1.65; 95% CI: 0.98-2.78, P = 0.06) and GDM risk.
CONCLUSIONS: We found that following an overall plant-based diet was associated with lower risk of GDM. Future studies are warranted with longitudinal designs to confirm these findings.

DOI: 10.1111/1747-0080.12512
PMID: 30680868 [Indexed for MEDLINE]

3. Ann Nutr Metab. 2008;52(2):96-104. doi: 10.1159/000121365. Epub 2008 Mar 18.

Meats, processed meats, obesity, weight gain and occurrence of diabetes among adults: findings from Adventist Health Studies.

Vang A(1), Singh PN, Lee JW, Haddad EH, Brinegar CH.

Author information:
(1)Department of Health Promotion and Education, School of Public Health, Loma Linda University, Loma Linda, CA 92350, USA.

Erratum in
Ann Nutr Metab. 2010;56(3):232.

AIM: To examine the relation between meat intake and diabetes occurrence in adults.
METHODS: In a prospective cohort study we examined the relation between diet and incident diabetes recorded among 8,401 cohort members (ages 45-88 years) of the Adventist Mortality Study and Adventist Health Study (California, USA) who were non-diabetic at baseline. During the 17-year follow-up, we identified 543 incident diabetes cases.
RESULTS: (1) Subjects who were weekly consumers of all meats were 29% (OR = 1.29; 95% CI 1.08, 1.55) more likely (relative to zero meat intake) to develop diabetes. (2) Subjects who consumed any processed meats (salted fish and frankfurters) were 38% (OR = 1.38; 95% CI 1.05-1.82) more likely to develop diabetes. (3) Long-term adherence (over a 17-year interval) to a diet that included at least weekly meat intake was associated with a 74% increase (OR = 1.74; 95% CI 1.36-2.22) in odds of diabetes relative to long-term adherence to a vegetarian diet (zero meat intake). Further analyses indicated that some of this risk may be attributable to obesity and/or weight gain--both of which were strong risk factors in this cohort. It is noteworthy that even after control for weight and weight change, weekly meat intake remained an important risk factor (OR = 1.38; 95% CI 1.06-1.68) for diabetes [corrected].
CONCLUSIONS: Our findings raise the possibility that meat intake, particularly

processed meats, is a dietary risk factor for diabetes.

2008 S. Karger AG, Basel.

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PMID: 18349528 [Indexed for MEDLINE]

4. Eur J Epidemiol. 2018 Sep;33(9):883-893. doi: 10.1007/s10654-018-0414-8. Epub 2018 Jun 8.

Plant versus animal based diets and insulin resistance, prediabetes and type 2 diabetes: the Rotterdam Study.

Chen Z(1), Zuurmond MG(1), van der Schaft N(1), Nano J(1), Wijnhoven HAH(2), Ikram MA(1), Franco OH(1), Voortman T(3).

Author information:
(1)Department of Epidemiology, Erasmus University Medical Center, Office Na-2903, PO Box 2040, 3000 CA, Rotterdam, The Netherlands.
(2)Department of Health Sciences, Faculty of Earth and Life Sciences, Vrije Universiteit, Amsterdam, The Netherlands.
(3)Department of Epidemiology, Erasmus University Medical Center, Office Na-2903, PO Box 2040, 3000 CA, Rotterdam, The Netherlands. trudy.voortman@erasmusmc.nl.

Vegan or vegetarian diets have been suggested to reduce type 2 diabetes (T2D) risk. However, not much is known on whether variation in the degree of having a plant-based versus animal-based diet may be beneficial for prevention of T2D. We aimed to investigate whether level of adherence to a diet high in plant-based foods and low in animal-based foods is associated with insulin resistance, prediabetes, and T2D. Our analysis included 6798 participants (62.7 ± 7.8 years) from the Rotterdam Study (RS), a prospective population-based cohort in the Netherlands. Dietary intake data were collected with food-frequency questionnaires at baseline of three sub-cohorts of RS (RS-I-1: 1989-1993, RS-II-1: 2000-2001, RS-III-1: 2006-2008). We constructed a continuous plant-based dietary index (range 0-92) assessing adherence to a plant-based versus animal-based diet. Insulin resistance at baseline and follow-up was assessed using homeostasis model assessment of insulin resistance (HOMA-IR). Prediabetes and T2D were collected from general practitioners' records, pharmacies' databases, and follow-up examinations in our research center until 2012. We used multivariable linear mixed models to examine association of the index with longitudinal HOMA-IR, and multivariable Cox proportional-hazards regression models to examine associations of the index with risk of prediabetes and T2D. During median 5.7, and 7.3 years of follow-up, we documented 928 prediabetes cases and 642 T2D cases. After adjusting for sociodemographic and lifestyle factors, a higher score on the plant-based dietary index was

associated with lower insulin resistance (per 10 units higher score: β = -0.09; 95% CI: - 0.10; - 0.08), lower prediabetes risk (HR = 0.89; 95% CI: 0.81; 0.98), and lower T2D risk [HR = 0.82 (0.73; 0.92)]. After additional adjustment for BMI, associations attenuated and remained statistically significant for longitudinal insulin resistance [β = -0.05 (- 0.06; - 0.04)] and T2D risk [HR = 0.87 (0.79; 0.99)], but no longer for prediabetes risk [HR = 0.93 (0.85; 1.03)]. In conclusion, a more plant-based and less animal-based diet may lower risk of insulin resistance, prediabetes and T2D. These findings strengthen recent dietary recommendations to adopt a more plant-based diet.Clinical Trial Registry number and website NTR6831, http://www.trialregister.nl/trialreg/admin/rctview.asp?TC=6831 .

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PMID: 29948369 [Indexed for MEDLINE]

Conflict of interest statement: CONFLICT OF INTEREST: No conflict of interest. ETHICAL APPROVAL: The Rotterdam Study has been approved by the institutional review board (Medical Ethics Committee) of the Erasmus Medical Center and by the review board of The Netherlands Ministry of Health, Welfare and Sports. The approval has been renewed every 5 years. All participants gave informed consent.

5. Diabetes Care. 2009 May;32(5):791-6. doi: 10.2337/dc08-1886. Epub 2009 Apr 7.

Type of vegetarian diet, body weight, and prevalence of type 2 diabetes.

Tonstad S(1), Butler T, Yan R, Fraser GE.

Author information:
(1)Department of Health Promotion and Education, School of Public Health, Loma Linda University, Loma Linda, California, USA. stonstad@llu.edu

OBJECTIVE: We assessed the prevalence of type 2 diabetes in people following different types of vegetarian diets compared with that in nonvegetarians.
RESEARCH DESIGN AND METHODS: The study population comprised 22,434 men and
38,469 women who participated in the Adventist Health Study-2 conducted in 2002-2006. We collected self-reported demographic, anthropometric, medical history, and lifestyle data from Seventh-Day Adventist church members across North America. The type of vegetarian diet was categorized based on a food-frequency questionnaire. We calculated odds ratios (ORs) and 95% CIs using multivariate-adjusted logistic regression.
RESULTS: Mean BMI was lowest in vegans (23.6 kg/m(2)) and incrementally higher in lacto-ovo vegetarians (25.7 kg/m(2)), pesco-vegetarians (26.3 kg/m(2)), semi-vegetarians (27.3 kg/m(2)), and nonvegetarians (28.8 kg/m(2)). Prevalence of type 2 diabetes increased from 2.9% in vegans to 7.6% in nonvegetarians; the

prevalence was intermediate in participants consuming lacto-ovo (3.2%), pesco (4.8%), or semi-vegetarian (6.1%) diets. After adjustment for age, sex, ethnicity, education, income, physical activity, television watching, sleep habits, alcohol use, and BMI, vegans (OR 0.51 [95% CI 0.40-0.66]), lacto-ovo vegetarians (0.54 [0.49-0.60]), pesco-vegetarians (0.70 [0.61-0.80]), and semi-vegetarians (0.76 [0.65-0.90]) had a lower risk of type 2 diabetes than nonvegetarians.
CONCLUSIONS: The 5-unit BMI difference between vegans and nonvegetarians indicates a substantial potential of vegetarianism to protect against obesity. Increased conformity to vegetarian diets protected against risk of type 2 diabetes after lifestyle characteristics and BMI were taken into account. Pesco- and semi-vegetarian diets afforded intermediate protection.

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6. Nutr Diabetes. 2018 Mar 9;8(1):12. doi: 10.1038/s41387-018-0022-4.

Vegetarian diet, change in dietary patterns, and diabetes risk: a prospective study.

Chiu THT(1)(2)(3), Pan WH(2)(4), Lin MN(5)(6), Lin CL(7)(8).

Author information:
(1)Department of Nutrition Therapy, Dalin Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation. No. 2, Min-Sheng Road, Dalin Town, Chiayi County, 622, Taiwan.
(2)Graduate Institute of Epidemiology and Preventive Medicine, National Taiwan University, No. 17, Xu-Zhou Road, Taipei, 100, Taiwan.
(3)Department of Medicine, College of Medicine, Tzu Chi University, Hualien, Taiwan. No.701, Sec. 3, Chung Yang Road, Hualien, 970, Taiwan.
(4)Institute of Biomedical Sciences, Academia Sinica, Address: 128 Sec. 2, Academia Road, Nankang, Taipei, 115, Taiwan.
(5)Department of Family Medicine, Dalin Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation. No. 2, Min-Sheng Road, Dalin Town, Chiayi County, 622, Taiwan. mingnan.lin@gmail.com.
(6)Department of Family Medicine, College of Medicine, Tzu Chi University, Hualien, Taiwan. No.701, Sec. 3, Chung Yang Road, Hualien, 970, Taiwan. mingnan.lin@gmail.com.
(7)Department of Internal Medicine, Hualien Tzu Chi Medical Center, Hualien, Taiwan. No. 707, Sec. 3, Chung Yang Road, Hualien, 970, Taiwan.
(8)Department of Internal Medicine, College of Medicine, Tzu Chi University, Hualien, Taiwan. No.701, Sec. 3, Chung Yang Road, Hualien, 970, Taiwan.

BACKGROUND/OBJECTIVES: Vegetarian diets are inversely associated with diabetes

in Westerners but their impact on Asians-whose pathophysiology differ from Westerners-is unknown. We aim to investigate the association between a vegetarian diet, change in dietary patterns and diabetes risk in a Taiwanese Buddhist population.
METHODS: We prospectively followed 2918 non-smoking, non-alcohol drinking Buddhists free of diabetes, cancer, and cardiovascular diseases at baseline, for a median of 5 years, with 183 incident diabetes cases confirmed. Diet was assessed through a validated food frequency questionnaire at baseline and a simple questionnaire during follow-ups. Incident cases of diabetes were ascertained through follow-up questionnaires, fasting glucose and HbA1C. Stratified Cox Proportional Hazards Regression was used to assess the effect of diets on risk of diabetes.
RESULTS: Consistent vegetarian diet was associated with 35% lower hazards (HR: 0.65, 95% CI: 0.46, 0.92), while converting from a nonvegetarian to a vegetarian pattern was associated with 53% lower hazards (HR: 0.47, 95% CI: 0.30, 0.71) for diabetes, comparing with nonvegetarians while adjusting for age, gender, education, physical activity, family history of diabetes, follow-up methods, use of lipid-lowering medications, and baseline BMI.
CONCLUSION: Vegetarian diet and converting to vegetarian diet may protect against diabetes independent of BMI among Taiwanese.

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7. Nutr Metab Cardiovasc Dis. 2013 Apr;23(4):292-9. doi: 10.1016/j.numecd.2011.07.004. Epub 2011 Oct 7.

Vegetarian diets and incidence of diabetes in the Adventist Health Study-2.

Tonstad S(1), Stewart K, Oda K, Batech M, Herring RP, Fraser GE.

Author information:
(1)Loma Linda University School of Public Health, Department of Health Promotion and Education, Loma Linda, CA 92354, USA. stonstad@llu.edu

AIM: To evaluate the relationship of diet to incident diabetes among non-Black and Black participants in the Adventist Health Study-2.
METHODS AND RESULTS: Participants were 15,200 men and 26,187 women (17.3% Blacks) across the U.S. and Canada who were free of diabetes and who provided demographic, anthropometric, lifestyle and dietary data. Participants were

grouped as vegan, lacto ovo vegetarian, pesco vegetarian, semi-vegetarian or non-vegetarian (reference group). A follow-up questionnaire after two years elicited information on the development of diabetes. Cases of diabetes developed in 0.54% of vegans, 1.08% of lacto ovo vegetarians, 1.29% of pesco vegetarians, 0.92% of semi-vegetarians and 2.12% of non-vegetarians. Blacks had an increased risk compared to non-Blacks (odds ratio [OR] 1.364; 95% confidence interval [CI], 1.093-1.702). In multiple logistic regression analysis controlling for age, gender, education, income, television watching, physical activity, sleep, alcohol use, smoking and BMI, vegans (OR 0.381; 95% CI 0.236-0.617), lacto ovo vegetarians (OR 0.618; 95% CI 0.503-0.760) and semi-vegetarians (OR 0.486, 95% CI 0.312-0.755) had a lower risk of diabetes than non-vegetarians. In non-Blacks vegan, lacto ovo and semi-vegetarian diets were protective against diabetes (OR 0.429, 95% CI 0.249-0.740; OR 0.684, 95% CI 0.542-0.862; OR 0.501, 95% CI 0.303-0.827); among Blacks vegan and lacto ovo vegetarian diets were protective (OR 0.304, 95% CI 0.110-0.842; OR 0.472, 95% CI 0.270-0.825). These associations were strengthened when BMI was removed from the analyses.
CONCLUSION: Vegetarian diets (vegan, lacto ovo, semi-) were associated with a substantial and independent reduction in diabetes incidence. In Blacks the dimension of the protection associated with vegetarian diets was as great as the excess risk associated with Black ethnicity.

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8. Nutr Diabetes. 2019 Feb 25;9(1):7. doi: 10.1038/s41387-019-0074-0.

Vegetarian diets and risk of hospitalisation or death with diabetes in British adults: results from the EPIC-Oxford study.

Papier K(1), Appleby PN(2), Fensom GK(2), Knuppel A(2), Perez-Cornago A(2), Schmidt JA(2), Tong TYN(2), Key TJ(2).

Author information:
(1)Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, Richard Doll Building, Old Road Campus, Oxford, UK. Keren.Papier@ndph.ox.ac.uk.
(2)Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, Richard Doll Building, Old Road Campus, Oxford, UK.

BACKGROUND: The global prevalence of diabetes is high and rapidly increasing. Some previous studies have found that vegetarians might have a lower risk of diabetes than non-vegetarians.

OBJECTIVE: We examined the association between vegetarianism and risk of hospitalisation or death with diabetes in a large, prospective cohort study of British adults.

METHODS: The analysed cohort included participants from the European Prospective Investigation into Cancer and Nutrition (EPIC)-Oxford study who were diabetes free at recruitment (1993-2001), with available dietary intake data at baseline, and linked hospital admissions and death data for diabetes over follow-up (n = 45,314). Participants were categorised as regular meat eaters (≥50 g per day: n = 15,181); low meat eaters (<50 g of meat per day: n = 7615); fish eaters (ate no meat but consumed fish: n = 7092); and vegetarians (ate no meat or fish, including vegans: n = 15,426). We used multivariable Cox proportional hazards models to assess associations between diet group and risk of diabetes.

RESULTS: Over a mean of 17.6 years of follow-up, 1224 incident cases of diabetes were recorded. Compared with regular meat eaters, the low meat eaters, fish eaters, and vegetarians were less likely to develop diabetes (hazard ratio (HR) = 0.63, 95% confidence interval (CI) 0.54-0.75; HR = 0.47, 95% CI 0.38-0.59; and HR = 0.63, 95% CI 0.54-0.74, respectively). These associations were substantially attenuated after adjusting for body mass index (BMI) (low meat eaters: HR = 0.78, 95% CI 0.66-0.92; fish eaters: HR = 0.64, 95% CI 0.51-0.80; and vegetarians: HR = 0.89, 95% CI 0.76-1.05).

CONCLUSIONS: Low meat and non-meat eaters had a lower risk of diabetes, in part because of a lower BMI.

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