Title: A systematic review on the relations between pasta consumption and cardio-metabolic risk factors

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ABSTRACT

Aims: The traditional Italian dish pasta is major food source of starch with low glycemic index (GI), and also an important low-GI component of the Mediterranean diet. This systematic review aimed at assessing comprehensively and in-depth the potential benefit of pasta on cardio-metabolic disease risk factors.

Data Synthesis: Following a standard protocol, we conducted a systematic literature search of PubMed, CINAHL, and Cochrane Central Register of Controlled Trials, for prospective cohort studies and randomized controlled dietary intervention trials that examined pasta, and pasta-related fiber and grain intake in relation to cardio-metabolic risk factors of interest. Studies evaluating postprandial glucose response to pasta compared to bread or potato were quantitatively summarized using meta-analysis of standardized mean difference. Evidence from studies with pasta as part of low-GI dietary intervention and studies investigating different types of pasta were qualitatively summarized.

Conclusions: Pasta meals have significant lower postprandial glucose response compared to bread or potato meals, but evidence was lacking in terms of how the intake of pasta can influence cardio-metabolic disease risk. More long-term randomized controlled trials are needed where investigators directly contrast the cardio-metabolic effects of pasta and bread or potato. Long-term prospective cohort studies with required data available should also be analyzed regarding the effect of pasta intake on disease endpoints.

INTRODUCTION

Pasta, traditionally an Italian dish, is now accepted by many cultures and available as a major dietary source of energy around the world. After the concept of glycemic index (GI) was proposed in 1981[1], many carbohydrate-dense foods such as pasta have been evaluated. GI measures the relative glucose-raising property of carbohydrates-containing foods compared to glucose or white bread with equivalent amount of carbohydrates. The GI for pasta was found to be in the low to moderate range (GI ≤ 55 on the glucose scale).[2] This is somewhat surprising since pasta is largely composed of starch, and other starchy foods such as potato and white bread have much higher GI (75-87).[2] Yet pasta has attracted less attention than another low-GI food, legumes, in terms of its potential in the prevention and control of type 2 diabetes (T2D), cardiovascular disease (CVD), and other related cardio-metabolic conditions. Pasta is overlooked as an important low-GI component of the Mediterranean diet, which has been proven to have beneficial effect on T2D and cardiovascular risk factors in randomized clinical trials,[3] possibly because the Mediterranean diet usually includes large amounts of fruits, vegetables, and unsaturated fatty acids that may also exert cardio-metabolic benefits. Nevertheless, the role of pasta deserves more extensive investigation. To our knowledge, no study has summarized the available evidence in its totality regarding the potential benefit of pasta on cardio-metabolic diseases and related risk factors.

In this systematic review we attempted to summarize comprehensively the existing literature regarding pasta and various cardio-metabolic traits. The purpose of this study was to systematically, comprehensively and critically examine the roles of pasta in total amount and various forms in relation to risk factors for cardio-metabolic diseases such as T2D and CVD. The primary outcomes of interest weight loss, fasting blood glucose reduction, improved insulin response (insulin sensitivity), and improved glycated hemoglobin (HbA1c). The secondary outcomes of interest were blood pressure and cholesterol level improvement. Identification of potential heterogeneity in existing studies would allow for the planning of further high-quality research to fill the knowledge gaps.

METHODS

Study Selection

We conducted a comprehensive literature search of PubMed, Cumulative Index to Nursing & Allied Health Literature (CINAHL), and Cochrane Central Register of Controlled Trials, for published prospective cohort studies and randomized controlled dietary intervention trials that examined pasta, and pasta-related fiber and grain intake in relation to risk of T2D and cardiovascular outcomes, and risk factors of interest up until Mar 31, 2016 in humans in English language (supplemental search conducted on Jun 1, 2017). Search terms used to identify relevant articles included pasta, spaghetti, diabetes, cardiovascular disease, obesity, weight gain, insulin resistance, insulin sensitivity, fasting glucose, HbA1c, blood pressure, cholesterol (Appendix 1). Additional studies were identified from expert recommendation and reference lists of articles. Records were imported into Endnote (Version X8) for screening by titles and abstracts using predetermined inclusion and exclusion criteria (Appendix 2). Full-text articles were retrieved for potentially relevant studies, and were included in this review if relevant information can be extracted.

Data Extraction

Two independent investigators (MH and JL) each independently reviewed the titles and abstracts, and extracted the relevant data. Discrepancies were resolved by referencing the original article and by group discussion. Information extracted for randomized controlled trials included: first author; publication year; sample size; age and sex of participants; health condition of participants; study design; study duration; diet evaluation methods; number of treatment and control groups; amount of pasta consumed; diet or meal information; measurements for postprandial glucose/insulin responses, and surrogate markers including fasting blood glucose, fasting insulin, HbA1c, insulin sensitivity by homeostatic model assessment, lipid profiles, blood pressure, and body weight, wherever applicable.

Data Synthesis

Data from seven studies reporting postprandial glucose response (incremental area under the curve, iAUC) of pasta vs. white bread, and six studies reporting postprandial glucose iAUC of pasta vs. potato were meta-analyzed using the standardized mean difference method with random-effects models,[4, 5] since the studies quantified iAUC in different length of time causing them to be on difference scale. Heterogeneity of the studies were assessed using the I^2 statistic. Cumulative meta-analysis with random-effects models was also performed to evaluate how the effect evolved over time. All quantitative analyses were conducted in R version 3.3.2 (The R Foundation for Statistical Computing, Vienna, Austria),[6] and RStudio version 1.0.136.[7]

RESULTS

A total of 197 unique publications were identified from literature search in CINHAL, Cochrane, PubMed, and expert recommendation and reference list of articles. After evaluating their titles and abstracts, 136 publications were excluded for the following reasons: topic/exposure/outcome not of interest (n=116), non-RCT/non-cohort design (n=8), no abstract/no full text (n=5), review/commentary/letter/editorial (n=3), type 1/gestational diabetes (n=2), and non-human studies (n=2). Full-texts were evaluated for the remaining 61 potentially relevant studies. Among these, we were unable to extract data from 9 studies of Mediterranean dietary patterns,[8-16] since no specific effect measure for pasta as a single exposure was estimated. The rest were RCTs and classified into three categories (Appendix 3):

- First, 25 studies of postprandial responses were identified. Full texts were found for 21 of them. After reviewing these full texts, one study was deemed as non-randomized design.[17] Five studies examined exposure comparisons or outcomes not of interest.[18-22] We were unable to extract data from another five due to the way the outcomes were reported.[23-27] Among the remaining studies, 8 independently evaluated the glucose response iAUC of pasta relative to white bread or potato,[28-35] and 5 independently calculated observed GI.[28, 31, 35-37] Three studies evaluated the insulin response iAUC of pasta relative to white bread or potato,[29, 30, 32] while one study calculated relative insulinemic index (defined similarly as GI).[36]

- Second, 13 studies where pasta was part of low-GI diet interventions were identified and 6 of them were studies of the same group or subgroup of participants, and were treated as one. Another study had very low consumption of pasta and we were not able to extract data.[37] Seven independent studies were included in this category with outcomes including insulin sensitivity,[38, 39] HbA1c,[40-42] fasting plasma glucose,[38, 40-43] total plasma cholesterol,[40-44] low-density-lipoprotein (LDL) cholesterol,[39-41, 43, 44] high-density-lipoprotein (HDL) cholesterol,[39-44] LDL/HDL cholesterol ratio,[40, 41] plasma triglycerides,[39-44] body weight,[38, 40-42, 45] waist circumference,[40, 45] and blood pressure.[39, 40] We were not able to locate trials with T2D or CVD as outcome, but one study calculated the 10-year Framingham coronary heart disease (CHD) risk score.[40]
- Third, 14 studies were identified where different types of pasta were compared, including 3 studies that compared whole grain to refined grain pasta,[46-48] 6 studies that compared fiber-fortified to non-fiber-fortified pasta,[49-54] 2 studies that compared soy pasta to conventional pasta,[55, 56] and 3 studies that contrasted pasta made from an ancient wheat grain variety, the Khorasan wheat, to pasta made from regular durum or soft wheat.[57-59]

1. Postprandial responses of pasta

Among studies that evaluated postprandial glucose response in terms of iAUC and/or GI in the context of mixed meals in diabetic patients (Table 1), most found significantly lower glucose response to pasta meals compared to bread meals[29, 31, 33-36, 60] and/or potato meals.[30, 32-35] The glucose response differences expressed in percentages ranged from 35% to over 50%. Lower peak glucose responses were also observed for pasta meals. In the only study that was conducted in healthy overweight adults,[28] the authors observed lower glucose iAUC after pasta consumption compared to white bread or instant mashed potato consumption, but the results did not reach statistical significance.

Using the standardized mean difference (SMD) meta-analysis, we confirmed quantitatively that the postprandial glucose response difference between pasta and bread was statistically significant (Figure 1a) (SMD=-0.96, 95% CI: -1.52, -0.40, I^2=56%). The difference was also significant comparing pasta and potato (Figure 1b) (SMD=-0.87, 95% CI: -1.30, -0.43, I^2=0%). Results from cumulative meta-analysis indicated that these differences had been stable since the late 1980s (Figure 1c and 1d).

Fewer studies investigated insulin response (Table 2). The results regarding insulin response iAUC and/or relative insulinemic index were somewhat mixed. One study observed significant lower insulin response to spaghetti than to potato,[32] and another found significant lower insulin response to pasta compared to bread when both are made from durum wheat.[36] In two other studies, the pasta meal induced non-significantly lowered insulin response than the potato meal[30] and bread meal.[29]

2. Pasta as part of low-GI interventions

Within this group of 7 RCTs (Table 3), pasta did not seem detrimental as part of low-GI diets. A pasta-containing low-GI diet was found to significantly lower HbA1c in type 2 diabetics in two studies,[40, 41] and significantly reduced plasma triglycerides in another study.[42] The 12-week low-GI legume diet in Jenkins et al 2012[40] also significantly lowered body weight, waist circumference, fasting glucose, total cholesterol, HDL cholesterol, triglyceride, systolic and diastolic blood pressure, and 10-year CHD risk score in comparison to a high wheat fiber diet. However, while pasta was recommended in the low-GI legume diet, most of the effects cannot be attributed to the pasta component of the diet. In another crossover study, a low-GI diet decreased insulin sensitivity and increased LDL cholesterol compared to high-GI diet in the context of high carbohydrate content, and decreased triglycerides in the context of low carbohydrate content.[39] Other than these results, none of the outcomes differed significantly between the pasta-containing low-GI diet group and the high-GI diet group.[41-44] Overall, RCTs comparing pasta to other high-GI starchy foods are lacking. Since it is difficult to disentangle the effects of pasta in a mixed diet, there was not sufficient evidence for us to draw any conclusions regarding the effect of pasta on cardio-metabolic biomarkers.

3. Different types of pasta

Whole grain vs. refined grain

These three studies compared a series of carbohydrate-dense foods made either with whole grains or refined grains, where pasta was a substantial component of the diets.[46-48] They were all of crossover design and each diet period lasted 4 to 6 weeks. In one study of overweight/obese and hyperinsulinemic participants, the authors observed significantly reduced fasting insulin, insulin resistance, as well as improved insulin sensitivity after whole-grain diet compared to refined-grain diet, without a significant change in body weight.[46] However, another study in healthy, moderately overweight adults could not confirm the beneficial effects of whole-grain foods on insulin sensitivity.[47] The third study in this group specifically investigated whole-grain foods rich in lignans, where a modest cholesterol-lowering effect was demonstrated.[48]

Fiber-enriched vs. non-fiber-enriched

Three out of the 6 studies that contrasted fiber-enriched and regular pasta evaluated postprandial responses. In two studies where one of the test pasta was enriched with β-glucan and the other was made with regular wheat flour, plasma insulin response, but not glucose response, was blunted by the high-fiber meals in Bourdon et al.[49] The lack of statistically significant reduction in glucose response was confirmed by Regand et al.[51] The latter also compared β-glucan oat pasta and wheat pasta with other foods such as wheat muffin, oat porridge, oat granola, and wheat and oat crisp bread. In general only the two types of pasta had significantly reduced glucose iAUC compared to wheat muffin,[51] thus confirming our previous finding that pasta induces lower glucose response than other foods with equivalent content of available carbohydrates. The third study revealed that addition of 1.7 gram of psyllium to pasta had no apparent effect on postprandial glucose/insulin responses.[50]

The other three publications included two that originated from the same trial. This trial compared inulin-enriched pasta diet with standard durum wheat pasta diet,[52, 53] while the other compared regular pasta, biscuits, and bread to soluble-fiber-enriched counterparts, where the fibers included guar guam, glucomannan, inulin, and wheat fiber.[54] They were both of short duration, with 4 to 5 weeks for each diet period. The former observed significant differences in HDL-cholesterol, total/HDL-cholesterol ratio, and triglycerides,[52] while the latter demonstrated reduction in insulin resistance, body weight and body mass index (BMI) for the fiber-enriched diet compared to control diet,[54] but the weight and BMI decrease might have contributed to the lowering in the insulin resistance.

Soy germ vs. conventional

In the two randomized controlled trials that compared soy germ pasta to conventional pasta, soy germ pasta enriched in isoflavone aglycons was found to reduce total and LDL cholesterol, and increase flow-mediated vasodilation more than conventional pasta in adults with hypercholesterolemia in 4 weeks,[55] and was also found to significantly reduce systolic and diastolic blood pressure, plasma homocysteine, and improved flow-mediated vasodilation and plasma total antioxidant capacity in T2D patients after an 8-week intervention,[56] both in the virtual absence of soy protein.

Khorasan wheat vs. durum and soft wheat

This group of studies were conducted by the same group of investigators in Italy and performed in three different samples of the population: healthy adults,[57] patients with acute coronary syndrome,[58] and patients with T2D.[59] Reduction in total and LDL-cholesterol, as well as fasting glucose concentrations were found in all three population samples for the Khorasan-wheat products (pasta, bread, and crackers) compared to products made from regular durum or soft wheat. For patients with T2D, reductions in fasting insulin and insulin resistance associated with the Khorasan wheat diet were also observed.[59]

DISCUSSION

In this systematic review, we summarized the available scientific evidence regarding the potential effect of pasta consumption on postprandial responses and short-to-medium term changes in cardio-metabolic biomarkers, including fasting glucose and insulin concentrations, insulin resistance and insulin sensitivity, HbA1c, lipid profile, blood pressure, and anthropometric measures. Many of the earlier studies focused on the postprandial glycemic and insulinemic responses, while more recent randomized controlled trials tended to incorporate pasta as part of low-GI dietary interventions, or compare different types of pasta such as whole-grain and refined-grain, or fiber-enriched and non-fiber-enriched. Overall the evidence is convincing that pasta meals induce lower postprandial glucose responses as compared to other carbohydrate-abundant foods, for example white bread and potato, which are frequently consumed in Western diets. In other words, we confirmed that pasta is a type of low-GI carbohydrate, especially compared with other starch-dense foods. It is also probable that pasta consumption can result in blunter postprandial insulinemic response, which fewer studies examined probably because it is more variable and dependent on disease progression in diabetic patients.

However, we could not draw any conclusions regarding the effect of consuming pasta on cardio-metabolic biomarkers included in this review. The RCTs identified were too heterogeneous and there was a lack of direct comparison between pasta and other types of carbohydrate or starch-dense foods. None of the RCTs included in this review had an intervention longer than three months (12 weeks) for each diet period. In dietary trials that used pasta as part of a low-GI diet, the extent to which pasta was incorporated into the diet was difficult to ascertain, thus making it difficult to evaluate how much of the beneficial effects associated with the low-GI diets, if any, could be attributed to pasta consumption.

In studies where different types of pasta were contrasted, the focus was shifted to the comparison between whole-grain and refined-grain, fiber-enriched and non-fiber-enriched, soy germ and conventional, and Khorasan wheat and regular wheat, where pasta was consumed by all intervention groups. While these studies could not facilitate in evaluating the potential effects of replacing high-GI starchy foods with pasta, they certainly provided insight into how we can further improve pasta as an alternative to bread or potato in our daily diet. Even though the small number of studies prevented us from drawing definitive conclusions, based on what was summarized, all types of fortified pasta demonstrated possible beneficial influences on glucose and insulin metabolism or lipid profile when compared to regular pasta. Thus, it might also be important to take the type of pasta into consideration when evaluating its effects.

A recent cross-sectional analysis in two Italian cohorts demonstrated that higher pasta intake was associated with better adherence to Mediterranean diet, and was also negatively associated with BMI, waist circumference, waist-to-hip ratio and prevalence of overweight and obesity, independent of adherence to Mediterranean diet and total energy intake.[61] Although this study was not included in the current review due to its cross-sectional nature, it confirmed the findings from an earlier international cross-sectional investigation where pasta intake, among other food groups, was negatively associated with BMI.[62] As obesity is the most important risk factor for T2D, it is then reasonable to hypothesize that pasta intake may have a beneficial effect on long-term cardio-metabolic disease risk. The mechanisms behind the low GI of pasta include its dense structure resulting from the extrusion process during manufacture and the associated slower digestion and delayed gastric emptying.[20, 30] While the evidence regarding the long-term benefit on risk of T2D and CHD is already convincing for a low-GI/GL diet in the context of a healthy diet,[63] there are many different ways through which one can achieve a low-GI/GL diet while keeping optimal macronutrient proportions. When more evidence pertaining its cardio-metabolic benefit emerges, consumption of pasta may represent a feasible and easy-to-implement method of dietary modification.

The strength of this systematic review is that it is to our knowledge the first to comprehensively summarize the currently available literature on pasta and cardio-metabolic risk factors. However, several limitations should be noted. Due to the small numbers of studies eligible for the meta-analysis, we were not able to perform subgroup analysis or meta-regression, which hindered our ability to detect any sources of heterogeneity. We used the standardized mean difference method so that the outcome measures were on the same scale, which rendered the results less interpretable.

In conclusion, other than the low-GI property of pasta, evidence is lacking in terms of how pasta intake can influence long-term cardio-metabolic risk factors and ultimately the risk of obesity, type 2 diabetes and cardiovascular diseases. However, recent cross-sectional findings warrant closer attention to this cereal product that has been consumed since ancient times and also an important component of the Mediterranean diet. More long-term RCTs are needed to directly contrast the cardio-metabolic effects of pasta to bread or potato that are very common in Western diets. Additionally, long-term prospective cohort studies should also be analyzed regarding the effect of pasta intake on disease endpoints, where RCTs are often not feasible.

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APPENDICES

Appendix 1. Search strategy

- PubMed: (pasta OR spaghetti) in All Fields AND (diabetes OR (cardiovascular disease) OR obesity OR (weight gain) OR (insulin resistance) OR (insulin sensitivity) OR (fasting glucose) OR HbA1c OR (glycated hemoglobin) OR (blood pressure) OR cholesterol) in All Fields AND (cohort OR prospective OR trial) in All Fields
- CINAHL: (pasta OR spaghetti) in All Text AND (diabetes OR (cardiovascular disease) OR obesity OR (weight gain) OR (insulin resistance) OR (insulin sensitivity) OR (fasting glucose) OR HbA1c OR (glycated hemoglobin) OR (blood pressure) OR cholesterol) in All Text AND (cohort OR prospective OR trial) in All Text
- Cochrane: (pasta OR spaghetti) in Search All Text AND (diabetes OR (cardiovascular disease) OR obesity OR (weight gain) OR (insulin resistance) OR (insulin sensitivity) OR (fasting glucose) OR HbA1c OR (glycated hemoglobin) OR (blood pressure) OR cholesterol) in Search All Text AND (cohort OR prospective OR trial) in Search All Text

Filters of human study and English language were applied where possible. The search included publications dated until June 1, 2017.

Appendix 2. Inclusion and exclusion criteria for study selection

Inclusion criteria:

1. randomized controlled intervention or prospective cohort study design;
2. studies in healthy subjects or healthy subjects with at least one major risk factors for type 2 diabetes such as overweight, obesity, impaired glucose tolerance or insulin resistance, or subjects with cardio-metabolic disease;
3. studies that compare diets of pasta with diets without pasta, or different properties of pasta;
4. description of amount of pasta consumed during the intervention period
5. assessment of changes in surrogate markers for type 2 diabetes such as glycated hemoglobin (HbA1c), fasting glucose levels, fasting plasma insulin levels, insulin resistance, cholesterol levels, blood pressures, or weight changes. For studies of postprandial responses, incremental area under the curve (iAUC) of glucose / insulin response, and observed glycemic index relative to white bread / potato were of interest.

Studies will be excluded for meeting at least one of the following criteria:

1. non-human study
2. type 1 diabetes
3. gestational diabetes
4. review, letter, commentary or editorial
5. case reports
6. study proposals

7. not randomized controlled trials or prospective cohort studies

8. other dietary interventions than pasta, grain, or dietary fiber studied

9. multiple publications

10. no assessment of pasta, grain, or fiber intake

11. interventions as part of multiple intervention such as life style changes

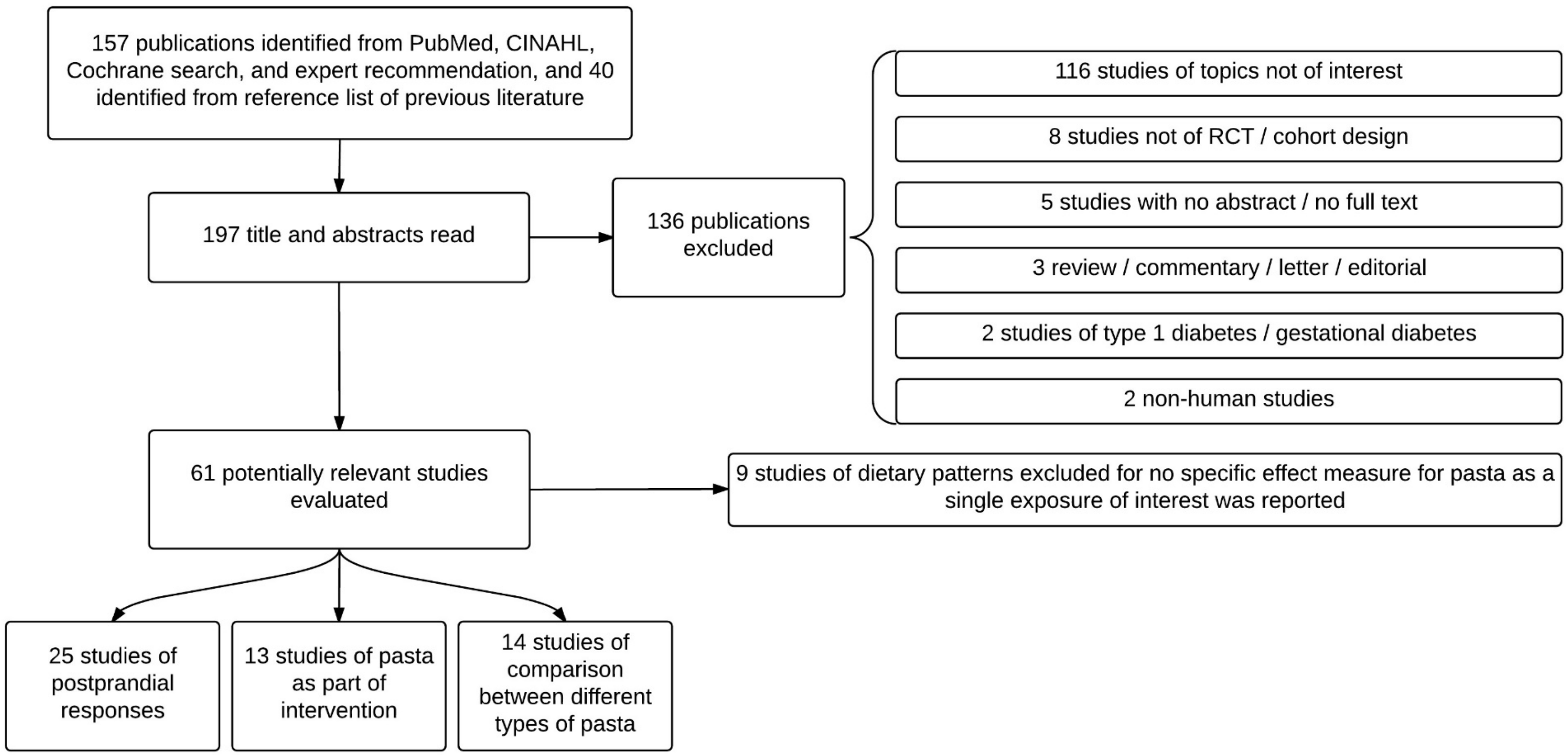
12. intervention studies without control treatment

13. intervention studies with no assessment of relevant outcomes

14. supplementation of whole grain or fiber

15. unknown articles/no abstract/no full text

Appendix 3. Flow chart of study selection



TABLES

Table 1. Summary of characteristics of studies evaluating **postprandial glucose responses**

Study	Study population	Age (SD) or range	Sex	Design	Postprandial Duration	# of participants per group	Meal 1	Meal 2	Meal 3	Meal 4	Meal 5	Meal 6
Kendall, 2011	Healthy overweight	48.3 (6.4)	7F3M	Crossover	120 min	10	Pasta	White bread	Rice	Instant mashed potato	/	/
Lunetta, 1996	T2D	55 (5)	6F6M	Crossover	240 min	12	Pasta	Bread	/	/	/	/
Jarvi, 1995	T2D	36 – 72	5F5M	Crossover	240 min	10	Pasta durum wheat	Bread durum wheat	/	/	/	/
Thomsen, 1994	T2D	61 – 73	3F5M	Crossover	240 min	8	Spaghetti	Mashed potato	/	/	/	/
Wolever, 1990	Diabetes	36 – 83	8F4M	Crossover	180 min	12	Spaghetti	Bread	Rice	/	/	/
Gulliford, 1989	T2D	55.5 (1.6)	3F3M	Crossover	180 min	6	Pasta	Pasta & protein	Pasta & Protein & fat	Mashed potato	Mashed potato & protein	Mashed potato & protein & fat
Rasmussen, 1988	T2D	65 (8)	8F1M	Crossover	180 min	9	Spaghetti	White bread	Potato	/	/	/
Bornet, 1987	T2D	57 (2)	6F12M	Parallel	180 min	3	Spaghetti	White bread	White rice	Instant flaked potatoes	Dried kidney beans	Dried lentils
Collier, 1986	T2D	59 (7)	5F1M	Crossover	180 min	6	Spaghetti	White bread	Rice	Potato	Lentils & barley	/
Parillo, 1985	Diabetes	53.3 (4.5)	3F4M	Crossover	300 min	7	Spaghetti	White bread	Potato	/	/	/

Abbreviations: T2D, type 2 diabetes; F, female; M, male.

Table 2. Summary of characteristics of studies evaluating **postprandial insulin responses**

Study	Study population	Age (SD) or range	Sex	Design	Postprandial Duration	# of participants per group	Meal 1	Meal 2	Meal 3	Meal 4	Meal 5	Meal 6
Lunetta, 1996	T2D	55 (5)	6F6M	Crossover	240 min	12	Pasta	Bread	/	/	/	/
Jarvi, 1995	T2D	36 – 72	5F5M	Crossover	240 min	10	Pasta durum wheat	Bread durum wheat	/	/	/	/
Thomsen, 1994	T2D	61 – 73	3F5M	Crossover	240 min	8	Spaghetti	Mashed potato	/	/	/	/
Gulliford, 1989	T2D	55.5 (1.6)	3F3M	Crossover	180 min	6	Pasta	Pasta & protein	Pasta & Protein & fat	Mashed potato	Mashed potato & protein	Mashed potato & protein & fat

Abbreviations: T2D, type 2 diabetes; F, female; M, male.

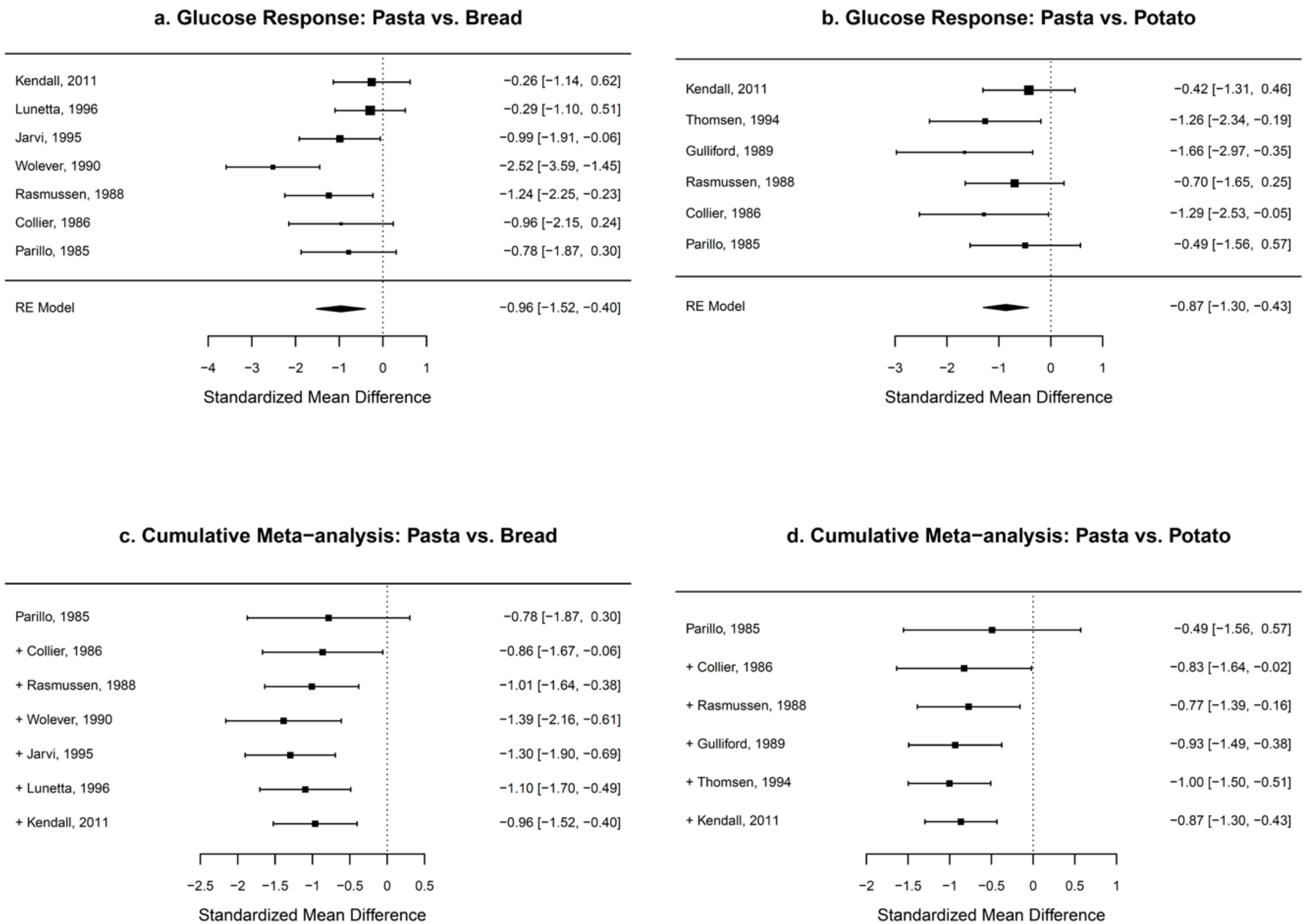
Table 3. Summary of characteristics of studies with pasta as part of dietary intervention

Study	Study population	Age (SD) or range	Sex	Design	Duration	Method of diet evaluation	Intervention diet	Control diet	Pasta portion
Brand, 1991	T2D	62 (9)	6F10M	Crossover	12 weeks	4-day weighed food record	Low-GI (pasta, porridge)	High-GI (processed cereals, potato)	21% of carb in intervention diet
Laaksonen, 2005 & Hallikainen, 2006	MetS overweight/ obese	40 – 70	36F36M	Parallel	12 weeks	4-day food record	RPa (rye bread and pasta)	OWPo (oat, wheat bread, and potato)	>=1 portion of pasta (70 g dry pasta), >=3 times/week
Aston, 2008	Overweight /obese	51.9 (7.6)	37F	Crossover	12 weeks	4-day diet diaries	Low-GI (cereal, rice, pasta, bread)	High-GI (cereal, rice, potato, bread)	Not available
Cobiac, 1990	Mildly hypercholesterolaemic	29 – 65	20M	Crossover	4 weeks	3-day weighed food inventories	Canned spaghetti	Canned baked beans	One daily meal
Fontvieille, 1992	Diabetes	47.2 (11.6)	6F12M	Crossover	5 weeks	7-day food records	Low-GI (pasta, rice, biscuits, apple, peas, beans, rye bread)	High-GI (bread, potato, banana)	Not available
Jenkins, 2012*	T2D	61 (1) 58 (1.3)	60F61M	Parallel	12 weeks	7-day food records	Low-GI legume diet	High wheat fiber diet	Recommended in low-GI diet but quantity not available
Sacks, 2014†	Overweight	53 (11)	85F78M	Crossover	5 weeks	Daily food diary	Low-GI	High-GI	Recommended in low-GI diet but quantity not available

Abbreviations: T2D, type 2 diabetes; MetS, metabolic syndrome; F, female; M, male.
* Jenkins, 2012 reported age separately for intervention diet participants and control diet participants.
† Sacks, 2014 had four study diets: high-GI & high carbohydrate, low-GI & high carbohydrate, high-GI & low carbohydrate, and low-GI & low carbohydrate.

FIGURE LEGENDS

Figure 1. Forest plots for meta-analysis (a&b) and cumulative meta-analysis (c&d) of standardized mean differences in postprandial glucose response (incremental area under the curve) comparing pasta vs. bread and pasta vs. potato. For Figure 1a & 1b, the sizes of the squares represented the weights of each study, and in the order of the studies presented in each figure, the weights were 15.8%, 16.8%, 15.1%, 13.3%, 14.1%, 11.9%, and 13.1% for Figure 1a, and 23.8%, 16.2%, 10.8%, 20.6%, 12.1%, and 16.50% for Figure 1b.


a. Glucose Response: Pasta vs. Bread
Kendall, 2011 −0.26 [−1.14, 0.62]
Lunetta, 1996 −0.29 [−1.10, 0.51]
Jarvi, 1995 −0.99 [−1.91, −0.06]
Wolever, 1990 −2.52 [−3.59, −1.45]
Rasmussen, 1988 −1.24 [−2.25, −0.23]
Collier, 1986 −0.96 [−2.15, 0.24]
Parillo, 1985 −0.78 [−1.87, 0.30]
RE Model −0.96 [−1.52, −0.40]
−4 −3 −2 −1 0 1
Standardized Mean Difference
b. Glucose Response: Pasta vs. Potato
Kendall, 2011 −0.42 [−1.31, 0.46]
Thomsen, 1994 −1.26 [−2.34, −0.19]
Gulliford, 1989 −1.66 [−2.97, −0.35]
Rasmussen, 1988 −0.70 [−1.65, 0.25]
Collier, 1986 −1.29 [−2.53, −0.05]
Parillo, 1985 −0.49 [−1.56, 0.57]
RE Model −0.87 [−1.30, −0.43]
−3 −2 −1 0 1
Standardized Mean Difference
c. Cumulative Meta−analysis: Pasta vs. Bread
Parillo, 1985 −0.78 [−1.87, 0.30]
+ Collier, 1986 −0.86 [−1.67, −0.06]
+ Rasmussen, 1988 −1.01 [−1.64, −0.38]
+ Wolever, 1990 −1.39 [−2.16, −0.61]
+ Jarvi, 1995 −1.30 [−1.90, −0.69]
+ Lunetta, 1996 −1.10 [−1.70, −0.49]
+ Kendall, 2011 −0.96 [−1.52, −0.40]
−2.5 −2 −1.5 −1 −0.5 0 0.5
Standardized Mean Difference
d. Cumulative Meta−analysis: Pasta vs. Potato
Parillo, 1985 −0.49 [−1.56, 0.57]
+ Collier, 1986 −0.83 [−1.64, −0.02]
+ Rasmussen, 1988 −0.77 [−1.39, −0.16]
+ Gulliford, 1989 −0.93 [−1.49, −0.38]
+ Thomsen, 1994 −1.00 [−1.50, −0.51]
+ Kendall, 2011 −0.87 [−1.30, −0.43]
−2 −1.5 −1 −0.5 0 0.5 1
Standardized Mean Difference