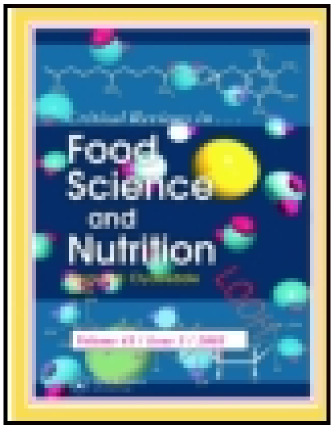

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Fruit Consumption and Adiposity Status in Adults: A Systematic Review of Current Evidence

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TITLE

Fruit consumption and adiposity status in adults: a systematic review of current evidence

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KEY WORDS

Fruit; Adult; Adiposity; Review, Systematic

ABSTRACT

The aim of this review was to update current understanding of the potential association between fruit consumption and adiposity status in adult populations. Electronic databases were searched from 01/01/1997 to the search date of 15/08/2014, retrieving 4, 382 abstracts that were reviewed for eligibility: randomised controlled trial (RCT) or prospective cohort (PC), published in English, assessing the effect of whole fruit or fruit juice consumption on adiposity in healthy adult populations. Quality ratings for the 11 included RCTs were either positive (n=2), neutral (n=8) or negative (n=1), while the six included PCs were either positive (n=4) or neutral (n=2).

Consumption of whole fruit was found to contribute to a reduced risk for long-term weight gain in middle-aged adults. Experimental trials suggest this beneficial effect of whole fruit is mediated by a reduction in total energy intake. Fruit juice however, had an opposing effect, promoting weight gain over the long term. This review reinforces national food based dietary guidelines encouraging the consumption of whole fruits and replacing fruit juices with plain water, as part of a broader set of dietary strategies to reduce total dietary energy intake in adult populations.

INTRODUCTION

Consuming a diet low in fruits has been identified as the fourth leading risk factor for the burden of disease worldwide, behind air pollution, high blood pressure and tobacco smoking (Lim et al., 2012). National food-based dietary guidelines recommend approximately 300g or two cups of fruit daily for adult populations (National Health and Medical Research Council, 2013; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010), yet national dietary monitoring data has been used to demonstrate that current intakes are, on average, about two-thirds to half this amount (Australian Bureau of Statistics, 2013; U.S. Department of Agriculture: Agricultural Research Service, 2013). Recent controversy regarding the detrimental metabolic-related health effects of fructose sugar has however raised public concern over increasing fruit consumption, despite this evidence being founded on high fructose corn syrup rather than naturally occurring fructose in fruit (Stanhope et al., 2013).

The increasing prevalence of excess adiposity among adult populations across the globe is of great concern, due to the positive associations between excess adiposity and all-cause mortality (Finucane et al., 2011; Flegal et al., 2013; Kahn et al., 2012). Fruit may be beneficial for preventing excess adiposity due to its relatively low energy content compared with other foods. Despite this, few studies have examined the independent effects of fruit consumption on adiposity, with most not distinguishing between fruit and vegetable intake (Boeing et al., 2012; Ledoux et al., 2011). Earlier research by Alina and colleagues reported a possible inverse association between fruit consumption and body weight in adults although the available evidence

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was considered inadequate to draw firm conclusions (Alinia et al., 2009). Hence, the aim of this review was to systematically review available evidence to update current understanding of the potential association between fruit consumption and adiposity status in adult populations.

METHODS

This study reports a systematic review of published randomised controlled trials (RCTs) and observational studies with prospective cohorts (PCs), examining the effect of fruit consumption on adiposity status in adult populations. The reporting of this research was informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009).

Inclusion and Exclusion Criteria

Included studies were either PCs which provide evidence of feasibility under free-living conditions, or RCTs which provide evidence required to infer causality under controlled conditions; conducted among healthy adult populations (aged ≥ 18 years) i.e. not pregnant and no evidence of diagnosed chronic disease; and published in English between 01/01/1997 and the search date of 15/08/2014. The earliest publication date of 01/01/1997 was selected as it was during this year that the World Health Organization held the first expert consultation on obesity in Geneva, Switzerland (World Health Organization, 2000), marking the time when obesity

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became recognised as an international population health issue. This date was also consistent with preliminary literature searches revealing the majority of evidence on this topic to have been published during the last decade.

The primary outcome of interest was any valid indicator of adiposity including body weight, body mass index (BMI), or other measures of body fatness i.e. skin-fold thickness or waist circumference (WC). The explanatory variable of interest was quantity of fruit consumed. To translate the findings from this review into practical dietary recommendations for fruit consumption, our definition of 'fruit' included whole or dried fruits and fruit juices, but excluded nuts, seeds, avocado or tomato, to reflect current social definitions of 'fruit'. Studies were excluded if they examined the effect of a specific dietary pattern (e.g. high fibre diet) or multi-component intervention, as the effect of fruit consumption cannot be isolated from the potential effects of other intervention components in these studies.

Systematic Search Strategy

Electronic databases for health sciences were searched on 15/08/2014, including CINAHL, Cochrane Library, EMBASE, Expanded Academic ASAP, Informit Online (Health Collection), MEDLINE, PREMEDLINE, ProQuest Central, Science Direct, Scopus, Web of Science. Search terms used to query these databases included combinations of 'body weight', 'body fat', 'body mass index', 'waist circumference', 'skinfold thickness', 'waist-hip ratio', 'fruit', 'whole fruit', 'fruit juice', 'dried fruit', 'canned fruit' and 'tinned fruit' (see Appendix 1 for specific search strategies). In addition to this search strategy, the reference lists of included studies were searched for additional eligible papers. Citations and abstracts of all papers retrieved from these searches were downloaded into Endnote X6 reference management software (Thomson Reuters, PA, USA). After removing duplicates, abstracts were reviewed and coded by two authors (LH and FO'L) independently for inclusion and exclusion criteria. Conflicting judgements were discussed between authors, with a third independent judgment sought if agreement could not be achieved. Figure 1 illustrates the flow of excluding papers to obtain those included in the present review.

Data extraction

Data items extracted for included papers were author, year, country, study design, study duration, sample size, retention rate, participant characteristics (age, gender and BMI status), method(s) for assessing fruit intake (explanatory variable) and adiposity indicator(s) (outcome variable), intervention and control conditions (for RCTs), results reported for adiposity indicators, and any confounders accounted for in statistical analyses. Data were extracted independently by two authors (ESL and LH) for RCTs, and separate authors for PCs (AR and VH), with any conflicting judgements discussed and a third independent judgment sought if agreement could not be achieved.

Quality assessment

Quality of included studies was assessed using Academy of Nutrition and Dietetics *Quality Criteria Checklist* (Academy of Nutrition and Dietetics, 2012). Each study was critiqued against this checklist and assigned an overall quality rating of ‘Negative (-)’, ‘Neutral (Ø)’ or ‘Positive (+)’. The checklist includes 14 questions, four on study relevance e.g. significance of the study aim, and ten on aspects of validity, e.g. selection bias, study design, comparability of study groups, intervention and exposure factors, outcome measures, statistical analysis and funding sources. Quality was scored independently by two authors (FO’L and ESL) for RCTs, and separate authors for PCs (AR and VH), with conflicting scores discussed and a third independent judgment sought if agreement could not be achieved.

RESULTS

A total of 4, 382 abstracts were reviewed against inclusion and exclusion criteria (Figure 1). After primary and secondary exclusions, 17 studies (11 RCTs and six PCs) were included in the present review.

Characteristics of included studies

Tables 1 and 2 respectively, present characteristics for which data were extracted from the 11 RCTs and six PCs included in this review.

Randomised Controlled Trials (RCTs)

Majority (7/11) of the RCTs were conducted in the United States of America (USA), with the remainder in Brazil, Spain, Mexico and New Zealand. Duration ranged from three to 52 weeks and publication dates from 2005 to 2012. Participant samples ranged from 12-100, were predominantly female, and aged, on average, between 33-58 years. Adiposity indicators included body weight in kilograms (kg) (n=10) (reported in one trial as percentage of initial body weight (Rodríguez et al., 2005)), BMI in kilograms per metre squared (kg/m^2) (n=7), WC in centimetres (cm) (n=6), body fat mass as a percentage of total body mass (n=6) (also as total kg fat mass in one trial (Silver et al., 2011)), as well as hip circumference in cm (n=1), waist-to-hip ratio (WHR) (n=1), or skinfold thickness in millimetres (mm) (n=1).

Prospective Cohorts (PCs)

Four of the six included PCs were conducted in the USA, with the remaining two in Europe. Duration ranged from 3.7 to 20 years, with four published between 2004 and 2013 and data from two older cohorts published in 1997 (Parker et al., 1997; Stamler and Dolecek, 1997). Numbers of participants ranged from 206 in a smaller cohort from one region in Spain to 124, 988 for a pooled analysis of cohorts from the Nurses' Health Study and Health Professionals Follow-up Study in the USA. Compared with the RCTs, cohorts included fewer females with three including 57-62% females, and the remaining three including either 100% females or 100% males. At baseline, participants were aged ≥15, between 18-64, 35-57, or 38-63 or an average of 51-54 years, hence, as for RCTs, the majority were middle-aged adults, and were all at the lower end of the overweight range (i.e. approximately 25.0 – 26.0 kg/m^2). While the inclusion criteria limited the included studies to adult populations aged ≥18 years, the cohort from Vioque and colleagues with subjects aged ≥15 years was retained as the mean (SD) age of participants was 41.5 (17.9) years. Adiposity was reported in the form of adjusted odds ratios for incident obesity or weight gain (He et al., 2004; Vioque et al., 2008), regression coefficients for average weight change per one unit increase in fruit intake (Buijsse et al., 2009; Pan et al., 2013; Parker et al., 1997), or the mean annual change in percent contribution of fruit to total energy (Stamler and Dolecek, 1997).

Quality assessment

Randomised Controlled Trials (RCTs)

Eight RCTs were rated neutral quality, one negative quality (Rush et al., 2006) and two positive quality (Puglisi et al., 2008; Silver et al., 2011) (see quality scores in Table 1). Selective reporting bias was evident in one trial where waist and hip circumferences were reportedly measured, although outcomes were not reported (Udani et al., 2009). Retention rates were 80% or greater in all except two trials (Chai et al., 2012; Conceição de Oliveira et al., 2008). Only four provided details of randomisation. Two used a placebo although this was poorly described (Gonzalez-Ortiz et al., 2011; Udani et al., 2009). Five trials were blinded, but only two provided adequate information on the blinding process (Chai et al., 2012; Udani et al., 2009). Adiposity was the primary outcome in only five studies (Conceição de Oliveira et al., 2008; Dow et al., 2012; Fujioka et al., 2006; Rodríguez et al., 2005; Silver et al., 2011). Dietary intake was assessed in most (9/11) trials, seven undertaking pre- and post- assessments using either a dietary questionnaire (not specified), a repeated 24 hour, three day, or seven day recall, or a food frequency questionnaire (FFQ) combined with either a five-day food record or 24 hour recall. None of the trials reported conflicts of interest, however industry support was evident in all but two studies (Gonzalez-Ortiz et al., 2011; Rodríguez et al., 2005).

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Prospective Cohorts (PCs)

Four PCs were rated positive quality and two of neutral quality (see quality scores in Table 2). All cohorts specified explicit inclusion and/or exclusion criteria. Retention rates were > 70% in all except three cohorts, of which two did not report the retention rate and one retained only half over 10 years (Vioque et al., 2008). Duration was sufficient to demonstrate an effect of fruit consumption on changes in body weight (the only adiposity indicator studied). Three cohorts used self-reported body weight which is traditionally under-reported (Ayre et al., 2012), although all three studies adjusted self-reported weights using measured body weight data. Note that one of these three cohorts combined data from multiple countries where measured body weight was collected at follow-up in some countries, and self-reported body weight in other countries (Buijsse et al., 2009). Methods for assessing fruit intake was by FFQ, except one study which used the 24 hour recall method (Stamler and Dolecek, 1997), although the types of fruit included were not specified in two studies (He et al., 2004; Parker et al., 1997). None reported conflicts of interest and there was no evidence of selective reporting.

Effect of fruit consumption on adiposity

Randomised Controlled Trials (RCTs)

Among the included RCTs, a range of interventions were tested including addition of fruit to the diet compared with a ‘usual diet’ control (Aptekmann and Cesar, 2010; Dow et al., 2012; Puglisi et al., 2008; Rush et al., 2006; Silver et al., 2011), addition of fruit to the diet compared with other types of fruit, other foods, or an energy-giving placebo (Chai et al., 2012; Conceição de Oliveira et al., 2008; Fujioka et al., 2006; Gonzalez-Ortiz et al., 2011; Silver et al., 2011; Udani et al., 2009), or modifying the amount of fruit as a proportion of total energy in the diet (Rodríguez et al., 2005).

Five RCTs tested the effect of adding fruit to the usual diet and compared this with controls who were also instructed to follow their usual diet. Intervention participants were instructed to consume 500mL orange juice a day (Aptekmann and Cesar, 2010), half a grapefruit three times a day (Dow et al., 2012; Silver et al., 2011), 127g grapefruit juice three times a day (Silver et al., 2011), one household cup of raisins a day (Puglisi et al., 2008), or one kiwifruit per 30kg body weight a day (Rush et al., 2006), and were otherwise subject to the same conditions as controls (Table 1). Total energy intakes of participants were not reported in two trials (Puglisi et al., 2008; Rush et al., 2006), however the remaining three trials reported comparable changes in energy intake between groups (i.e. isocaloric conditions), with high compliance to the intervention (assessed directly at 93-100% or indirectly by increases in dietary fibre and vitamin C intakes) (Aptekmann and Cesar, 2010; Dow et al., 2012; Silver et al., 2011). However, only one of these trials reported the difference in total fruit intake between intervention and control participants, which was found to differ significantly at follow-up ($P < 0.001$), with intervention participants increasing their fruit intake by 2.2 servings per day compared with controls who decreased their intake by 0.8 servings per day (Dow et al., 2012). All three trials found no significant difference in adiposity outcomes when fruit was added to the diet compared with consuming a usual diet, under isocaloric conditions. Data on adiposity outcomes from these trials were considered for combining through meta-analysis, although due to the small number of participants and high degree of inconsistency in observed effects across studies ($I^2 = 100\%$), this was decided to be inappropriate (Higgins et al., 2011; Higgins et al., 2003).

A further five RCTs tested the effect of addition of fruit to the diet compared with other types of fruit, other foods, or an energy-giving placebo, rather than using a 'usual diet' control (Chai et al., 2012; Conceição de Oliveira et al., 2008; Fujioka et al., 2006; Gonzalez-Ortiz et al., 2011; Udani et al., 2009). Of these trials, two compared the effect of different types of fruit (Chai et al., 2012; Fujioka et al., 2006). Chai and colleagues compared the effect of two isocaloric diets to which isocaloric amounts of either dried apple or plum were added and found no significant differences in body weight or BMI between groups (Chai et al., 2012). Alternatively, Fujioka and colleagues compared the effects of adding apple juice (~110 calories), grapefruit juice (~110 calories) or ½ whole grapefruit (calories not stated but contains ~30 calories (Food Standards Australia New Zealand, 2008)) each day to the usual diet (Fujioka et al., 2006). The authors reported a significantly greater weight loss between those consuming whole grapefruit compared with the apple juice (1.6kg vs. 0.2kg, $P = 0.048$), although total energy intakes of each group were not reported. Interestingly, Conceição de Oliveira and colleagues reported a significantly greater weight loss among participants consuming three apples or three pears each day, compared with three oat biscuits, (-1.3kg or -2.2kg, vs. -0.7kg, $P < 0.05$). Correspondingly, reported total daily energy intakes decreased significantly within both the apple and pear groups ($P < 0.05$), but remained similar in the oat biscuits group ($P = 0.92$) (Conceição de Oliveira et al., 2008). Alternatively, Rodriguez and colleagues compared the effects of two energy restricted isocaloric diets comprising either 15% or 5% of total energy from fructose sugar from fruit and found a similar percentage of initial body weight and fat mass lost on the high-fruit compared with the low-fruit diet (6.6% vs. 6.9% and 2.9% vs. 2.3%, respectively) (Rodríguez et al., 2005).

Prospective Cohorts (PCs)

Two of the six included PCs found negative associations between change in body weight and intake of whole fruit (*excluding fruit juices*) (Buijsse et al., 2009; Vioque et al., 2008). Buijsse and colleagues reported an average 0.017 kg less weight gain per year with an increase in whole fruit intake of 100g per day (Buijsse et al., 2009). Alternatively, Vioque and colleagues did not observe a dose response effect, rather the likelihood of gaining ≥ 3.4 kg over ten years was found to be lowest (70%) at a baseline intake of 249 – 386g whole fruit per day, compared with 50% or 60% reduced likelihood if intake was 149 – 248g or > 386g per day, respectively (Vioque et al., 2008). Note however, that the PC conducted by Vioque and colleagues included olives as whole fruit. A further three studies examined relationships between incident obesity or weight change and intake of whole fruit (*including fruit juices*) (He et al., 2004; Parker et al., 1997; Stamler and Dolecek, 1997). He and colleagues reported a reduced likelihood of incident obesity over 12 years with an increase in median daily fruit servings (He et al., 2004). In this study, an increase of only 0.22 servings of fruit per day was associated with an average 14% reduced risk of incident obesity, while an increase of 1.86 servings per day was associated with an average 24% reduced risk (one serving of fruit being equivalent to 1 piece, ½ cup berries, or a small glass of juice). Stamler and Dolecek reported greater weight loss with higher average annual percent of total energy from fruit and increase in percent total energy from fruits over six years (Stamler

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and Dolecek, 1997). This was equivalent to an average weight loss of 2.3 – 6.8 kg per annum with a diet comprising an average 5-6% total energy from whole fruit and fruit juice, or an average annual increase of 1.2 – 2.6% total energy from whole fruit and fruit juice (Stamler and Dolecek, 1997). In contrast, Parker and colleagues found a small non-significant positive association between fruit intake and body weight, reporting an average 0.4 kg weight gain over four years for an increase in whole fruit and fruit juice intake of one serving per week (Parker et al., 1997). In the pooled analysis by Pan and colleagues which examined fruit juice intake alone, average four year-weight gain increased by 0.22 kg per serving (small glass) of fruit juice; the observed effect being greater among subjects classified as obese at baseline, gaining an average 0.57kg over four years (Pan et al., 2013). Further, the substitution of one small glass per day of fruit juice with an equivalent serving of plain water was associated with 0.35 kg less weight gain over four years (Pan et al., 2013).

DISCUSSION

The aim of this review was to update current understanding of the potential association between fruit consumption and adiposity status in adult populations. It was found that over the long-term (3-10 years), intake of whole fruit assists with the prevention of weight gain in middle-age populations from highly developed countries. While the observed effects on adiposity status were small, at a population level this can have meaningful benefits for public health. Further evidence from experimental trials illustrate that this beneficial effect of whole fruit intake is likely to be mediated by a reduction in total energy intake, due to the relatively lower energy density of fruits compared to other foods in the diet. Fruit juice however, appears to have the opposite effect, with higher intakes associated with greater weight gain over the long term (16-20 years), particularly among obese individuals.

There was a lack of evidence to inform an amount of fruit to recommend for preventing weight gain in adults, as most cohort studies reported dose-response relationships. However, one cohort study demonstrated the lowest risk of weight gain with a fruit intake approximating 80-130% of current national recommendations (i.e. approximately 300g per day), among a Spanish adult population (Vioque et al., 2008). Future experimental research should examine the effect of different amounts of whole fruit or fruit juices added to an a*d libitum* diet on total energy and energy density of the diet. This would be complimented by data from large cohort studies in other countries being used to examine total energy, energy density, and adiposity outcomes at different levels of whole fruit or fruit juice consumption. Evidence from this review illustrates the need to separate whole foods from their juices in future dietary studies with adiposity related outcomes, as one large cohort study found opposing effects of fruit juices on weight gain (Pan et al., 2013), compared with findings for whole fruit in this review.

Experimental trials from this review demonstrated that increasing the amount of fruit consumed in the diet has no effect on body weight if energy intake is constant (i.e. diets are isocaloric). However, one trial added fruits to an *ad libitum* diet and compared this to adding a food with higher energy-density finding corresponding reductions in energy intake and body weight among the fruit groups (Conceição de Oliveira et al., 2008); thus suggesting fruit consumption to be beneficial for reducing total energy consumption and may therefore assist with weight management in adult populations. This finding is supported by recent research concluding strong and consistent evidence for a relationship between consuming a diet of lower energy density and weight loss or weight maintenance in adults (Perez-Escamilla et al., 2012).

Limitations to the current evidence base include the lack of adjustment for other dietary nutrients or food groups associated with adiposity in humans in experimental and cohort studies. All except one cohort study (Pan et al., 2013), included adjustment for energy intake thus reflecting the relative contribution of fruit to the diet, although it appears energy intake is a mediating variable in the relationship between fruit consumption and adiposity status. The predominance of industry support in experimental trials must also be considered. Finally, the application of findings from cohort studies in practice is limited by inconsistencies in the range and types of fruits included under definitions for fruit, with one cohort including olives (Vioque et al., 2008), which are not considered a fruit by current social definitions, at least in Westernised countries.

While this study focuses specifically on fruit consumption, it is essential to acknowledge the role of other foods, as individuals do not eat singular food groups they eat a diet comprised of multiple foods in different amounts. For example, one cohort study found a stronger associations between increased vegetable intake and risk of weight gain, compared with fruit intake alone (Vioque et al., 2008), thus suggesting vegetable intake may be more important than fruit for long-term weight management in adult populations. Further, this review focuses on adult populations, however it appears little research has been conducted in youth which provides another avenue of future research.

CONCLUSIONS

Consumption of whole fruit contributes to a reduced risk for long-term weight gain in middle-aged adult populations from highly developed countries. Experimental trials suggest this beneficial effect of whole fruit is likely to be mediated by a reduction in total energy intake. Alternatively, fruit juice appears to have the opposite effect, promoting weight gain over the long term. This review reinforces national food based dietary guidelines encouraging the consumption of whole fruits and replacing fruit juices with plain water, as part of a broader set of dietary strategies to reduce total dietary energy intake in adult populations.

ACKNOWLEDGMENTS

FO’L and LH developed the review protocol, with contributions from the other authors, and reviewed abstracts for inclusion in the review. ES-L performed the search strategy, extraction data for the RCTs with LH and quality assessment of the RCTs with F’OL; AR and VH extracted data and conducted quality assessments for the included PCs; LH wrote the majority of the manuscript, and devised the protocol for and conducted the meta-analysis. MA-F, AR, FO’L

and LH prepared the discussion of findings and all authors reviewed and approved the final manuscript.

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APPENDIX 1

Search strategies applied to each database

Medline, Pre-medline

1.exp Body Weight Changes/

2.exp Body Fat Distribution/

3.exp Body Mass Index/

4.exp Body Weight/

5.exp Waist Circumference/

6.exp Skinfold Thickness/

7.exp Waist-Hip Ratio/

8.1 or 2 or 3 or 4 or 5 or 6 or 7

9. exp Fruit/

10.whole fruit.mp.

11.fruit juice.mp.

12.dried fruit.mp.

13.canned fruit.mp.

14.tinned fruit.mp.

15.9 or 10 or 11 or 12 or 13 or 14

16.8 and 15

17.limit 16 to (English language and humans and yr=1997-Current and all adults(19 plus years)

Cochrane Library

#1 MeSH DESCRIPTOR: [Body Weight Changes] explode all trees

#2 MeSH descriptor: [Body Fat Distribution] explode all trees

#3 MeSH descriptor:[Body Mass Index] explode all trees

#4 MeSH descriptor: [Body Weight] explode all trees

#5 MeSH descriptor :[Waist Circumference] explode all trees

#6 MeSH descriptor:[Skinfold Thickness] explode all trees

#7 MeSH descriptor : { Waist-Hip Ratio] explode all trees

#8 MeSH descriptor: [Fruit] explode all trees

#9 whole fruit or canned fruit or tinned fruit or fruit juice or dried fruit:ti,ab,kw (Word variations have been searched)

#10 (#1 or #2 or #3 or #4 or #5 or #6 or #7) and (#8 or #9)

CINAHL

Cinahl #	Query	Limiters/Expanders
S17	S8 AND S15	Limiters - English Language; Published Date: 19970101-20131231 Search modes - Boolean/Phrase
S16	S8 AND S15	Limiters - English Language; Published Date: 19970101-20131231 Search modes - Boolean/Phrase
S15	S9 OR S10 OR S11 OR S12 OR S13 OR S14	Search modes - Boolean/Phrase
S14	"tinned fruit"	Search modes - Boolean/Phrase
S13	"canned fruit"	Search modes - Boolean/Phrase
S12	"dried fruit"	Search modes - Boolean/Phrase
S11	"fruit juices"	Search modes - Boolean/Phrase
S10	'"whole fruit'"	Search modes - Boolean/Phrase
S9	(MH "Fruit+")	Search modes - Boolean/Phrase
S8	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7	Search modes - Boolean/Phrase
S7	(MH "Waist-Hip Ratio")	Search modes - Boolean/Phrase
S6	(MH "Skinfold Thickness")	Search modes - Boolean/Phrase
S5	(MH "Waist Circumference")	Search modes - Boolean/Phrase
S4	(MH "Body Weight+")	Search modes - Boolean/Phrase

S3	(MH "Body Mass Index")	Search modes - Boolean/Phrase
S2	(MH "Adipose Tissue Distribution")	Search modes - Boolean/Phrase
S1	(MH "Body Weight Changes+")	Search modes - Boolean/Phrase

EMBASE

#fruit-17 (#17)

#17.8 AND #17.15 AND ([adult]/lim OR [aged]/lim) AND [humans]/lim AND [english]/lim AND [embase]/lim AND [1997-2013]/py

#fruit-16 (#16)

#16.8 AND #16.15

#fruit-15 (#15)

#15.1 OR #15.2 OR #15.3 OR #15.4 OR #15.5 OR #15.6

#fruit-14 (#14)

'tinned fruit'

#fruit-13 (#13)

'canned fruit'/exp OR 'canned fruit'

#fruit-12 (#12)

'dried fruit'

#fruit-11 (#11)

'fruit juice'/exp OR 'fruit juice'

#fruit-10 (#10)

'whole fruit'

#fruit-9 (#9)

'fruit'/de AND [embase]/lim

#fruit-8 (#8)

 ACCEPTED MANUSCRIPT

#8.1 OR #8.2 OR #8.3 OR #8.4 OR #8.5 OR #8.6 OR #8.7

#fruit-7 (#7)

'waist hip ratio'/de AND [embase]/lim

#fruit-6 (#6)

'skinfold thickness'/de AND [embase]/lim

#fruit-5 (#5)

'waist circumference'/de AND [embase]/lim

#fruit-4 (#4)

'body weight'/de AND [embase]/lim

#fruit-3 (#3)

'body mass'/de

#fruit-2 (#2)

'body fat distribution'/de

#fruit-1 (#1)

'weight change'/de

Proquest

ab(fruit) AND (ab(body weight) OR ab(body mass index) OR ab(waist circumference) OR ab(waist to hip ratio) OR ab(skinfold thickness) OR ab(body fat)) AND schol(yes) AND peer(yes) AND human(yes) AND pd(>19971231) NOT ab(child*) NOT ab(adolescen*) NOT ab(school*)

Science Direct

title-abs-key(fruit) AND (title-abs-key(body weight) OR title-abs-key(body mass index) OR title-abs-key(body fat) OR title-abs-key(waist circumference) OR title-abs-key(skinfold thickness))AND NOT (title-abs-key(child*) OR title-abs-key(adolescen*) OR title-abs-key(school*))

Scopus

(TITLE(fruit) AND (TITLE(body weight) OR TITLE(body mass index) OR TITLE(body fat) OR TITLE(waist circumference) OR TITLE(waist-hip ratio) OR TITLE(skinfold thickness))) OR (ABS(fruit) AND (ABS(body weight) OR ABS(body mass index) OR ABS(body fat) OR ABS(waist circumference) OR ABS(waist-hip ratio) OR ABS(skinfold thickness))) AND DOCTYPE(ar OR re) AND SUBJAREA(mult OR medi OR nurs OR vete OR dent OR heal) AND PUBYEAR > 1996 AND (LIMIT-TO(EXACTKEYWORD, "Humans")) AND (LIMIT-TO(LANGUAGE, "English"))

Web of Science

(TS=(fruit) AND (TS=(body weight) OR TS=(body fat) OR TS=(body mass index) OR TS=(waist circumference) OR TS=(waist-hip ratio) OR TS=(skinfold thickness)) NOT TS=child* NOT TS=adolescen*) AND Language=(English) AND Document Types=(Article OR Review)

DocType=All document types; Language=All languages;

ACCEPTED MANUSCRIPT

Table 1 Characteristics of included studies: Randomised Controlled Trials (RCTs)

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
(Aptekmann and Cesar, 2010); USA; ∅	26 (**IG**: 13, **CG**: 13); 3 months; 86.7%; Age (years) 30-48 years, Female (%) 100; BMI (mean (sd) kg/m^2) **IG**: 28.4 (4.5), **CG**: 29.0 (5.5)	Body weight, height, triceps, abdominal and thigh skinfolds and body fat %, each measured twice on days 1(*baseline*) and 90 (*follow-up*) of study	*Both groups performed 1hr aerobic training 3 times / week, and asked to follow usual diet.* **IG**: 500ml Orange Juice /day + training; **CG**: training *Total energy (MJ/d) baseline, follow-up* **IG**: 7.85 (1.90), 7.70 (1.32); **CG**: 8.48 (2.09), 8.04 (1.97) Decreases in total energy *ns* within both groups.	*Mean (sd) at baseline and follow-up. *P < 0.05 for difference within group* BW (kg) **IG**: 74.6 (13.0), 73.6 (12.4)*; **CG:** 76.3 (15.3), 74.5 (15.9)*; BMI (kg/m^2) **IG**: 28.4 (4.46), 28.1 (4.47)*; **CG:** 29.0 (5.53), 28.3 (5.81)*; BF (%) **IG:** 37.7 (7.56), 33.4 (7.42)*; **CG:** 39.3 (7.33), 33.8 (7.89)* TrST (mm) **IG:** 31.9 (7.90), 26.6 (6.85); **CG:** 32.0	No changes significantly different between groups (*P < 0.05*)

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
				(10.1), 27.3 (9.33) AST (mm) **IG:** 32.2 (11.8), 29.3 (9.60); **CG:** 30.2 (14.3), 25.5 (11.9) ThST **IG:** 52.6 (11.5), 43.4 (9.99); **CG:** 53.0 (12.8), 45.9 (14.9)	
(Chai et al., 2012); USA; Ø	100 (**IG-A**: 45, **IG-B**: 55); 52 weeks; 62.5%; Age (LSM (se) years) **IG-A**: 55.6 (5.0), **IG-B**: 57.5 (4.0); Female (%) 100; BMI (LSM (se) kg/m^2) **IG-A**: 24.8 (4.1), **IG-B**: 24.9 (4.6)	Height (cm) measured at baseline, body weight (kg) measured at baseline and at 3, 6 and 12 months	*Both groups asked to follow usual diet.* **IG-A**: 75g dried apple/d (219kcal); **IG-B**: 100g dried plum/d (220kcal) *Total energy (kcal/d) at 12 months* **IG-A**: 1805 (64); **IG-B**: 1847 (77) Differences between groups *ns* at baseline, or 3, 6 or 12 months.	*Baseline and 12 months* BW (kg) **IG-A**: 68.3 (12.0) and 66.8 (12.3), **IG-B**: 66.3 (12.2) and 66.8 (13.2) BMI (kg/m^2) **IG-A**: 24.8 (4.1) and 24.2 (4.0), **IG-B**: 24.9 (4.6) and 25.2 (4.8)	No significant differences between groups at any time point

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
(Conceição de Oliveira et al., 2008); Brazil; Ø	33 (**IG-A**: 13, **IG-B**: 13, **CG**: 7); 10 weeks; 67.3%; Age (mean (sd) years) **IG-A**: 41.6 (6.4) years, **IG-B**: 44.2 (5.1), **CG**: 46.2 (4.6); Female (%) 100; BMI (mean (sd) kg/m^2) **IG-Apple**: 32.0 (4.9), **IG-Pear**: 31.7 (4.2), **CG**: 31.9 (3.3)	Weight, height and mid-arm circumference measured every 2 weeks	*All participants advised to follow a hypocaloric diet (↓250kcal/d) aiming for 0.5kg weight reduction/week and adjusted fortnightly according to changes in BW and differences in energy intake.* **IG-A**: 3 apples (300g, 188.5kcal)/d; **IG-B**: 3 pears (300g, 191.6 kcal)/d; **CG**: 3 oat cookies (60g, 222.1 kcal)/d *Total energy (kcal/d) at baseline* **IG-A**: 2401 (389); **IG-B**: 2459 (464); **CG**: 2383 (31) Differences between groups ns.	*ANCOVA coefficients at 7 weeks (adjusted for age and treatment group) * P < 0.05 for partial regression coefficient* **IG-A** BW: -0. 92*, MAC: -0. 22, BMI: -0.39*; **IG-B** BW: -0. 84*, MAC: -0. 49*, BMI: -0. 34*; **CG** BW: 0.21, MAC: 0.007, BMI: 0.005	*BW change (kg) at 10 weeks * P < 0.05 compared with CG* **IG-A:** -1.32*, **IG-B:** -2.17*, **CG:** -0.73
(Dow et al., 2012); USA; Ø	71 (**IG**: 39, **CG**: 32), 9 weeks; 83.5%; Age (mean (sd) years) **IG**: 39.4	Body weight (lb), height (inches), WC, HC, and body fat measured at baseline,	*Both groups followed a washout diet (specific bio-active rich fruits and vegetables*	*Mean (sd) changes baseline to week 9 *P < 0.05 IG vs. CG*	No significant differences between groups after adjusting for

Author, Year, Country, Quality Score	Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)	Assessment of adiposity	Intervention / Control Group	Results	
				Within group	Between group
	(10.7), **CG**: 44.0 (11.0); Female (%) **IG**: 74.3, **CG:** 78.1; BMI (mean (sd) kg/m^2) **IG**: 32.9 (4.2), **CG**: 31.4 (3.8)	week 3 and week 9	*restricted, otherwise usual diet) for 3 weeks prior to randomisation and during intervention.* **IG**: ½ grapefruit 15 min before B, L & D + washout diet (weeks 4-9); **CG**: washout diet (weeks 4-9) *Total energy (kcal/d) during intervention phase* **IG**: 1839 (488); **CG**: 1913 (536) Differences between groups ns.	BW (kg) **IG**: -0.61 (2.23), **CG**: -0.11 (1.10) BMI (kg/m^2) **IG**: -0.23 (0.13), **CG**: -0.03 (0.06) BF (%) **IG**: 0.67 (1.00), **CG**: 0.12 (0.30) WC (cm) **IG**: -2.45 (0.60)*, **CG**: -1.23 (0.71) HC (cm) **IG**: -0.77 (3.17), **CG**: 0.02 (0.44) WHR **IG**: -0.01 (0.01)*, **CG**: -0.01 (0.01)	washout values, baseline BMI, age and sex
(Fujioka et al., 2006); USA; Ø	77 (**IG-A** 22, **IG-B** 18, **IG-C** 19, **IG-D** 18); 12 weeks; 84.6%; Age 18-65 years; Female (%) **IG-A** 79.2%, **IG-B** 81.0%, **IG-C**	Body weight and WC measured each month *(including screening visit and at 12 weeks)*	*All groups asked to consume usual diet, and walk 20-30 mins 3-4 times/week* **IG-A**: Grapefruit capsule (500mg freeze dried grapefruit) + 270ml Apple	*Mean changes at 12 weeks* BW (kg) **IG-A**: -1.1; **IG-B**: -1.5, **IG-C**: -1.6, **IG-D**: -0.2 WC (cm) **IG-A**: -3.0,	*Difference in weight loss between **IG-C** and **IG-D**, P = 0.048*

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
	75.0%, **IG-D** 90.9%; BMI (mean (sd) kg/m^2) **IG-A** 34.6 (4.3), **IG-B** 36.5 (5.4), **IG-C** 36.8 (5.6), **IG-D** 34.5 (3.1)		Juice, **IG-B**: Placebo capsule + 237ml Grapefruit Juice, **IG-C**: Placebo capsule + ½ Grapefruit, **IG-D**: Placebo capsule + 207ml Apple Juice. *Total energy (kcal/d)* NR	**IG-B**: -1.2, **IG-C**: -4.6, **IG-D**: -2.5	
(Gonzalez-Ortiz et al., 2011); Mexico; ∅	20 (**IG**:10, **CG**:10); 1 month; 100%; Age (mean (sd) years) **IG**: 36.3 (8.3), **CG**: 38.3 (10.4); Female (NR) BMI (mean (sd) kg/m^2) **IG**: 35.2 (3.1), **CG**: 33.8 (4.1)	Body weight (kg), height (cm), WC and fat mass measured at baseline and after 1 month (*follow-up*)	*Both groups received recommendations about 'their medical nutrition therapy' and instructed to not modify their usual exercise* **IG**: 120mL pomegranate juice/d before breakfast, **CG**: 120mL placebo drink (NR) before breakfast *Total energy (kcal/d)* NR	*Mean (sd) changes baseline to 1 month* BW (kg) **IG**: -0.5 (2.3), **CG**: 1.1 (1.3) BMI (kg/m^2) **IG**: -0.2 (0.9), **CG**: 0.4 (0.5) FM (%) **IG**: -1.4 (3.0), **CG**: 1.1 (1.1)	Significant change in fat mass between groups *P = 0.010*, but not changes in weight or BMI (*P=0.089* and *P = 0.112*, respectively)
(Puglisi et al., 2008); USA; +	34 (**IG-A**: 12, **CG**: 12, **IG-B**: 10); 6 weeks; 100%; Age (mean (sd)	Body weight (kg), height (cm), and WC (cm) measured at weeks 2	*All groups asked to avoid polyphenol rich foods and dietary supplements for weeks 0-8. Then*	*Mean (sd) at baseline and follow-up. No significant changes*	No significant changes between groups at follow-up.

Author, Year, Country, Quality Score	Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)	Assessment of adiposity	Intervention / Control Group	Results	
				Within group	Between group
	years) **IG-A**: 54.4 (3.5), **CG**: 55.0 (3.8), **IG-B**: 57.8 (5.2); Female (%) **IG-A**: 50, **CG**: 50, **IG-B**: 50; BMI (mean (sd) kg/m^2) **IG-A**: 24.9 (2.3), **CG**: 27.9 (3.9), **IG-B**: 27.5 (3.8);	(*baseline*) and 8 (*follow-up*).	*randomised to following groups for weeks 3-8:* **IG-A**: 1 cup raisins/d, **CG**: increase daily steps by 10 minutes/d, **IG-B**: 1 cup raisins/d + increase daily steps by 10 minutes/d. *Registered dietitian counselled subjects on incorporating raisins and/or increased steps to ensure weight maintenance. Total energy (kcal/d)* NR	*within groups.* BW (kg) **IG-A**: 70.8 (12.2) and 70.9 (11.9), **CG**: 78.7 (16.8) and 78.6 (17.1), **IG-B**: 78.4 (15.9) and 78.4 (16.0) WC (cm) **IG-A**: 86.4 (8.2) and 85.7 (9.1), **CG**: 90.5 (13.4) and 90.5 (13.2), **IG-B**: 91.0 (11.0) and 90.6 (11.8)	
(Rodríguez et al., 2005); Spain; Ø	15 (**IG-A**: 8, **IG-B**: 7); 8 weeks; 100%; Age (mean (sd) years) 32.6 (5.8); Female (%) 100; BMI (mean (sd) kg/m^2) **IG-A**: 34.2 (2.6), **IG-B**: 35.6 (3.3)	Body weight (kg), height (cm), WC, HC and body composition were measured at baseline, and days 14, 35 and 56 (*follow-up*).	*Both groups asked to follow isocaloric diet with 600kcal/d energy restriction and subjects reported no changes in PA.* **IG-A**: High fruit diet (15% energy from fructose); **IG-B**: Low fruit	*Mean (sd) changes baseline to follow-up* BW (% of baseline BW) **IG-A**: -6.6 (2.0), **IG-B**: -6.9 (2.0) FM (% of baseline FM) **IG-A**:	Change in WC between **IG-A** and **IG-B** (*P = 0.048*)

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
			diet (5% energy from fructose) *Total energy (kcal/d)- average weeks 2, 5 and 8 of study* **IG-A**: 1304.3 (223.6); **IG-B**: 1256.9 (283.0) Differences between groups *ns* throughout study.	-2.9 (2.0), **IG-B**: -2.3 (2.0) *Mean (sd) at baseline and follow-up* BW (kg) **IG-A**: 91.6 (6.0), 85.5 (6.1); **IG-B**: 91.1 (13.0), 84.7 (11.6) BMI (kg/m^2) **IG-A**: 34.2 (2.6), 32.0 (2.9); **IG-B**: 35.6 (3.3), 33.1 (3.0) FM (%) **IG-A**: 41.2 (3.3), 38.5 (4.3); **IG-B**: 43.6 (3.9), 41.3 (3.7) WC (cm) **IG-A**: 95.1 (5.2), 89.6 (5.2); **IG-B**: 96.3 (8.9), 93.9 (6.9)	

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
				WHR **IG-A**: 0.81 (0.07), 0.80 (0.07); **IG-B**: 0.81 (0.07), 0.83 (0.08)	
(Rush et al., 2006); NZ; -	12 (IG: 6, CG: 6); 3 weeks; 100%; Age (mean (sd) years) **IG**: 40 (7), **CG**: 46 (8); Female (%) **IG**: 50, **CG**: 50; BMI (mean (sd) kg/m^2) **IG**: 28 (6), **CG**: 27 (3)	Body weight (kg) measured at *baseline* and after 3 weeks (*follow-up*)	*Both groups provided same lifestyle intervention during 3 weeks prior to intervention.* **IG**: 1 kiwifruit/30kg BW/d for 3 weeks, **CG**: No kiwi fruit for 3 weeks. *Total energy (kcal/d)* NR	*Mean (sd) change in body weight baseline to follow-up* **IG**: 0.5 (0.9), **CG**: -0.4 (0.9)	Change in BW not significant between **IG** and **CG**
(Silver et al., 2011); USA; +	68 (IG-A: 23, IG-B: 22, CG: 23); 12 weeks; 80%; Age (mean (sd) years) **IG-A**: 37.6 (7.4), **IG-B**: 39.8 (8.4), **CG**: 38.7 (8.8); Female (%) **IG-A**: 62, **IG-B**: 89, **CG**: 75;	Body weight (kg), height (cm), WC and hip circumference (cm) measured at weeks 0 (*baseline*), 2 and 14 (*follow-up*).	*All groups provided a 12.5% calorie restricted diet (weeks 0-14). Then randomised to different preloads to be consumed daily before B, L & D (weeks 3-14):* **IG-A**: ½ grapefruit (42	*Mean (sd) changes week 2 to follow-up (week 14)* BW (kg) **IG-A**: -5.8 (3.9), **IG-B**: -5.9 (3.6), **CG**: -6.7 (3.1) *Mean (sd) changes*	No significant differences between groups after controlling for baseline values

Author, Year, Country, Quality Score	Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)	Assessment of adiposity	Intervention / Control Group	Results	
				Within group	Between group
	BMI (mean (sd) kg/m^2) **IG-A**: 36.3 (3.1), **IG-B**: 35.2 (3.1), **CG**: 35.7 (3.5)		kcal); **IG-B**: 127g grapefruit juice (46 kcal); **CG**: 127g water (0kcal) *Total energy (kcal/d) at week 14* **IG-A**: 1679.7, **IG-B**: 1517.3, **CG**: 1542.2 Differences between groups *ns* at baseline, week 2 or week 14.	*baseline (week 0) to follow-up (week 14)* BMI (kg/m^2) **IG-A**: -1.6 (1.6), **IG-B**: -1.9 (1.4), **CG**: -2.1 (1.1) WC (cm) **IG-A**: -4.0 (4.1), **IG-B**: -5.5 (5.7), **CG**: -5.4 (4.8) FM (kg) **IG-A**: -2.6 (2.1), **IG-B**: -2.9 (2.9), **CG**: -2.5 (2.1) FM (%) **IG-A**: -1.1 (1.8), **IG-B**: -1.1 (1.9), **CG**: -1.2 (2.6) TF (%) **IG-A**: -1.4 (2.9), **IG-B**: -1.7 (2.6), **CG**: -1.2 (2.6) AF (%) **IG-A**: -1.9	

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
				(2.4), **IG-B**: -1.2 (2.7), **CG**: -1.5 (3.3) GF (%) **IG-A**: -1.5 (2.4), **IG-B**: -0.5 (2.9), **CG**: -0.7 (4.5)	
(Udani et al., 2009); USA; ∅	40 (IG-A: 11, IG-B: 12, IG-C: 9, CG: 8); 8 weeks; 91%; Age **IG-A**: 52, **IG-B**: 33, **IG-C**: 50, **CG**: 45 years; Female **IG-A**: 91%, **IG-B**: 100%, **IG-C**: 89%, **CG**: 100%; OW 100%;	Body weight (kg), height, WC and hip circumference (cm) were measured at screening and weeks 0 (*baseline*), 4 and 8 (*follow-up*). Methods for body fat measurement NR.	*All groups asked to follow usual diet. Randomised to different amounts of Xango Juice (mangosteen puree and other fruit juice) to be taken twice daily.* **IG-A**: 3oz Xango Juice + 6oz placebo drink *contained sucrose (3g/30ml), citric acid, red grape juice concentrate, fibre complex, grape skin, whey protein isolate, sodium benzoate, xanthan gum and cloud (ester gum), flavourings and colourings*),	*Mean at baseline and follow-up* BMI (kg/m^2) **IG-A**: 33.7, 32.2; **IG-B**: 32.6, 33.9; **IG-C**: 34.1, 35.0; **CG**: 34.8, 36.1 FM (%) **IG-A**: 41.5, 39.8; **IG-B**: 39.3, 34.5; **IG-C**: 37.8, 37; **CG**: 39.3, 38.0	Significantly lower BMI in **IG-A** at 8 weeks (*P = 0.006*), and in **IG-B** at weeks 4 and 8 (*P = 0.005*, respectively), compared with **CG**. Significantly lower %FM in **IG-A** at 8 weeks (*P = 0.016*) compared with **CG**.

Author, Year, Country, Quality Score	**Participants: N; Follow Up; Retention rate; Characteristics (*age, gender, BMI status*)**	**Assessment of adiposity**	**Intervention / Control Group**	**Results**	
				Within group	**Between group**
			IG-B: 6oz Xango Juice + 3oz placebo, **IG-C**: 9oz Xango Juice **CG**: 9oz placebo *Total energy (kcal/d)* NR		

Abbreviations: AF = Android Fat, AST = Abdominal Skinfold Thickness, B = breakfast, BMI = body mass index, BW = body weight, CG = control group, D = dinner, F = female, GF = Gynoid Fat, IG = intervention group, L = lunch, LSM = least square mean, M = male, MAC = mid-arm-circumference, NR = not stated, *ns* = non-significant, OB = obese, OW = overweight, TF = Trunk Fat, ThST = Thigh Skinfold Thickness, TrST = triceps skinfold thickness, WC = waist circumference, WHR = waist-hip-ratio.

Ø = neutral quality rating, **+** = positive quality rating, **-** = negative quality rating

Table 2 Characteristics of included studies: Prospective Cohorts (PCs)

Author, Year; Country; Quality Score	**Participants: N (*at follow-up*); Baseline year; Follow Up; Retention rate; Characteristics**	**Assessment of adiposity**	**Assessment of fruit intake**	**Confounders**	**Results**
(Buijsse et al., 2009); Denmark/ Germany/ UK/ Italy/ Netherlands; +	89, 432; 1992-8; 3.7 – 10.0 years; 69.8%; Female 58.5%, Age *at baseline* (range mean (sd) years): 51.3 (9.8) – 53.9 (7.9); BMI *at baseline* (range mean (sd) kg/m^2): 25.2 (4.1) – 26.4 (3.3)	Body weight (kg) and height (cm) were measured at baseline by trained staff without shoes and in underwear or light clothing (*in latter case 1kg body weight subtracted for clothing*), and again at follow-up: either (1) measured (*as per above*) in the UK and the Netherlands (Doetinchem) or (2) self-reported in Italy, the Netherlands (Amsterdam, Maastricht), Germany, and Denmark (*self-reported body weight was adjusted for under-reporting using measured and self-reported body weight data from separate UK cohort*).	Random sample of (~8%) from each cohort completed standardise 24-hr recall. Fruit intake from 24-hr recall regressed on FFQ in sex- and centre-specific linear model to calibrate fruit intake to account for errors across country specific FFQs. 'Fruit' included fresh, dried and canned fruit, and fruit compote; excluded fruit juices and olives.	**Model A:** age, sex, cohort, energy intake, effect modifier (*UK cohort * F&V intake*), duration of follow-up. **Model B:** *as for A plus* baseline weight. **Model C:** *as for B plus* baseline height, education level, PA, smoking status, alcohol intake, post-menopausal status, HRT use.	*Mean change (95%CI) in body weight (g/year) per 100g/day increase in fruit intake* **Model A:** -17 (-23, -11) **Model B:** -14 (-20, -8) **Model C:** -16 (-22, -10) *Mean change (95%CI) in body weight (g/year) per 100g/day increase in fruit intake (using intakes from FFQ rather than calibrated intakes)* **Model C:** -8 (-12, -4)
(He et al., 2004); USA; +	NR (*74, 063 at baseline*); 1984; 12 years; NR;	Body weight (kg) and height (cm) self-reported at baseline and follow-up; body	Semi-quantitative FFQ (*Willet et al*) at baseline and follow-up.	**Model 1:** age. **Model 2:** *as for 1 plus* baseline BMI, year of follow-up, as well as changes	*Adjusted odds ratio (95%CI) of incident obesity (30 kg/m^2) by increasing quintile of median change in daily servings of fruit* **Reference:** -1.27 = 1.00

<table>
<tr><th>Author, Year; Country; Quality Score</th><th>Participants:
N (at follow-up);
Baseline year;
Follow Up;
Retention rate;
Characteristics</th><th>Assessment of adiposity</th><th>Assessment of fruit intake</th><th>Confounders</th><th colspan="3">Results</th></tr>
<tr><td rowspan="3"></td><td rowspan="3">Female 100.0%;
Age (at baseline) 38-63 years, mean (sd) range: 49.0 (7.0) – 52.0 (7.0);
BMI mean (sd) range kg/m^2 24.8 (5.0) – 25.0 (5.0)</td><td rowspan="3">weight validated against measured weights for population.</td><td rowspan="3">Included 16 fruit items (NR but included fruit juices). Validated against four 7-day dietary records with correlation coefficients of 0.80 for apples, 0.79 for bananas and 0.84 for grapefruit.</td><td rowspan="3">in PA, smoking status, alcohol and caffeine intake, HRT use, total energy intake and energy-adjusted intakes of saturated fat, polyunsaturated fat, monounsaturated fat, trans-unsaturated fats, and protein.</td><td>-0.29
0.22
0.80
1.86</td><td>Model 1:
0.95 (0.88, 1.03)
0.85 (0.78, 0.92)
0.82 (0.76, 0.89)
0.75 (0.69, 0.81)
P for trend <0.0001</td><td>Model 2:
0.95 (0.85, 1.05)
0.86 (0.77, 0.96)
0.84 (0.76, 0.94)
0.76 (0.68, 0.84)
P for trend = 0.0007</td></tr>
<tr><td colspan="3">Adjusted odds ratio of major weight gain (≥ 25 kg) by increasing quintile of median change in daily servings of fruit
Reference: -1.27 = 1.00</td></tr>
<tr><td>-0.29
0.22
0.80
1.86</td><td>Model 1:
0.70 (0.56, 0.89)
0.75 (0.59, 0.94)
0.71 (0.56, 0.90)
0.72 (0.57, 0.91)
P for trend = 0.008</td><td>Model 2:
0.68 (0.53, 0.89)
0.78 (0.60, 1.01)
0.72 (0.55, 0.94)
0.73 (0.56, 0.95)
P for trend = 0.03</td></tr>
<tr><td>(Pan et al., 2013);
USA; +</td><td>NHS 50, 013;
1976;
20 years;
> 90% per 2-year interval;
Female 100.0%;
Age at baseline (mean years): 51.8;
BMI at baseline (mean kg/m^2): 25.1</td><td>Body weight (kg) and height (cm) self-reported at baseline and each 2-year interval; body weight validated against measured weights for NHS population.</td><td>Semi-quantitative FFQ (Willet et al) at baseline and every 4 years during follow-up. Included item for ‘fruit juices’ (apple juice, orange juice,</td><td>Model 1: age.
Model 2: as for 1 plus baseline BMI at beginning of each 4-year period, sleep duration, changes in physical activity, alcohol use, television watching, smoking, dietary</td><td colspan="3">Note: Results are for pooled analyses from the three cohorts

Mean change (95%CI) in body weight (kg/4-years) per one ‘small glass’ per day increase in fruit juice consumption
Model 1: 0.21 (0.12, 0.30)
Model 2: 0.22 (0.15, 0.28)

Model 2 (stratified by BMI):
< 25.0 0.09 (0.04,</td></tr>
</table>

Author, Year; Country; Quality Score	**Participants: N (*at follow-up*); Baseline year; Follow Up; Retention rate; Characteristics**	**Assessment of adiposity**	**Assessment of fruit intake**	**Confounders**	**Results**
	NHS II 52, 987; 1989; 16 years; > 90% per 2-year interval; Female 100.0%; Age *at baseline* (mean years): 37.7; BMI *at baseline* (mean kg/m^2): 24.9 HPFS 21, 988; 1986; 20 years; > 90% per 2-year interval; Female 0.0%; Age *at baseline* (mean years): 50.6; BMI *at baseline* (mean kg/m^2): 25.3		*grapefruit juice and other juice*).	variables (fruits, vegetables, whole grain, refined grain, potatoes, potato chips, red meat, other dairy products, sweets and desserts, nuts, fried foods and *trans*-fat) and other beverages (plain water, sugar-sweetened and diet beverages, whole and low-fat milk, tea and coffee).	0.13) 25.0 – 29.9 0.25 (0.16, 0.34) ≥ 30.0 0.57 (0.49, 0.66) **Model 2 (*substitution of one 'small glass' fruit juice per day with '1 cup' plain water per day):*** -0.35 (-0.23, -0.46)
(Parker et al., 1997); USA; Ø	465; 1986-87; 4 years; NR; Female (%) 62.2; Age (*at baseline*) 18-64 years, mean (sd) 46.6 (13.5); BMI mean (sd) kg/m^2 26.5 (5.0)	Body weight was measured in light clothing and height without shoes by trained interviewers at baseline and follow-up.	Semi-quantitative FFQ (*Willet et al*) at baseline only. 'All fruits' included (Willet et al FFQ includes whole fruits and fruit juices under 'fruit' category). Specific fruit items NR.	Age, BMI, smoking status, PA, total energy intake. *(Included interaction term for gender by fruit servings/week)*	*Regression co-efficient (se) for association between 4-year weight change and number of fruit servings per week* **0.40 (0.30) *P = 0.17***

Author, Year; Country; Quality Score	**Participants: N (*at follow-up*); Baseline year; Follow Up; Retention rate; Characteristics**	**Assessment of adiposity**	**Assessment of fruit intake**	**Confounders**	**Results**
(Vioque et al., 2008); Spain; +	206; 1994; 10 years; 51.1%; Female (%) 56.8, Age (*at baseline*) ≥15 years, mean (SD) 41.5 (17.9) years; BMI mean (sd) kg/m^2 25.8 (4.8)	Body weight (kg) and height (cm) measured using same protocol at baseline and follow-up: weight measured using electronic scales and height without shoes, standing, with back against stadiometer.	Semi-quantitative FFQ validated for Valencia population administered at baseline and 10-year follow-up. 'Fruit' included orange, apple, peach, nectarine, apricot, melon, grape, cherry, strawberry, fig, banana and olives (excluded fruit juices).	**Model 1:** age, sex, education level, BMI, time spent watching TV, presence of disease (CVD, DM, cancer), baseline height, total energy intake, and energy-adjusted intakes of protein, saturated fat, monounsaturated fat, polyunsaturated fat, fibre, caffeine, and alcohol. **Model 2:** *as for 1 plus* self-reported change in fruit intake over past 10-years (yes/no)	*Adjusted odds ratio (95%CI) of weight gain ≥ 3.41 kg by increasing quartile of baseline fruit intake* **Model 1:** <149g/day = 1.00 149-248g/day = 0.53 (0.20, 1.41) 249-386g/day = 0.27 (0.09, 0.76) >386g/day = 0.43 (0.13, 1.40) ***P for trend = 0.059*** **Model 2:** <149g/day = 1.00 149-248g/day = 0.56 (0.21, 1.53) 249-386g/day = 0.32 (0.11, 0.91) >386g/day = 0.62 (0.18, 2.1) ***P for trend = 0.211***
Cohorts from usual care arm of RCT					
(Stamler and Dolecek, 1997);* USA; ∅	6, 287; 1973-6; 6 years; 87.6% (*at year six visit*); Male 100%; Age (*at baseline*) 35-57 years;	Body weight (lb, *conversion: 1 lb = 0.45 kg*) and height (cm) measured at baseline; body weight additionally measured at each annual trial visit (years 1-6).	24-hr dietary recall recorded by trained nutritionist at annual trial visits (years 1-3 and 6). 'Fruit' included fresh and dried fruits and fruit juices with and without added sugars.	None stated.	*Mean annual fruit intake (% of total energy) for category of mean annual weight change, for trial years 1-6* ≥ + 2.3 = 4.4 < + 2.3 to < -2.3 = 4.6 - 2.3 to - 4.1 = 5.2 - 4.5 to - 6.4 = 5.3 ≥ - 6.8 = 6.4 ***P for trend < 0.001*** *Mean annual change in fruit intake (% of total energy) for category of mean annual weight change, for trial years 1-6* ≥ + 2.3 = 0.8 < + 2.3 to < -2.3 = 0.8 - 2.3 to - 4.1 = 1.2 - 4.5 to - 6.4 = 1.3 ≥ - 6.8 = 2.6 ***P for trend = 0.001***

* Information on trial methods sourced from (Kjelsberg et al., 1997).

Abbreviations: CVD = cardiovascular disease, DM = diabetes mellitus, FFQ = food frequency questionnaire, g = grams, HPFS = Health Professionals Follow-up Study, hr = hour, HRT = hormone replacement therapy, PA = physical activity, NHS = Nurses' Health Study.

∅ = neutral quality rating, + = positive quality rating, - = negative quality rating

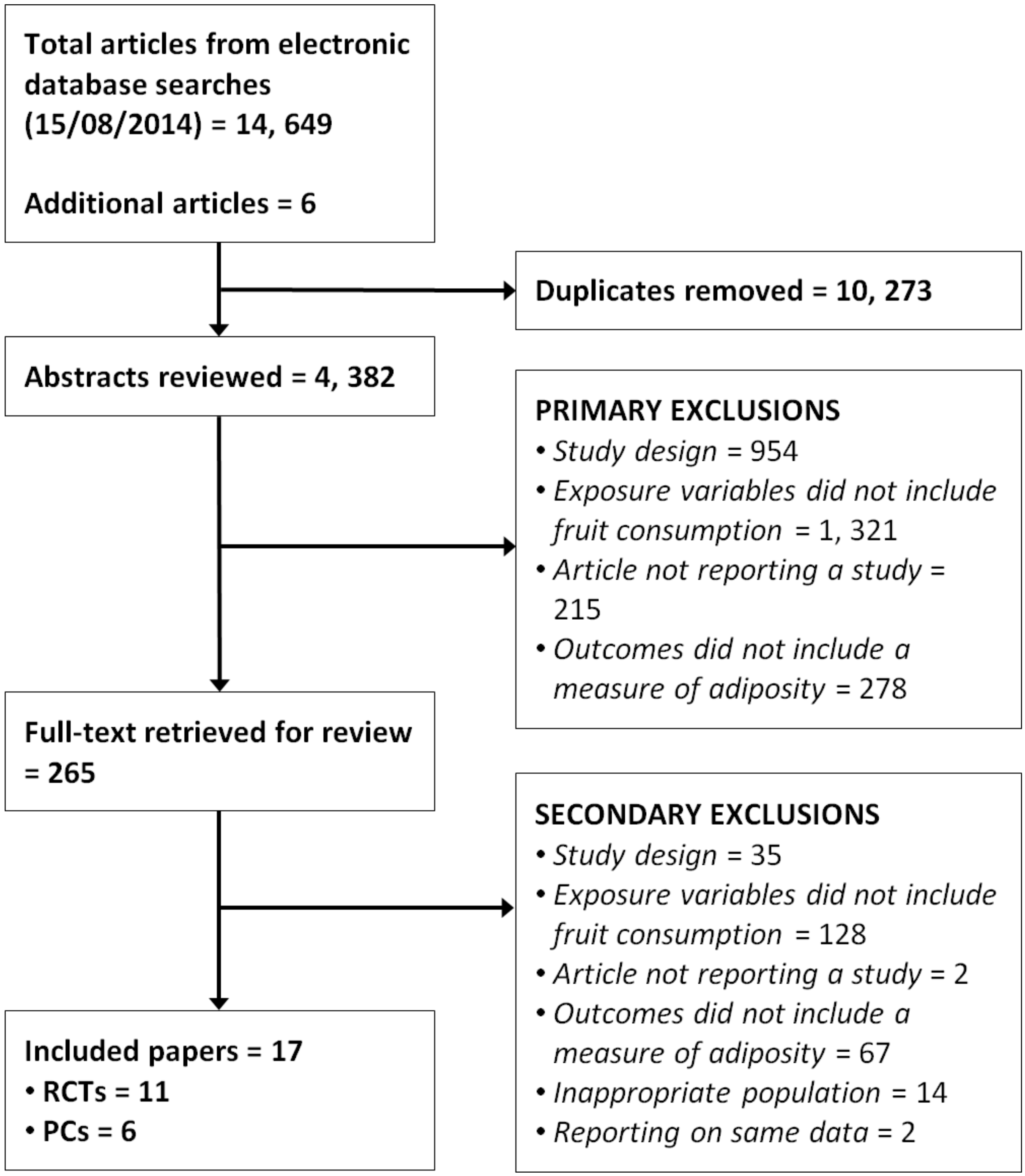

Figure 1 Flow of paper exclusions