Comparative effectiveness of interventions provided in primary care to promote fruit and vegetable consumption in adults: a systematic review and meta-analysis of randomised controlled trials

ABSTRACT

Background: The promotion of healthy dietary behaviours is a priority for primary health care, because nutrition-related chronic diseases place a significant burden on society and primary care professionals are in a good position to help improve patients' dietary behaviours. Our objective was to assess the comparative effectiveness of different forms of interventions in primary care to promote fruit and vegetable consumption in adults.

Design: We conducted a systematic review and meta-analysis of randomised controlled trials. Three reviewers screened title and abstracts independently. Two reviewers assessed risk of bias and extracted data from studies, a third member was an arbitrator in case of disagreement through the review.

Data sources: We searched MEDLINE (Ovid) for articles published until November 2019.

Eligibility criteria: Randomised controlled trials (RCTs) published in English of interventions aimed at increasing fruit and vegetable consumption in adults over the age of 18 in high-income countries.

Results: We found that various interventions can be moderately effective at increasing fruit and vegetable consumption in a primary care context as standardized mean difference (SMD) was 0.39 (95% CI: 0.21, 0.57; p = 0.000). Our analysis indicated that lifestyle education has the most favourable impact on fruit and vegetable consumption (SMD = 0.53; 95% CI: 0.26, 0.79; p = 0.000), whereas nutrition education could have a small effect on it (SMD = 0.14; 95% CI: 0.05, 0.22; p = 0.330).

Conclusion: Our review indicates that lifestyle education is the most effective intervention to implement in a primary care setting with a moderate effect on increasing fruit and vegetable consumption. Nutrition education seems to have a smaller effect on that, whereas printed information does not. These results should be considered with caution, because heterogeneity was very high and sub-group analysis did not always reach statistical significance.

1. Introduction

1.1 Background information and rationale

Nutrition-related chronic diseases such as obesity, cardiovascular disease, and type 2 diabetes mellitus place a significant burden on population health and health care systems.(Mitchell et al., 2017) Due to this, the promotion of healthy dietary behaviours is a priority for primary health care.(Ball et al., 2015) Fruits, vegetables, wholegrains and less meat are associated with reduced risk of chronic disease.(Ball et al., 2015) In order to improve the health conditions of people by promoting dietary behaviours, it needs to be well-understood what interventions of promotion are the most effective.

The focus of our review is on primary care for implementing interventions to increase the intake of fruits and vegetables, because primary care is one of the first options for support with health issues. Moore et al. (2000) reported that the public appears to be willing to accept dietary advice from primary care professionals, but the professionals do not want to provide it, because they do not feel that they have enough nutritional education. Kolasa & Rickett (2010) reported that they have seen a decline in nutrition counselling by primary care professionals and lack of knowledge remains as one of the factors. However, they also reported that 40% of office visits still include some sort of nutrition counselling. Fruits and vegetables are universally considered good for health and are promoted in national health guidelines.(Slavin & Lloyd, 2012) If primary care professionals knew how to promote the consumption of fruits and vegetables, they would likely feel more confident offering that advice and could achieve better results.

Some previous systematic reviews have concluded that a range of interventions used in primary care can have a small beneficial effect on changing fruit and vegetable consumption. Bhattarai et al. (2013) found three studies that together showed a pooled increment of 0.50 servings per day of fruits and vegetables using individual sessions, phone calls, print materials, and mail. Maderuelo-Fernandez et al. (2015) reported that eleven studies showed 9.7% to 59.3% increased fruit and vegetable intake with dietary counselling. Melvin et al. (2017) reported that two studies found no significant effect on fruit and vegetable intake, except when both physicians and patients were involved in interventions. Pignone et al. (2003) reported that dietary counselling produces modest changes in self-reported consumption of fruits and vegetables. Ball et al. (2015) reported that they found more studies with favourable results than not. Other systematic reviews have not studied the effectiveness of different interventions on fruit and vegetable consumption specifically or in primary care contexts.(Mitchell et al., 2017; Tsai & Wadden, 2009; van Sluijs et al., 2004; Whatnall et al., 2018)

Our aim was to answer the question what is the comparative effectiveness of interventions to promote fruit and vegetable intake in primary care for adults? Previous systematic reviews that are most relevant to our review included data until 2006 the latest.(Bhattarai et al., 2013) We added any recent data that had not been included in them. We assessed fruits and vegetables together not independently, because that is how they are generally promoted in national health guidelines (e.g. five fruits and vegetables a day). We also found that previous systematic reviews(Bhattarai et al., 2013) that have studied interventions in a primary care setting have actually included studies that we judge to be non-primary care settings and therefore, decided to exclude those studies.

1.2 Objectives

The objective of this review was to assess the comparative effectiveness of different forms of interventions in primary care to promote fruit and vegetable consumption in adults in high-income countries.

2. Methods

2.1 Eligibility criteria

2.1.1 Inclusion criteria

Population: We included adults aged 18 years and above. We included both men and women. This was used to be consistent with the previous reviews. The existing reviews that we analysed mostly included participants from high-income countries. We identified high-income countries according to the World Bank classification. We included people with high risks of disease or chronic illnesses, because we wanted to increase external validity. With higher external validity the conclusions of our review are applicable to a variety of contexts, including both healthy and unhealthy people visiting primary care.

Intervention: We added interventions carried out in a primary care setting with the aim of increasing fruits and vegetables. When we determined whether a specific study was conducted in a primary care setting or not, we used the definition of primary care provided by NHS.(*NHS*, n.d.) Due to this definition, we did not consider health maintenance organizations, for example, as primary care and excluded several studies that other reviews had included. Some of the interventions we included were the following: dietary counselling, telephone counselling, information packages, lifestyle counselling, etc.

Comparator: No intervention. For example, people who were provided counselling were compared to people without counselling. Comparing intervention with no intervention helped us to see the effect sizes

of interventions to determine which are the most effectives ones. Since we included data from various reviews and new studies, we could compare different interventions with each other.

Outcomes: Fruit and vegetable intake was our primary outcome. We focused on fruit and vegetable intake, because it was the most identified outcome in previous systematic reviews and since we were able to collect quantitative data about it, we were able to conduct a meta-analysis. The studies we included, used the following measures: servings per day, servings per week, tablespoons per week, grams per day, grams per week.

Study design: Only randomised controlled trials were included in our systematic review. Randomised controlled trials are the gold standard of scientific studies because of their ability to establish causality.(Hariton & Locascio, 2018) Random allocation can increase the likelihood that the difference in fruit and vegetable intake between the two groups was influenced by only the intervention.

2.1.2 Exclusion criteria

We excluded all non-English studies, studies with children, studies in non-primary care settings, studies that did not study fruit and vegetable intake, and studies without randomised and/or control group. Our judgments for excluded articles can be found in Appendix A.

2.2 Information sources

We searched the following database: MEDLINE (via Ovid) until November 2019. We also searched previous systematic reviews conducted on the topic. We contacted Ness et al. (2004) and Prochaska et al. (2005) because we were lacking information, but they did not respond. We also contacted Whatnall et al. (2018) for support on finding relevant RCTs.

2.3 Search

We searched studies in MEDLINE (via Ovid) until November 2019. Detailed search strategies are included in Appendix B.

2.4 Study selection

We divided studies between three reviewers evenly to screen titles and abstracts. After we had selected studies based on titles and abstracts, all studies were reviewed by two authors independently. In the case of disagreements, the third reviewer acted as an arbitrator.

2.5 Data extraction

Two authors extracted data independently and checked for agreement. The third reviewer acted as an arbitrator in the case of a disagreement. We included information about the study, intervention, follow-up duration, outcome measure, and outcome data there. Our data extraction table for intervention data can be found in Appendix C.

2.6 Data items

We included data about study characteristics such as the publication year, authors, location, funding, and length; participant characteristics such as gender, age, ethnic group, and education; methodological characteristics such as follow-up duration, timepoint, type of RCT, and setting; intervention characteristics such as intervention type, dose of intervention, regimen, and comparison group; outcome data such as measurement, baseline amount, post-intervention and control group amount, and attrition rate.

2.7 Risk of bias in individual studies

Each study was reviewed by two reviewers for risk of bias using the criteria in the Cochrane Handbook. The third reviewer acted as an arbitrator in the case of a disagreement. We collected information about the following potential biases: sequence generation, allocation concealment, blinding, incomplete outcome data, and selective outcome reporting, and other biases. We rated each study as high risk, low risk, or unclear in each category. The judgments for our risk of bias assessment can be found in appendix D.

2.8 Summary measures

The summary measures we used were mean differences and standardised mean differences, standard deviation, and number of participants.

2.9 Synthesis of results

We extracted data on a form created on Google Sheets. After assessing all the studies qualitatively, we considered 11 studies to be sufficiently homogenous to perform a meta-analysis using STATA.

We used random-effects analysis, because we thought that the effect sizes are quite different in different studies and the true effect size could vary. Our studies had a mix of participants, a range of different methods, and it is nutrition science conducted in non-laboratory conditions. In addition, we assessed I-squared to determine how much heterogeneity there is in our meta-analysis.

Some studies had missing values for standard deviations in intervention and control group: Adachi et al. (2012), Delichatsios et al. (2001), Dreihus et al. (2012), and Koelewijn-van Loon et al. (2010). We imputed standard deviations for those studies by using an average of standard deviation values from all other studies included for meta-analysis.

2.10 Risk of bias across all studies

Risks of bias that could affect the cumulative evidence in our study is publication bias as all of the studies had a positive or neutral effect.

2.11 Additional analyses

We ran a sensitivity analysis by excluding four studies from our forest plot, because they lacked data on standard deviations. We did not pre-specify this, but decided to do it when we saw that we were not able to find the missing standard deviations.

3. Results

3.1 Study selection

We identified 1195 articles through database searching and 162 articles through other sources. After removing duplicates, there were 1342 articles. After titles and abstracts screening, we were left with 117 articles. We assessed all of them by reading the full text-articles. After excluding all the studies that did not meet our eligibility criteria (according to our PICOS explained in section 2.1) or were duplicates, we had 16 studies left for a qualitative analysis and 11 studies for a meta-analysis.

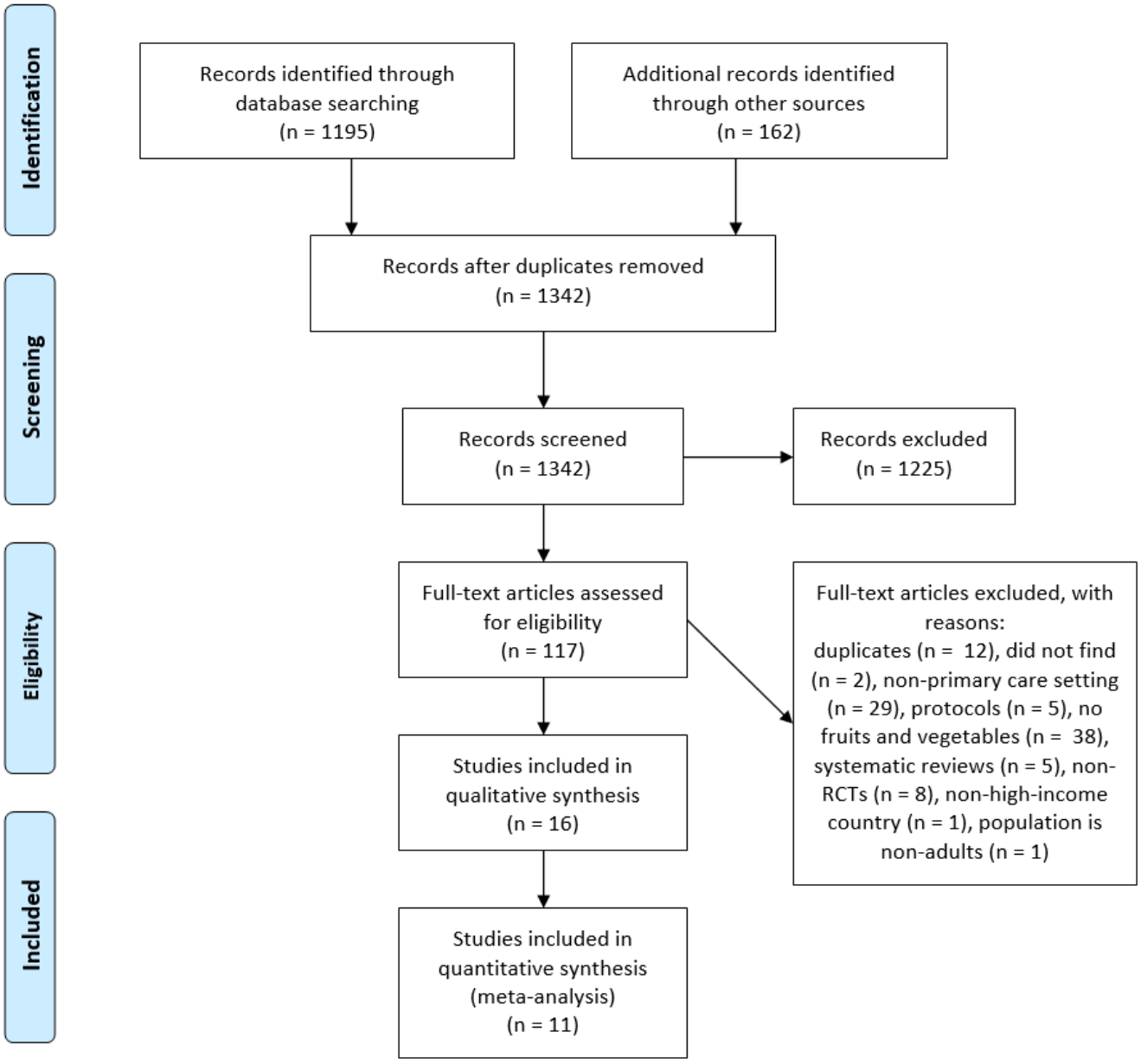

Figure 1. PRISMA flowchart.

3.2 Characteristics of included studies

A detailed description of the studies can be found in table 1. Since we focused on high-income countries, most of the studies were conducted in the United Kingdom and United States, multiple studies were also conducted in the Netherlands. The studies were run for as little as one year and as much as even 10 years. Most studies had approximately 100 participants or a few hundred, but two had over 1.000 participants. All studies except one included a larger proportion of women than men, which is uncommon as most clinical studies historically are done on men.(Liu & Mager, 2016) Nearly all studies except one included seriously ill or moderately ill people. The mean age of studies was generally over 40, except one study. All studies that reported the ethnicity of their participants consisted mostly of white people.

Table 1. Characteristics of included studies.												
Name	**Location**	**Length**	**Participant information**									
			Number		**% Female**		**Health Status**		**Mean Age**		**% White**	
			Intervention	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**	**Control**
Adachi et al. (2013)	Japan	09/2007-06/2011	100	93	55%	58%	All participants had type 2 diabetes		60.4	62.3	N/A	N/A
Bemelmans et al. (2000)	Netherlands	1997-1998	103	163	63%	51%	Included those with hypertension and exluded those with diabetes melitus type 2, hypothyroidism or use of acetylsalicylic acid, anticoagulant or cholesterol-lowering drugs.		55	54	N/A	N/A
Bouma et al. (2018)	Netherlands	09/2010-12/2015	a) Barrier belief counseling intervention - 113 b) Standard lifestyle intervention - 91	36	a) 59% b) 59%	62%	Excluded individuals with a diagnosis of acute coronary heart disease, stroke, severe hyper-tension (systolic pressure >180mmHg or diastolic pressure >120mmHg), chronic depression or chronic pain. Highly active participants were excluded, i.e. those who reported being		50	50	N/A	N/A

							moderately active, at >100 min/day.				
Calfas et al. (2002)	United States	N/A	125	46	67%	67%	47.4% overweight	37.5	37.5	72%	72%
Campbell et al. (1994)	United States	N/A	a) Tailored interventi on- 134 b) Non-tailored interventi on- 136	124	75%	75%	Excluded too ill or mentally unable to complete the survey	N/A	N/A	80%	80%
Delichats ios et al. (2001)	United States	02/199 0- 05/199 9	230	274	77%	63%	Hypertention- 28.3% Diabetes 12.2%	49.9	56.8	83.30%	97%
Driehus et al. (2012)	Netherla nds	N/A	225	232	N/A	N/A	Patients had hypertension and/or dyslipidemia.	N/A	N/A	N/A	N/A
Glasgow et al. (2000)	United States	N/A	a) Telephone interventi on only - 80 b) Communi ty resources interventi on only- 80 c) Combined interventi on- 80	80	a) 57% b) 47 % c) 56%	56%	Type 2 diabetes- 85.2%	a) 59 b) 60.5 c) 57.4	60.6	a) 88.6 % White, b) 90.9% White, c) 91.4% White	90%
John et al. (2003)	United Kingdom	N/A	344	346	47%	55%	All participants had no serious chronic illness.	45.7	46	N/A	N/A

Koelewijn-van Loon et al. (2010)	Netherlands	N/A	304	285	57%	53%	N/A	N/A	56	58	N/A	N/A
Ness et al. (2004)	United Kingdom	1990-2000	1191 total participants		100%	0%	All participants had some form of angina.		N/A	N/A	N/A	N/A
Prochaska et al. (2005)	United States	N/A	2667	2740	70%	70%	47.4% overweight		45.8	44.2	96.40%	97.30 %
Recio-Rodriguez et al. (2016)	Spain	N/A	415	418	60%	67%	298 had a BMI above 25	287 had a BMI above 25	51.4	52.3	N/A	N/A
Sacerdote et al. (2006)	Italy	N/A	1592	1587	50%	50%	N/A	N/A	44.7	44.2	N/A	N/A
Steptoe et al. (2003)	United Kingdom	N/A	136	135	60%	62%	Serious illness and pregnant women/planned to get pregnant in 12 months were excluded		43.3	43.2	69%	71%
Volger et al. (2013)	United States	01/2008-02/2011	a) Brief Learning Condition - 131 b) Enhanced brief learning condition-129	130	N/A	N/A	All had some form of a metabolic syndrome		52	51.7	N/A	N/A

3.3 Risk of bias within each study

A detailed description of reasons for our risk of bias judgment can be found in Appendix D. We were unable to find information about several studies, because they did not have a protocol available and/or they did not include any information in their reports about risk of bias. We rated blinding of outcome assessment low for all studies, because it is nearly impossible to do that in nutrition behaviour studies.

Participants know they will be assessed for the outcome, regardless of the intervention they are given.(Weaver & Miller, 2017) The least biased studies according to our judgment were Campbell et al. (1994) and Sacerdote et al. (2006). The most biased studies according to our judgment were Calfas et al. (2002 and Recio-Rodriquez et al. (2016).

Study	Adequate sequence generation	Allocation concealment	Blinding of particpants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Adachi et al. (2013)	Low	Unclear	Low	Low	Low	Low	Low
Bemelmans et al. (2000)	Low	Low	Unclear	Low	Low	Low	Low
Bouma et al. (2018)	Unclear	Low	Low	Low	Low	Unclear	High
Calfas et al. (2002)	Unclear	Unclear	High	Low	High	Unclear	High
Campbell et al. (1994)	Unclear	Low	Low	Low	Low	Low	Unclear
Delichatsios et al. (2006)	Unclear	Unclear	Unclear	Low	High	Low	High
Driehus et al. (2012)	Low	Unclear	Low	Low	High	Unclear	Unclear
Glasgow et al. (2000)	Low	Low	Unclear	Low	Low	Low	Low
John et al. (2003)	Low	Unclear	Low	Low	Unclear	Low	Unclear
Koelewijn-van Loon et al. (2010)	Low	Low	Low	Low	Unclear	High	High
Ness et al. (2004)	Unclear	Low	Low	Low	Unclear	High	Unclear
Prochaska et al. (2005)	Unclear	Unclear	Low	Low	High	Low	Unclear
Recio-Rodriguez et al. (2016)	High	Unclear	Low	Low	High	High	High
Sacerdote et al. (2006)	Low	Low	Low	Low	Unclear	Low	Low
Steptoe et al. (2003)	Low	Unclear	High	Low	Low	Unclear	Unclear
Volger et al. (2013)	Unclear	High	High	Low	Low	Low	Low

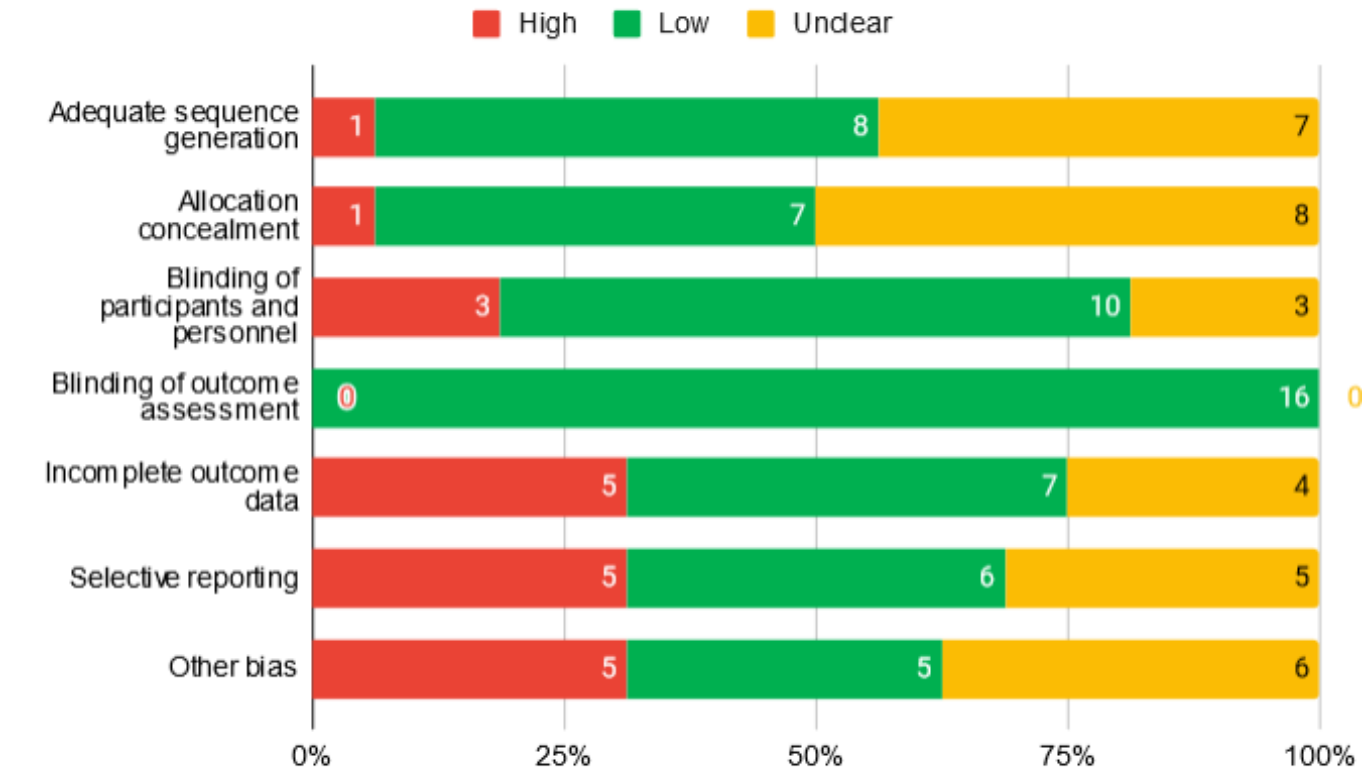

Figure 2. Summary of risk of bias.

3.4 Results of individual studies

We found that 10 interventions had a positive effect on fruit and vegetable consumption, 6 interventions did not. This can be seen on figure 3 as 7 interventions have confidence intervals that cross the line of no difference meaning that it is possible that their effect sizes are zero. In other words, the intervention could

have the same effect as the control group, which is usual care. 9 interventions have confidence intervals that do not cross the line of no difference and therefore, the intervention is seen to be more effective than the control.

The pooled estimate of all RCTs is 0.39 (95% CI: 0.21, 0.57). This should be interpreted as moderate effect size for standardised mean difference.(Faraone, 2008) The result is statistically significant with p = 0.000. We used a random effect analysis, because there was reason to think that the effect sizes are quite different in different studies and the true effect size could vary. Our studies had a mix of participants, a range of different methods, and it is nutrition science conducted in non-laboratory conditions.

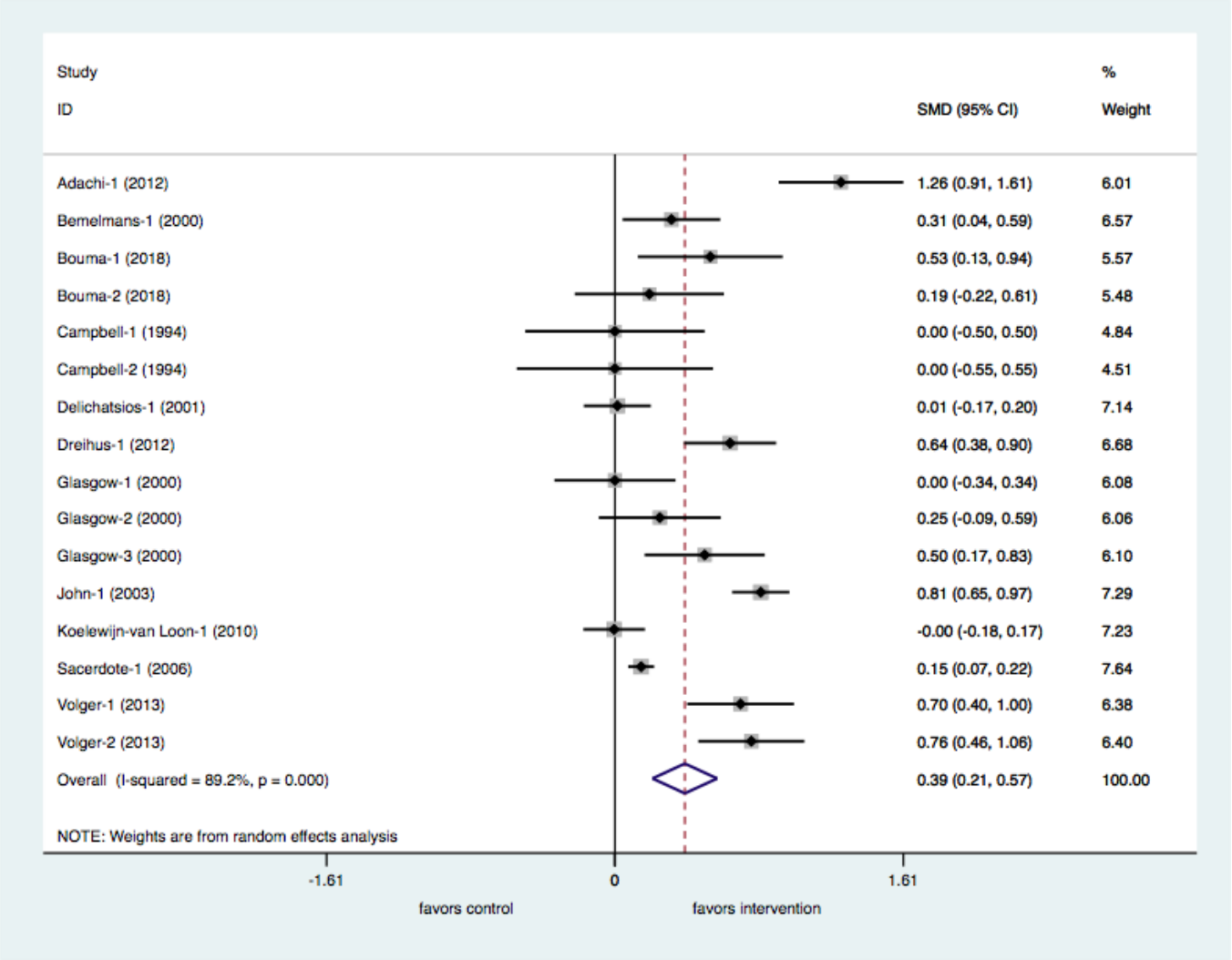

Figure 3. Forest plot for comparing the effectiveness of interventions for increasing fruit and vegetable consumption compared to usual care.

3.5 Risk of bias across studies

All of the studies we found suggested a neutral or positive effect of the intervention, which may suggest a publication bias. However, neutral and positive effects are to be expected with fruit and vegetable promotion as it increases attention to thinking about fruits and vegetables and hence is likely to increase

consumption. On the other hand, very restrictive and demanding methods for promoting fruits and vegetables could backfire and reduce consumption.

We created a funnel plot to visually understand meta-bias or in other words, the risk of bias across all studies. The funnel plot does indicate a slight asymmetry as the bottom right-hand corner is empty compared to the left one. This may be due to a meta-bias described above or due to heterogeneity and chance. We did not implement any strategies to deal with meta-bias due to time constraints and relied merely on one database for finding eligible studies.

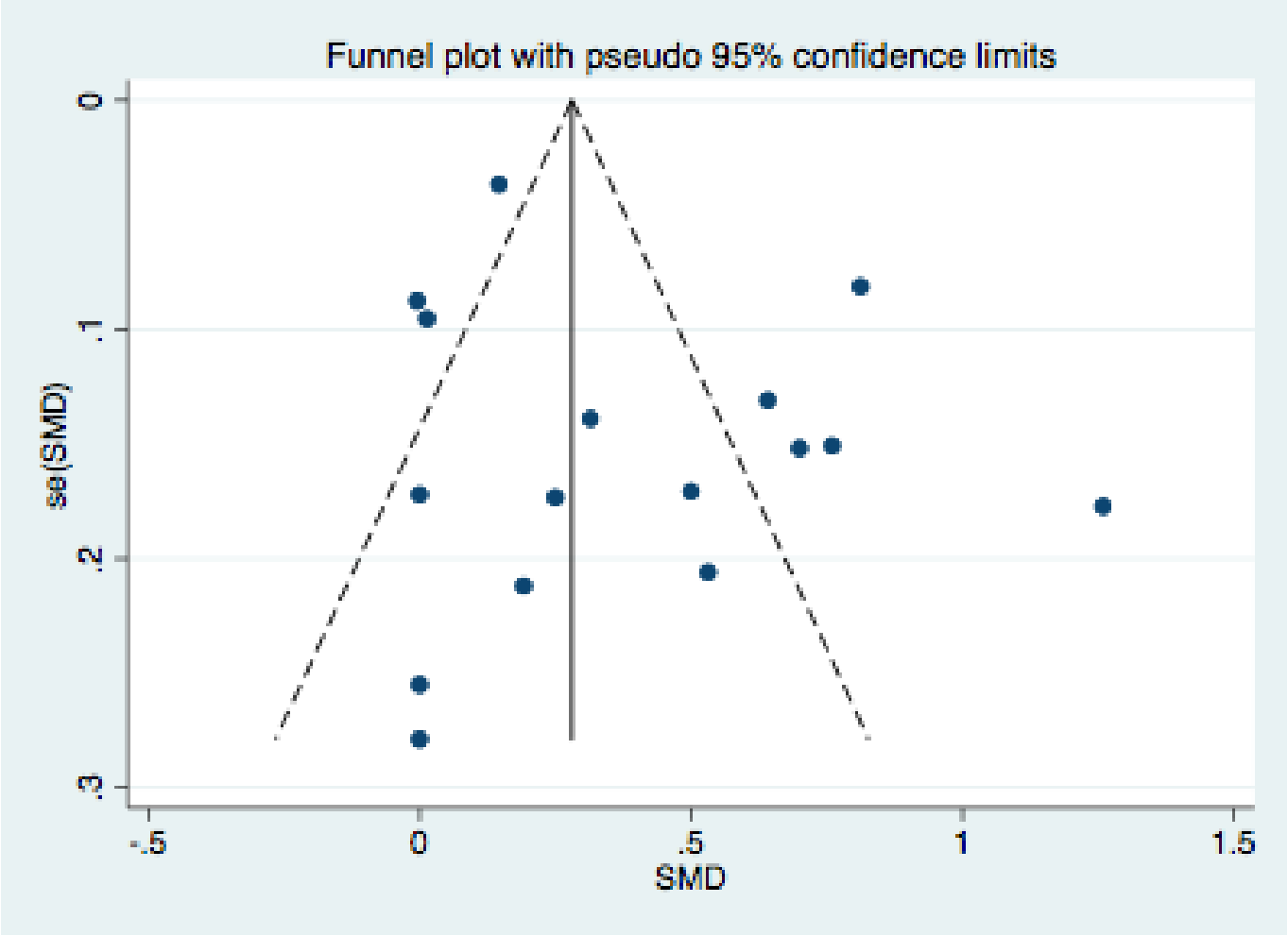

Figure 4. Funnel plot for visualizing meta-bias.

3.6 Additional analysis

We added four studies in our meta-analysis that lacked data about standard deviations. Because we imputed those standard deviations, we thought that it was necessary to run a sensitivity analysis by removing the studies that lacked data about standard deviations to see whether the findings are consistent in the case where we added missing information on our own. Standardised mean difference remained almost identical, SMD = 0.4 (95% CI: 0.19, 0.61) suggesting that replacing missing values did not influence the effect size and confidence interval to a large extent.

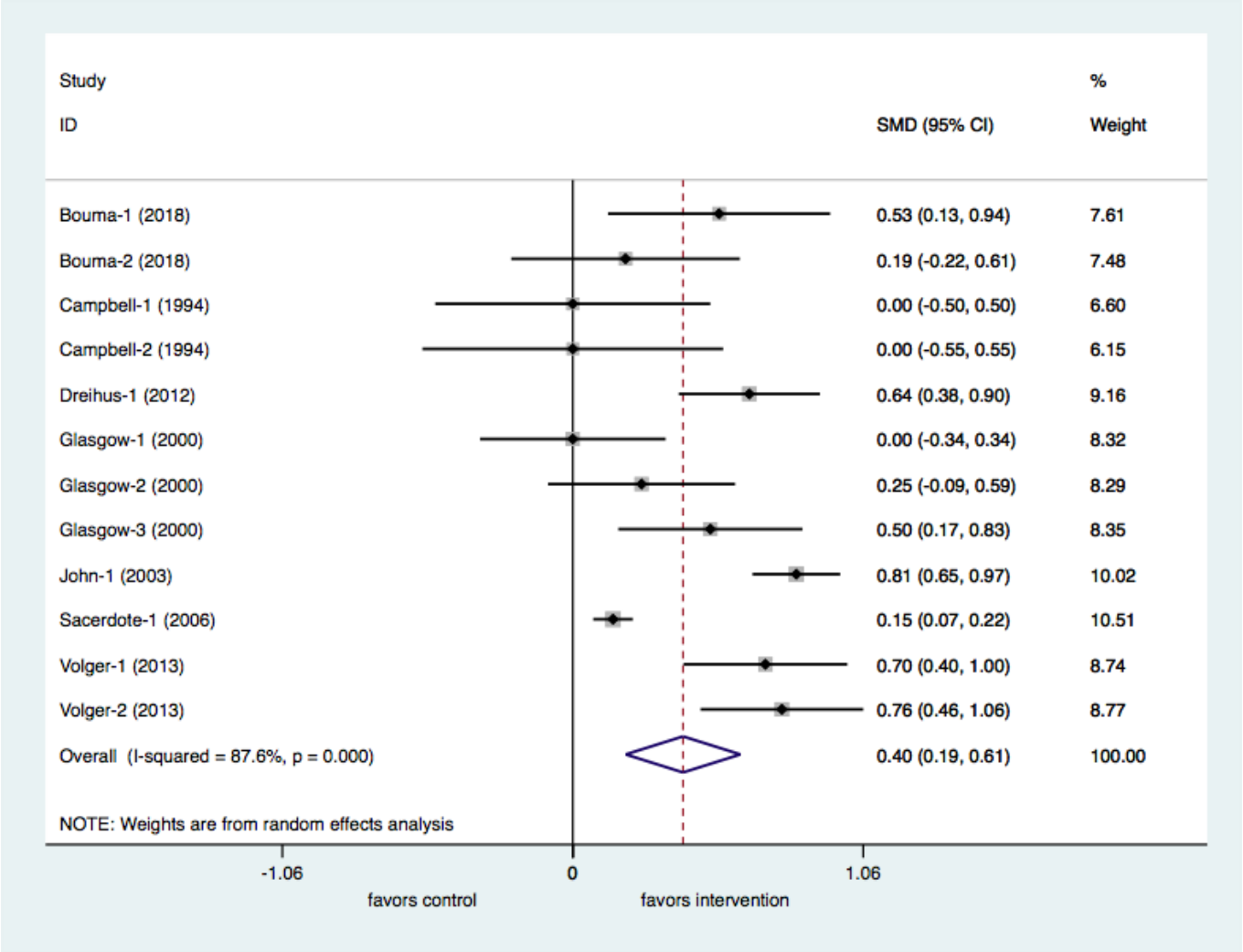

Figure 5. Forest plot with four studies that had missing values for standard deviation excluded.

We decided to do sub-group analysis on the dataset, because of the high heterogeneity. We analysed the data according to the following groups, because we thought that they may influence the variation in effect sizes: measure, intervention, health status, and region. All groups remained very high in heterogeneity, except one sub-group in measure: servings per week. The I-squared was 41.4%, which is moderate heterogeneity suggesting that the study methodology was more homogenous for studies using servings per week measure. Unfortunately, that category had only 2 studies and 3 interventions and p = 0.181, which means it is not statistically significant. Another sub-group that reduced heterogeneity was the category of intervention, but they did not reach statistical significance. All these plots can be found as appendices (figures 7-9).

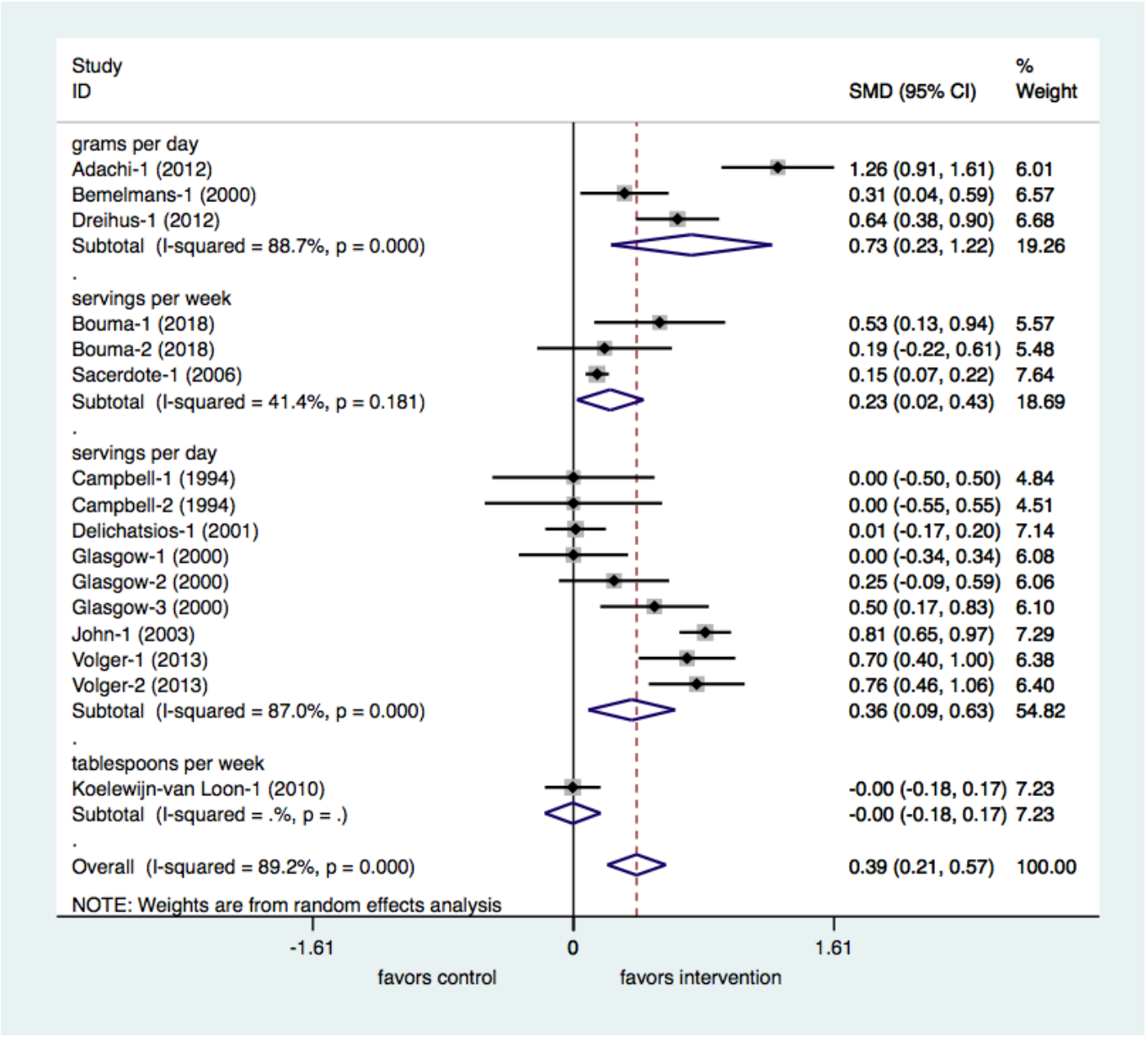

Figure 6. Sub-group analysis by measure.

4. Discussion

4.1 Summary of evidence

Our meta-analysis indicates that various interventions can be moderately effective at increasing fruit and vegetable consumption in a primary care context. Lifestyle education seems most promising as SMD was 1.26 (95% CI: 0.91, 1.61) and 0.81 (95% CI: 0.65, 0.97) as reported by Adachi et al. (2013) and John (2003), respectively. It is important not to interpret standardised mean difference as mean difference – we can only say that there was a moderate effect size, but not meaningfully interpret how much exactly fruit and vegetable consumption is expected to increase when implementing these interventions. The strength of these results is that we judged both studies to have low risk of bias suggesting that we can be more confident in the results.

These results are not entirely consistent with the results reported by Bhattarai et al. (2013) who found that individual diet counselling was more effective in one study than mail and telephone calls, but another study found the effect size to be lower than mail and telephone calls. In our study, nutrition information packages and telephone guidance did not achieve a favourable effect compared to the control group. We also found that in two studies nutrition education did not achieve a favourable effect compared to the control group. That said, nutrition education had a small to moderate effect size in Bemelmans et al. (2000) intervention and in Sacerdote et al. (2006). Unfortunately, nutrition education overall did not reach statistical significance with p = 0.330.

We found that heterogeneity was very large (I -squared = 89.2%) for all of the studies, which means that the observed effect sizes are more different than expected due to the study designs being very different and/or due to clinical diversity. We still decided to do a meta-analysis, because the previous systematic reviews reported a similarly high heterogeneity.(Bhattarai et al., 2013) We had to impute standard deviations for four studies: Adachi et al. (2012), Delichatsios et al. (2001), Dreihus et al. (2012), and Koelewjin-van Loon et al. (2010). They did not report the standard deviations in their full-text papers. We replaced missing values by using an average. Using a median for that did not seem appropriate, because some measures had much higher standard deviations and median would not have been able to account for them resulting in a very low standard deviation. When we did sub-group analysis to determine what was the cause of high heterogeneity, we found that it may have been due to difference in measures to some extent. When servings per week was used, the heterogeneity was moderate not high. However, that result did not reach statistical significance.

4.2 Limitations

All of our studies relied on self-reported intake of fruits and vegetables. It has been found that individuals underestimate energy intakes commonly up to 50% and even non-obese adults can report 20% errors in their energy intake.(Schoeller, 1995) So potentially there can be a large error rate in self-reported fruit and vegetable intake in the studies we analysed and used. The actual effect sizes in these interventions may be lower and could reduce the effect size from moderate to small.

Our systematic review focused on fruit and vegetable intake only, whereas there are many other components of a healthy diet. Our review should not be generalised to all other aspects of dieting, because it is possible that different interventions are more or less effective for improving different aspects of nutrition.

As we only included studies published in English, this might limit the generalisability of the findings. We included only high-income countries. This means that the findings of this review are less generalisable to a context in lower income countries.

4.3 Conclusion

Our systematic review implies that lifestyle education is the most effective intervention to implement in a primary care setting bringing about a moderate effect on the increase of fruit and vegetable consumption. Nutrition education seems to also have a small effect on that. In some studies primary care professionals have reported low level of nutrition knowledge, so this means that they should probably receive more education about nutrition since a lot of patients want that information and they are in a position to effectively influence at least their fruit and vegetable consumption. Print materials are not effective according to our findings and should be deprioritised.

5. Funding

This research received no external funding.

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Appendices

A – reasons for excluding studies

Table 2. Reasons for exclusion.

Study	Reasons for exclusion
Abu-Saad et al. (2019)	No fruits and vegetables
Almeida et al. (2011)	Non-high-income country
Alonso-Dominguez et al. (2017)	Protocol
Alonso-Dominguez et al. (2017)	Duplicate
Ammerman et al. (1994)	Did not find
An et al. (2015)	No fruits and vegetables
Arija et al. (2012)	Protocol
Ashfield-Watt et al. (2002)	No fruits and vegetables
Attux et al. (2013)	No fruits and vegetables
Badia et al. (2015)	No fruits and vegetables
Baker et al. (2002)	Non-primary care setting
Beck et al. (2015)	No fruits and vegetables
Block et al. (2004)	Non-primary care setting
Block et al., 2004	Duplicate
Boylan et al. (2003)	No fruits and vegetables
Brug et al. (1996)	Non-primary care setting
Butler et al. (1999)	No fruits and vegetables
Buyuktuncer et al. (2014)	Non-RCT
Campbell et al. (1994)	Duplicate
Campbell et al. (1994)	Duplicate
Campbell et al. (2004)	Non-primary care setting
Chad-Friedman et al. (2018)	Non-RCT
Chapman et al. (2009)	Non-primary care setting
Chapman et al. (2012)	Non-primary care setting
Cubillos et al. (2017)	No fruits and vegetables
Cutler et al. (2010)	Non-RCT
de Bruijn et al. (2015)	Non-primary care setting
de Nooijer et al. (2006)	No fruits and vegetables
de Vet et al. (2008)	No fruits and vegetables
de Vries et al. (2008)	Non-primary care setting
DeJesus et al. (2018)	No fruits and vegetables
Djuric et al. (2008)	Non-primary care setting
Djuric et al. (2010)	Non-RCT
Djuric et al. (2010)	Duplicate
Dodd et al. (2018)	Did not find
Eakin et al. (2008)	Not fruits and vegetables
Essa et al. (2018)	Non-primary care setting

Feldblum et al. (2011)	No fruits and vegetables
Gans et al. (2009)	Non-primary care setting
Gill et al. (2017)	Protocol
Godinho et al. (2015)	Non-primary care setting
Gomez-Huelgas et al. (2015)	No fruits and vegetables
Heimendinger et al. (2005)	Non-primary care setting
Huang et al. (2019)	Non-primary care setting
Huang et al. (2019)	Duplicate
Jansson et al. (2013)	No fruits and vegetables
Jansson et al. (2013)	Duplicate
Jiskoot et al. (2017)	Protocol
John et al. (2004)	No fruits and vegetables
Kellar et al. (2005)	Non-primary care setting
Kinnunen et al. (2007)	Non-RCT
Kreausukon et al. (2012)	Non-primary care setting
Lawler et al. (2010)	No fruits and vegetables
Lippke et al. (2015)	Non-primary care setting
Little et al. (2004)	Duplicate
Little et al. (2004)	Population is non-adults
Logan et al. (2010)	No fruits and vegetables
Luszczynska et al. (2007)	Non-primary care setting
Maderuelo-Fernandez et al. (2015)	Systematic review
Malta et al. (2016)	No fruits and vegetables
Melvin et al. (2017)	Systematic review
Mitchell et al. (2017)	Systematic review
Orlandoni et al. (2016)	No fruits and vegetables
Parekh et al. (2014)	No fruits and vegetables
Phillips et al. (2012)	No fruits and vegetables
Pignone et al. (2003)	Systematic review
Prochaska et al. (2012)	No fruits and vegetables
Reid et al. (2014)	No fruits and vegetables
Robb et al. (2010)	Non-primary care setting
Robinson et al. (2014)	Non-primary care setting
Rodriguez et al. (2010)	No fruits and vegetables
Rosal et al. (2012)	No fruits and vegetables
Rosas et al. (2016)	No fruits and vegetables
Ross et al. (2009)	No fruits and vegetables
Ross et al. (2012)	No fruits and vegetables
Rothschild et al. (2014)	No fruits and vegetables
Sacerdote et al. (2006)	Duplicate
Schmied et al. (2015)	Non-primary care setting
Scott et al. (2005)	No fruits and vegetables
Siero et al. (2000)	Non-RCT
Smeets et al. (2007)	Non-primary care setting
Sniehotta et al. (2011)	No fruits and vegetables
Soto Rodriguez et al. (2016)	No fruits and vegetables
Stadler et al. (2010)	Non-primary care setting
Staten et al. (2004)	Non-RCT
Steptoe et al. (1999)	No fruits and vegetables
Steptoe et al. (2003)	Duplicate
Steptoe et al. (2003)	Duplicate

Steptoe et al. (2004)	Duplicate
Stevens et al. (2003)	Non-primary care setting
Towfighi et al. (2017)	No fruits and vegetables
van Dongen et al. (2016)	No fruits and vegetables
van Sluijs et al. (2004)	Systematic review
Ventura Marra et al. (2019)	No fruits and vegetables
Werch et al. (2008)	Non-primary care setting
Vermunt et al. (2012)	No fruits and vegetables
Wiedemann et al. (2012)	Non-primary care setting
Winkleby et al. (1997)	Non-primary care setting
Wolf et al. (2009)	Non-primary care setting
Volger et al. (2013)	Duplicate
Woodruff et al. (2019)	Non-primary care setting

B – MEDLINE (Ovid) search strategy

1. Family Practice/
2. Physicians, Family/ or Physicians, Primary Care/
3. exp Primary Health Care/
4. General Practice/ or General Practitioner/
5. Community Health Services/
6. Community Health Nursing/
7. ((general or family) adj (practice$ or practitioner$ or physician$ or doctor$)).tw.
8. (gp$ adj3 (surger$ or care or service$ or centre$ or center$ or clinic$ or facilit$)).tw.
9. gp$.tw.
10. ((walk-in or "walk in" or walkin) adj3 (centre$ or center$ or clinic$ or facilit$)).tw.
11. (polyclinic$ or poly-clinic$ or poly clinic$).tw.
12. ((health or home$ or house$) adj4 (call$ or visit$)).tw.
13. (primary adj4 (care or health$ or service$ or center$ or centre$ or practice$)).tw.
14. (community health adj3 (care or service$ or centre$ or center$ or clinic$ or facilit$)).tw.
15. or/11-14
16. exp Nutrition Therapy/ or exp Eating/
17. ((nutrition* or diet* or eat* or food) adj4 (therap* or support* or help* or aid* or advice* or guid* or treat* or care* or program* or intervention* or health* or treat* or counsel* or lifestyle* or life-style*)).tw.
18. randomi#ed controlled trial.pt.
19. controlled clinical trial.pt.
20. randomi#ed.ab.
21. placebo.ab.
22. randomly.ab.
23. clinical trials as topic.sh.
24. trial.ti.
25. or/18-24
26. or/16-17
27. 15 and 25 and 26

C – characteristics of intervention data

Table 3. Intervention characteristics of included studies.

Study	Intervention	Follow-up duration	Measure	Baseline mean (standard deviation)		Post-intervention mean (standard deviation)		Attrition	
				Intervention	Control	Intervention	Control	Intervention	Control
Adachi et al. (2013)	Lifestyle education	6 months	Grams per day	196.5 (N/A)	223 (N/A)	236.5 (N/A)	208.5 (N/A)	16%	30%
Bemelmans et al. (2000)	Nutrition education	12 months	Grams per day	407.69 (232.51)	411.98 (240.15)	474.39 (223.3)	399.58 (245.64)	29%	22%
Bouma et al. (2018)	a) Lifestyle education and b) Nutrition education	18 months	Servings per week	a) 20.1 (8.89); b) 19.04 (8.91)	19.77 (11.6)	a) 26.62 (11.42); b) 22.47 (9.32)	20.56 (11.34)	a) 44%; b) 34%	11%
Calfas et al. (2002)	a) Mail only, b) infrequent phone and mail, and c) frequent phone and mail	4 months	Servings per day	a) 4.4 (2.26); b) 3.9 (2.18); c) 4.07 (2.51)	4.11 (2.13)	N/A	N/A	N/A	N/A
Campbell et al. (1994)	a) Lifestyle Education and b) Print information	4 months	Servings per day	a) 3.6 (0.19); b) 3.6 (0.02)	3.6 (0.2)	a) 3.3 (0.19); b) 3.3 (0.2)	3.3 (0.02)	N/A	N/A
Delichatsios et al. (2001)	Nutrition education	3 months	Servings per day	2.9 (N/A)	3.3 (N/A)	4 (N/A)	3.7 (N/A)	15%	8%
Driehuis et al. (2012)	Lifestyle education	36 months	Grams per day	277.1 (N/A)	283.4 (N/A)	372.8 (N/A)	358.4 (N/A)	28%	24%
Glasgow et al. (2000)	a) Lifestyle education, b) Print information, c) Lifestyle education	3 months	Servings per day	a) 2 (0.5); b) 2.2 (0.4); c) 2 (0.5)	1.9 (0.4)	a) 1.6 (0.4); b) 1.7 (0.4); c) 1.8 (0.4)	1.6 (0.4)	a) 15%; b) 16%; c) 6%	16%
John et al. (2003)	Lifestyle education	6 months	Servings per day	3.4 (1.7)	3.4 (1.5)	4.8 (1.6)	3.5 (1.6)	14%	10%
Koelewijn-van Loon et al. (2010)	Lifestyle education	3 months	Tablespoons per week	35.8 (N/A)	35.8 (N/A)	39.2 (N/A)	39.3 (N/A)	18%	12%
Ness et al. (2004)	Nutrition counseling	60 months	Grams per day	N/A	N/A	373.2 (170.9)	351.7 (161.5)	N/A	N/A
Prochaska et al. (2005)	Stage-based expert systems	24 months	Behavior score for fruits and vebetables	22.5 (5.0)	22.2 (5.0)	23.5 (5.0)	22.4 (5.1)	29%	22%
Recio-Rodriguez et al. (2016)	Mobile phone app	12 months	a) Change in adherence score to 3 or more fruits and b) change in adherence score to 4 or more vegetables per day	N/A	N/A	a) 8.2 (N/A); N/A	12.3 (N/A); N/A	N/A	N/A
Sacerdote et al. (2006)	Nutrition education	12 months	Servings per week	19.1 (8.4)	19.3 (8.5)	22 (6.4)	20.9 (8.5)	7%	6%

Steptoe et al. (2003)	Lifestyle education	12 months	Servings per day	3.60 (1.81)	3.67 (2.00)	N/A	N/A	19%	20%
Volger et al. (2013)	a) Lifestyle Education and b) Lifestyle Education	24 months	Servings per day	a) 6.06 (3.9); b) 5.79 (4.23)	5.61 (4.1)	a) 5.46 (0.5); b) 5.49 (0.5)	5.11 (0.5)	N/A	N/A

D – judgments of risk of bias

Table 4. Support for judgments of risk of bias.

Study	Adequate sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Adachi et al. (2013)	Cluster randomization was applied to avoid contamination bias [13]. use of a randomization list (random permutated blocks with block size 2) during September 2007 to December 2010. In this way, the first 20 GPs were sequentially enrolled to the study. For each GP, 10 patients were enrolled as study participants.	No information mentioned	Registered dietitians and GPs cannot be blinded to the intervention. Patients will hardly notice which intervention is assigned when he/she is informed of the education process, because only one of the two interventions is given in a specific clinic and the patient cannot be aware of what is going on at another clinic	No information mentioned	Low "Even though the protocol required enrollment of 10 patients per clinic, we permitted enrollment of 7–13 patients per clinic to allow for dropouts so that statistical power could be maintained and to take into account a shortfall in enrollment in some clinics. Furthermore, we conducted multiple imputation analyses to examine the effect of dropouts on the results."	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcome	Low "We cannot deny the possibility that the general practitioners of patients with less than optimal glycemic control might have changed the diabetes medication of some of these patients during the study period, which would bring about a bias. However, changes in diabetes medication are inevitable in the management of patients with less than optimal glycemic control."
Bemelmans et al. (2000)	Low - "generated by computer using a random number generator to assign the participants to one of the margarines"	To minimize cross-over of information, the participants of the intervention group were recruited in one county and the participants of the control group were	No information mentioned	No information mentioned	Unclear- "Before the First follow-up (T16) three persons dropped out and before the third examinations (T52) six persons dropped out for diverse reasons."	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all	The study appears to be free of other sources of bias, no missing outcomes

		recruited in neighbouring counties.				expected outcomes	
Bouma et al. (2018)	No information mentioned	"The intervention allocation was concealed until after the baseline measurements were completed."	"Participants and counselors were not informed about the results of the measurements. "	"Data on personal characteristics, PA(SQUASH) and fruit and vegetable intake were obtained the week before baseline. Questionnaires were sent out to participants home addresses and were asked to fill out the week before baseline.	All missing data from baseline and follow-up measurements were imputed with predictive mean matching method. The outcomes show that the magnitude of improvements in the all-cases analyses were similar to the results of the imputed analysis: no significant differences were found between trends. It may therefore be concluded that missing data did not have a significant effect on outcomes	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcomes	18 months follow up data was available for intervention group, compare to only 6 months follow up data for control group. Potential source of bias related to participants dropout rates. Differ drasically between intervention 44% and control group 11%, no explaintion included.
Calfas et al. (2002)	Unclear "After completing the computer program and provider counseling, participants were randomly assigned to one of four extended intervention conditions:"	Unclear - no information	"Subjects were asked to arrive 45 min early for their appointment to complete written informed consent and the PACE+ computer component." Participants and personnel were aware of intention, which would potentially affect the outcome as participants might report their FV intake differently once they know their treatment	Low "The computer program collected baseline measures, and trained telephone interviewers collected 4-month assessments using the same items.	They are not reporting that they don't have final participant data. 43 total participants failed to provide follow-up assessment data. ANOVAs failed to reveal any main effects or interactions involving dropout status on any baseline variable.	Unable to locate original protocol	minority participants were more likely to drop than white participants who speaks English, due to language barriers. No training was given for computer assessments, this could affect outcome data and the dropout rates for people that do not have certain computer knowledge
Campbell et al. (1994)	Unclear "randomly allocated to 3 groups"	Low -by designing both intervention materials similarly in terms of	phone interviewers were blinded to participants stud group membership	computer algorithms were debeloped to access the appropriate text pieces	stated the reason for drop outs (refusal, no answer after 15 attempts, no telephone provided	Full set of data were given in the sutdy. The study protocol is not	Cannot assess other risks base on the given information

		layout, logo, type, and pap0er; by sending personalised cover letters from the fmily physicians with all follow-up serveys		based on each individal baseline infor	High risk - 277 people left from 320, did not report the reasons for participants dropouts	available but it is clear that the published reports include all expected outcomes	
Delichatsios et al. (2006)	"We paired the centers based on size of patient panels and then randomly assigned the centers within each pair to either the intervention or the control group."	We adapted an algorithm for stage of change that included measures of perceived severity a	No information mentioned	We sent the tailored nutrition reports to the participants and their PCPs. We applied the algorithm to consumption of fruits and vegetables	imbalance in numbers or reasons for missing data across intervention groups - In the intervention group, the number of participants changed from 230 to 195 (15% attrition rate), in the control group, the number of participants changed from 274 to 252 (8% attrition rate) 7% point difference, difference of 57,	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcomes	African Americian 13.% in intervention group whereas 1% in control group. Age is very different between groups: in intervention group 49.9 (12.5) and in control grup 56.8 (12.9).
Driehus et al. (2012)	Low, computer generated random sequence was used.	No information mentioned	"In the second and third year subjects had one meeting with NP and received two feedback phone calls each year. In their counseling NPs were guided by a standardized computerized software program"	No information mentioned	dropouts were more often smokers	Unable to locate original protocol	Cannot assess other risks base on the given information
Glasgow et al. (2000)	Low - The computer interaction assessed, immediately analysed, and provided feedback on the patient's dietary patterns, barriers to and support for dietary self-management,	Automated and manually delivered as-pects of the intervention were implemented quite consistently.	Low - The computer interaction assessed, immediately analysed, and provided feedback on the patient's dietary patterns, barriers to and support for dietary self-management,	Total blinding of outcome assessment is impossible in nutrition studies where participants know they will be assessment for the outcome, regardless of the intervention status.	there were no significant differences between conditions on attrition, the representativenes s of those lost through attrition, and the low to moderate overall attrition rate for an effectiveness study (13%)	Full set of data were given in the study. The study protocol is not available but it is clear that the published reports include all	The study appears to be free of other sources of bias, no missing outcomes

	and preferences for different intervention strategies.					expected outcomes	
John et al. (2003)	The trial administrator using a computer-generated randomization list. Randomization was in blocks of four and was stratified by reported smoking status. All those randomised were invited to attend two appointments 6 months apart with a trained research nurse at the health centre	No information mentioned	low "Questions about fruit and vegetables were embedded within other questions to avoid alerting the control group to the nature of the intervention."	Due to including follow-up, participants were aware of assessment.	No information mentioned	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcomes	Cannot assess other risks base on the given information
Koelewijn-van Loon et al. (2010)	An independent statistician performed a central block randomization to allocate 13 practices to the intervention group and 12 practices to the controlgroup, after stratification into 4 geographical regions.	Because of the training,nurses could not be blinded. To minimise potential bias, patients wereinformed about the aim of the study, but not about being part of an intervention or control group.	Patients were aware of study but not outcome results or group allocation	No information mentioned	Insufficient reporting of attrition	Unable to locate original protocol High - no standard deviation data	there was a certain recruitment bias, as there were significantly more smokers in the intervention group than in the control group. This cannot be a random result; significantly higher number of diabetes patients in the control group compared to the intervention group
Ness et al. (2004)	A dietitian randomly allocated the eligible men, using prepared envelopes	Low- "A dietitian randomly allocated the eligible men, using prepared envelopes, to receive advice to eat more fruit and	Low- Questionnaires were sent to participants' homes, making it impossible for another to know another's condition.	Unclear, but study design lends to concealment to participants.	Unclear - missing results from 92 people, the study did not report the reasons	Unable to locate original protocol High - no baseline data	Cannot assess other risks base on the given information

		vegetables, or advice to eat more"					
Prochaska et al. (2005)	Unclear- "The 5407 patients were randomly assigned to the home-based intervention or comparison condition independent ofwhether their physician's practice was assigned to thepractice-level intervention or comparison condition"	No information mentioned	Low: "The telephone surveyors were blind to group assignment."	No information mentioned	In the intervention group, the number of participants changed from 2667 to 1883 (29% attrition rate); in the control group, the number of participants changed from 2740 to 2145 (22% attrition rate). 7% point difference, difference of 263, seems high risk	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcomes	Outcomes were measured inconsistently , different united were used to measure outcome
Recio-Rodriguez et al. (2016)	participants were randomised in a 1:1 proportion on a centralised basis from Salamanca, using the Epidat 4.0 software package to the counseling+app group	No information mentioned	The investigator who performed the data analysis was blinded; Due to the nature of the study, the participants could not be blinded to the intervention	No information mentioned	High- no information regarding reasons for drop out provided	Unable to locate original protocol High - no baseline data and post interventio n data Entire of the study duration is 12 months, only reported 3 months data	the recorded loss rate of close to 10% may have biased the study sample composition to some extent
Sacerdote et al. (2006)	A progressive number was assigned to each eligible patient who attended the selected wards during 6 months. Randomization was performed by the Project Manager, who randomly selected the patients from each ward and assigned the subjects to two groups. Random numbers were generated by	Unclear, but participants were most likely unaware of allocation due to nature of the study design.	Outcome assessors and participants stated to be blinded	Outcome assessors and participants stated to be blinded	no mention of drop out	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcomes	The study appears to be free of other sources of bias, no missing outcomes

	using the computer. The sequence was concealed until interventions were assigned.						
Steptoe et al. (2003)	"We used a minimisation procedure to ensure balance between the groups in terms of age, sex, ethnic distribution, and smoking."	No information mentioned	both intervention groups were aware of type of intervention, but not control groups "Participants of the BBCI and SLI were all informed about the existence of both intervention groups (the BBCI and SLI) and the random allocation to the intervention groups." This would potentially affect the outcome as participants might report their FV intake differently	No information mentioned	Missing outcome data balanced in numbers across intervention groups, with similar reasons for missing data across groups. 110 and 108 remained population in two groups	Unable to locate original protocol High - no post interventio n data	the nurses administering the intervention had not been involved in assessments sent out 3858 invitations of whom only 775 (21%) replied. why some high income volunteers involved, Attrition rate similar, groups similar at the end
Volger et al. (2013)	Not clear - Participants were randomly assigned to one of the three treatment groups	No information mentioned	"As described previously, participants in the Enhanced Brief LC group, in consultation with their PCPs, also chose to receive either meal replacements or weight loss medication as part of their intervention." No blinding, which would potentially affect the outcome as participants might report their FV intake differently	No information mentioned	Sufficient reporting of dropout reasons in both intervention and control groups	Full set of data were given in the sutdy. The study protocol is not available but it is clear that the published reports include all expected outcomes	5-8% point difference between interventions and control, according to researchers not a significant difference. The study population was diverse and included patients at both urban and suburban practice sites, which further extends our findings to the general primary care population.

E – sub-group analysis

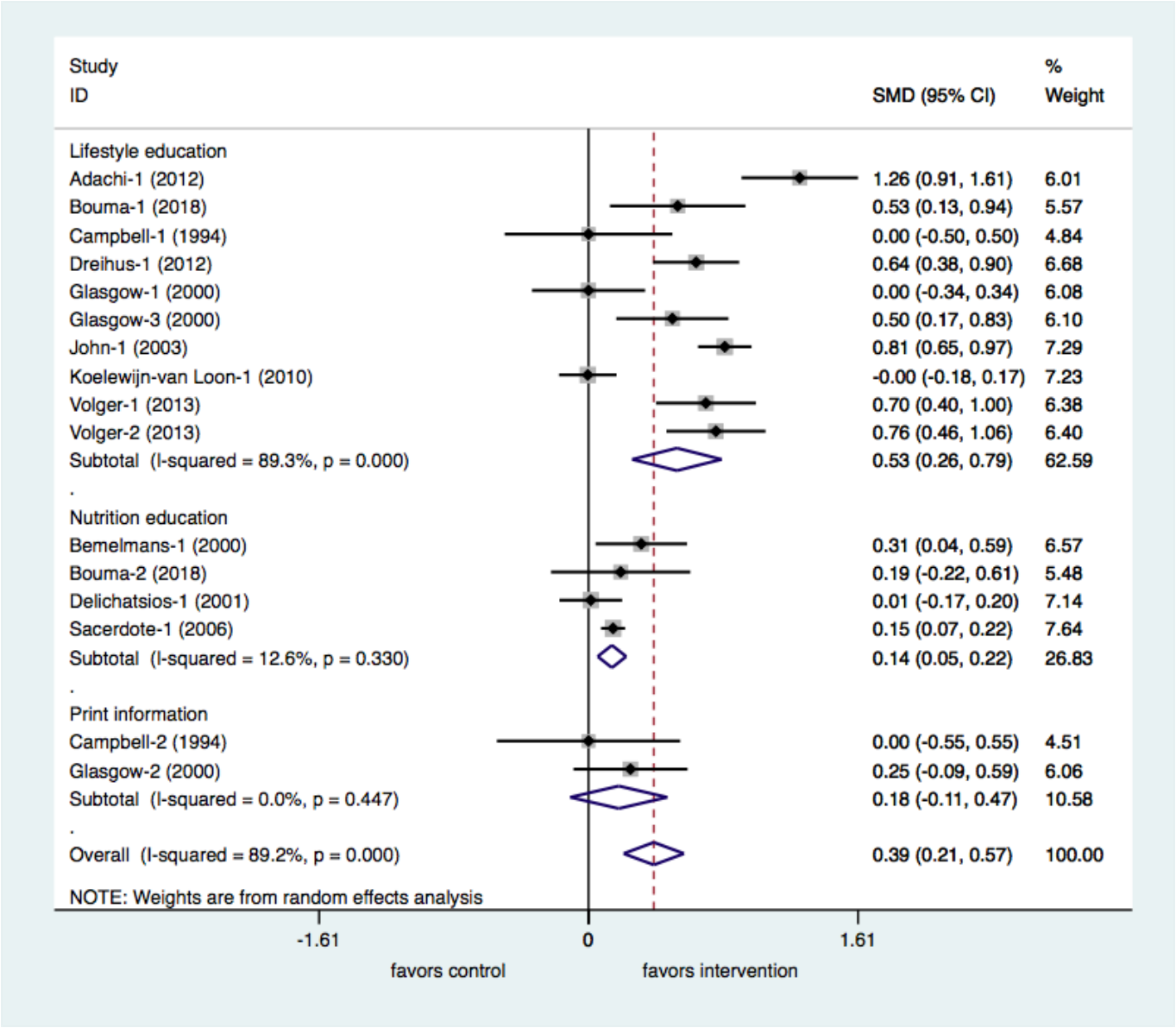

Figure 7. Sub-group by intervention.

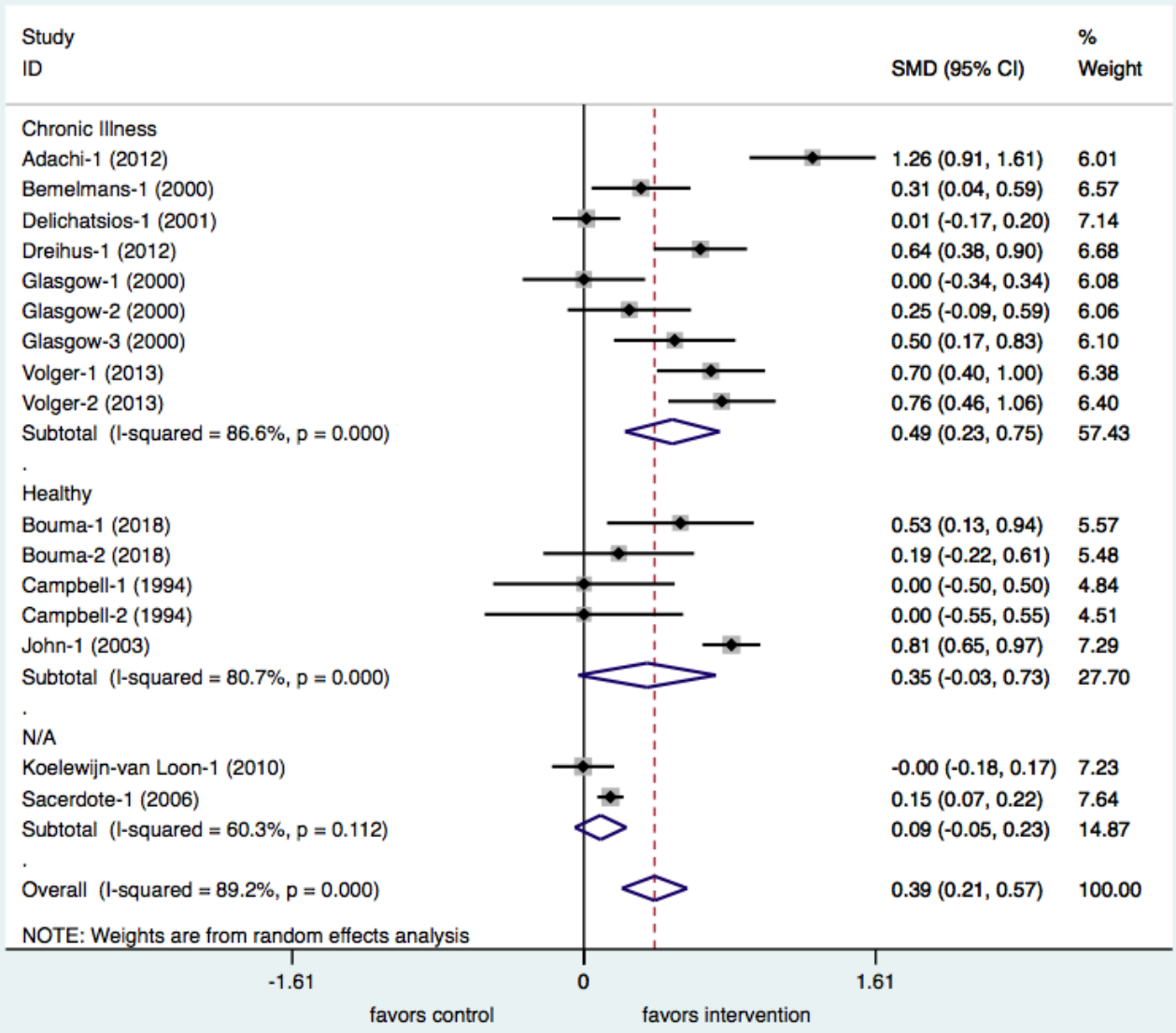

Figure 8. Sub-group by health status.

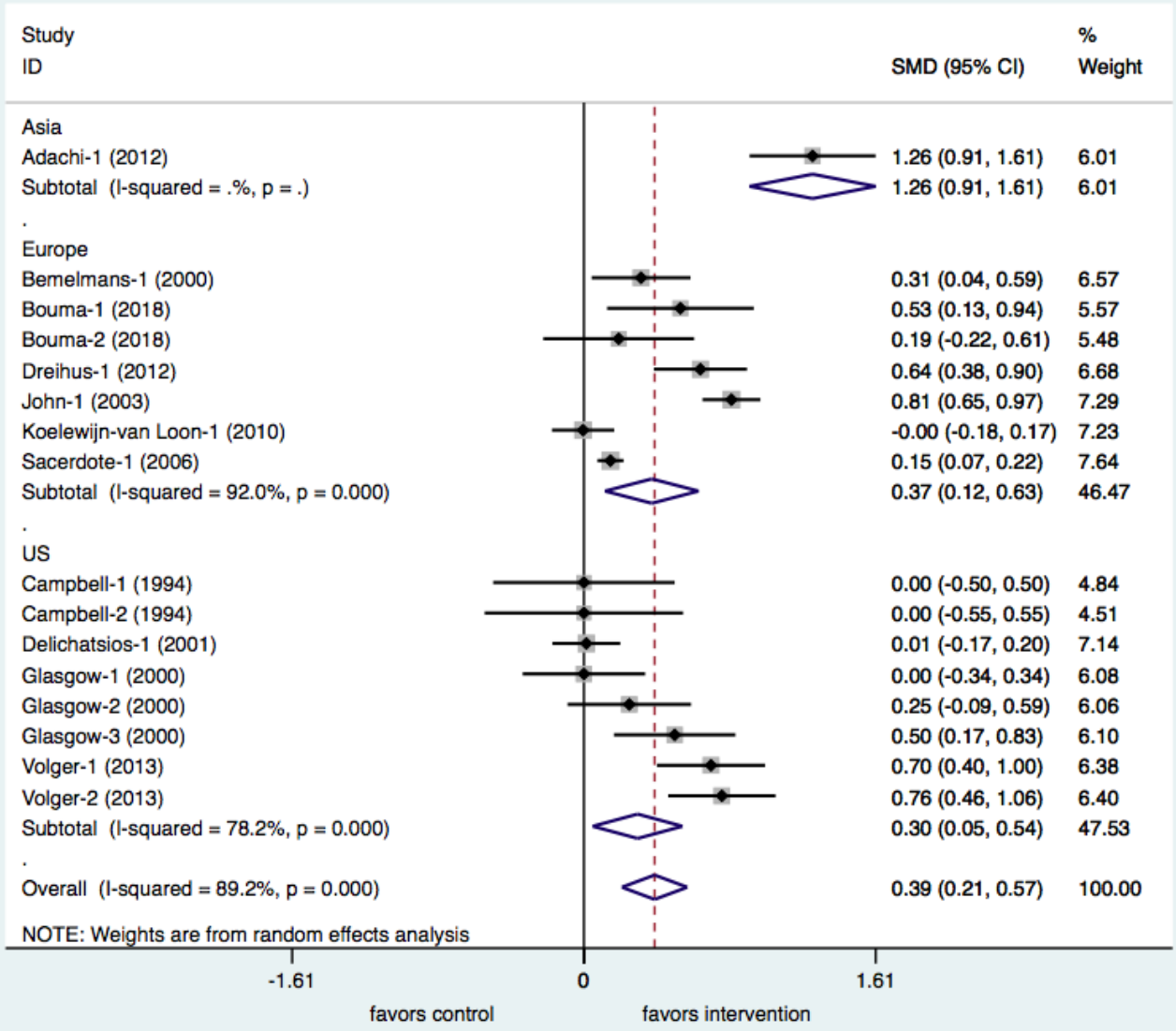

Figure 9. Sub-group by region.