Increased fruit and vegetable intake has no discernible effect on weight loss: a systematic review and meta-analysis

Kathryn A Kaiser, Andrew W Brown, Michelle M Bohan Brown, James M Shikany, Richard D Mattes, and David B Allison

ABSTRACT
Background: A common dietary recommendation for weight loss, especially in lay public outlets, is to eat more fruit and vegetables (F/Vs). Without a compensatory reduction in total energy intake, significant weight loss would be unlikely.

Objective: We aimed to synthesize the best available evidence on the effectiveness of the general recommendation to eat more F/Vs for weight loss or the prevention of weight gain.

Design: We searched multiple databases for human randomized controlled trials that evaluated the effect of increased F/V intake on body weight. Inclusion criteria were as follows: ≥15 subjects/treatment arm, ≥8-wk intervention, a stated primary or secondary outcome of body weight, the stated goal of the intervention was weight or fat loss or the prevention of weight or fat gain, and food intake provided or prescribed was of a variety of F/Vs that remained minimally processed.

Results: Two studies met all criteria; 5 other studies met all criteria but one. The primary analysis indicated an effect size of weight change (outcome of interest) from baseline [standardized mean difference (SMD) for studies that met all criteria] of -0.16 (95% CI: -0.78, 0.46) (P = 0.60). The SMD for 7 studies that met all or most criteria was 0.04 (95% CI: -0.10, 0.17) (P = 0.62).

Conclusions: Studies to date do not support the proposition that recommendations to increase F/V intake or the home delivery or provision of F/Vs will cause weight loss. On the basis of the current evidence, recommending increased F/V consumption to treat or prevent obesity without explicitly combining this approach with efforts to reduce intake of other energy sources is unwarranted. This systematic review and meta-analysis was registered at http://www.crd.york.ac.uk/PROSPERO/ as CRD42013004688.

INTRODUCTION

A common dietary recommendation for weight management, especially among lay public-oriented medical information portals, is to eat more fruit and vegetables (F/Vs). An example that specifically neglects the corollary reduction in foods that are more energy-dense is shown on WebMD (1). Another example is a more expert-targeted source: “A recent WHO/FAO expert consultation report (2) on diet, nutrition and prevention of chronic diseases, sets population nutrient goals and recommends intake of a minimum of 400 g of fruits and vegetables per day for the prevention of chronic diseases such as obesity. The report states that there is convincing evidence that fruits and vegetables decrease the risk for obesity” (3). However, it is intuitive that, without a compensatory reduction in intake of total energy, weight gain would be more likely than weight loss. The 2010 Dietary Guidelines for Americans (4) recommends an increased consumption of F/Vs to reduce risk of obesity associated with several chronic diseases. This recommendation is supported by the USDA MyPlate educational concept (5), which devotes one-half the plate to these 2 food groups. F/Vs exert their health effects through what they add to and subtract from the diet. F/Vs contribute micronutrients, fiber, and various phytochemicals, many of which are associated with reductions of risk for disorders such as heart disease (6–9), selected cancers (10–15), and diabetes (16). However, with respect to obesity, F/Vs are promoted for their satiating properties (volume and fiber) and as dietary diluents. Proposed mechanisms by which F/Vs may aid satiation and satiety include the activation of cognitive (17, 18), sensory (19), oromechanical (3), and gastric (20) signaling systems. F/Vs may further moderate energy intake by displacing foods that are more energy dense from the diet (21) and reduce energy absorption from the gastrointestinal tract (22, 23).

A resolution of observations about these proposed mechanisms with data on subsequent body-weight outcomes is required to inform public policy related to F/V consumption and weight management. Previous reviews in the past 5 y of observational and experimental evidence in adults and children have noted inconsistent or null findings and called for better prospective designs to address potentially causal effects (24, 25). In the

1 From the Office of Energetics, School of Public Health (KAK, AWB, and DBA), the Nutrition Obesity Research Center (KAK, AWB, MMBB, JMS, and DBA), the Department of Nutrition, School of Health Professions (MMBB), and the Division of Preventive Medicine, School of Medicine (JMS), University of Alabama at Birmingham, Birmingham, AL, and the Department of Nutrition Science, Purdue University, West Lafayette, IN (RDM).
2 The opinions expressed are those of the authors and not necessarily those of the NIH or any other organization. The authors had sole discretion of the design, conduct and results reported.
3 Supported by the University of Alabama at Birmingham Nutrition Obesity Research Center grants P30DK056336, NIH T32DK062710.
4 Address reprint requests and correspondence to DB Allison, Dean’s Office, Office of Energetics, Ryals Public Health Building 140J, 1720 Second Avenue South, Birmingham, AL 35294-0022. E-mail: dallison@uab.edu.
5 Abbreviations used: F/V, fruit and vegetable; LER, low-energy reporter; SMD, standardized mean difference.

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Inclusion criteria
All included studies had to meet the following criteria:
1) Number of subject randomly assigned per arm was ≥15.
2) Had a ≥8-wk intervention period (or per phase in a cross-over study).
3) A stated primary or secondary outcome variable was body weight or body composition.
4) The stated goal of the intervention was weight or fat loss, or prevention of weight or fat gain.
5) The food intake provided or prescribed was of a variety of fruit or vegetables that remained minimally processed (eg, when the main form was not significantly reduced or separated in a way that was not conventionally eaten by most people in that culture). In addition, the fruit or vegetable was not modified to such an extent that it would no longer be considered as falling into the fruit or vegetable food groups (eg, fried veggie chips would be excluded).
6) The study was published before 1 June 2013.

Exclusion criteria
Exclusion criteria were as follows:
1) Any intervention in which only nuts were added to the diet.
2) Any intervention in which only one specific fruit or vegetable was added.
3) Any studies in which the design or analysis did not allow for an independent evaluation of the effect of F/V intake.
4) Any studies in which the targeted population for recruitment was ill with any significant disease or genetic condition that affected body weight (eg, HIV or cancer) other than cardio-metabolic conditions such as diabetes, cardiovascular disease, or simple obesity but not excluding on the basis of a past history of any condition related to food intake.
5) Studies in which the investigators attempted to fix body weight or total energy intake to prespecified amounts.

 METHODS
Data sources

Inclusion criteria
All studies were included if they met the following criteria:
1) Any intervention involving an increase in fruit or vegetable intake.
2) Any intervention in which only one specific fruit or vegetable was added.
3) Any studies in which the design or analysis did not allow for an independent evaluation of the effect of F/V intake.
4) Any studies in which the targeted population for recruitment was ill with any significant disease or genetic condition that affected body weight (eg, HIV or cancer) other than cardio-metabolic conditions such as diabetes, cardiovascular disease, or simple obesity but not excluding on the basis of a past history of any condition related to food intake.
5) Studies in which the investigators attempted to fix body weight or total energy intake to prespecified amounts.

Study search terms
In each database, studies of type randomized controlled trials were searched (when that option was available) by using the following key words in the title or abstract: fruit*, vegetable*, weight, fat, body composition, body mass index, and random. Document types selected were as follows: review, article, meeting abstract, doctoral dissertation, or proceedings paper.

PubMed search
The PubMed search was follows: (random*) AND ((fruit*) OR (vegetable*)) AND ((weight) OR (fat) OR (body composition) OR (body mass index)). Limits were humans, clinical trial, randomized controlled trial, and review.

See Online Supplemental Material under “Supplemental data” in the online issue for details of filtering steps, study selection, and data acquisition. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram showing the process flow is presented in Figure 1. Additional details may be accessed at the University of York Centre for Reviews and Dissemination (PROSPERO) registry website (http://www.crd.york.ac.uk/PROSPERO/; CRD42013004688).

All authors reviewed final candidate papers to verify and agree that they met the inclusion criteria. Three authors (KAK, AWB, and MMBB) extracted data from each paper independently and compared these for discrepancies; consensus was reached by discussion.

Statistical analysis
We used Cochrane Collaboration Review Manager software (version 5.2) (26) to generate forest plots and a funnel plot by entering data for standardized mean differences (SMDs) with associated SEs by using inverse variance and random effects. In cases where per-group variance data were not reported, but means and probability values were available, we calculated variance estimates from the provided data by using the assumption of 2-tailed criteria (when not stated) with Microsoft Excel 2010 software (Microsoft Corp). When there were 2 treatment arms (27, 28), we split the control group n to adjust the relative weighting of the control sample size for each dose comparison (29). Heterogeneity was assessed by using the τ statistic.

Risk of bias analysis
Three authors (KAK, AWB, and MMBB) independently assessed each study for the assignment of ratings of low, unclear, or high risk of bias related to the selection, detection, attrition, reporting, lack of attention placebo (contact time with controls similar to those in intervention groups,) and other potential sources of bias by using the Cochrane Collaboration Handbook guidelines (30). Items that were not rated the same were discussed until consensus was reached. Because of the nature of the intervention, the blinding of participants would have been difficult,
if not impossible. Therefore, we evaluated blinding on the basis of researchers collecting and analyzing data.

RESULTS

Results of study search and selection
There were few randomized controlled trials that tested the singular effect of F/V intake on weight. A common reason for exclusion was the combination of the intervention of interest with other components of a program such that the independent effects of F/V intake could not be evaluated. There were no studies in children that passed the inclusion and exclusion criteria. Two studies met all criteria (28, 31) (primary analysis), and 5 other studies met all criteria except for not explicitly stating weight was an a priori outcome of interest [secondary analysis — 7 studies total; an additional 5 studies (27, 28, 32–34) were combined with the 2 studies in the primary analysis group]. We included the second group in the secondary analysis because weight outcomes were reported or data were provided on request in a usable form. See Table 1 for summaries of studies analyzed for primary and secondary analyses. In other cases, studies met our other criteria, but weight data were reported in an unusable form for the meta-analysis and could not be obtained by repeated requests (Table 2). We evaluated these studies in a tertiary analysis; this third group of studies for which we opted to perform a vote-counting (yes or no) analysis if weight outcomes were stated in a narrative way (eg, “no intervention effect was observed for body weight”). See Table 2 for summaries and weight-outcome descriptions for each study we evaluated by using a vote-count procedure in the tertiary analysis. All studies in all analyses were of parallel design.

Results of statistical analyses
Total-body fat outcomes were not reported for all but one of the included studies, and thus, we meta-analyzed weight change only. For primary and secondary analyses, no individual study or group of studies indicated a statistically significant effect of providing or prescribing increased F/V intake on weight and BMI outcomes reported. See Figure 2A (primary analysis) and Figure 2B (secondary analysis) for the synthesis of standardized treatment effect data for studies that met all or most inclusion criteria.
<table>
<thead>
<tr>
<th>First author, year of publication (reference)</th>
<th>Location of study</th>
<th>Population</th>
<th>Study design</th>
<th>Intervention</th>
<th>Main outcomes</th>
<th>BW results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wagner, 2012 (31)†</td>
<td>United States</td>
<td>Adults: n = 45; 45.2% F; mean age: 45.3 y; mean BMI (in kg/m²): 33.3</td>
<td>Simple RCT</td>
<td>10-wk education intervention (control) compared with 10 wk education plus 1 fruit and 2 vegetables/d provided</td>
<td>Interest and knowledge of antioxidants, biomarkers of oxidative stress and inflammation, and body composition (reported weight, BMI, percentage of BF, FM, FFM, and WC)</td>
<td>All P values for weight change within group for all BC indexes were &gt; 0.05 (paired-samples t test). Between groups for change values, all P values were also &gt;0.05. Raw mean weight change: in treatment group, +0.4 kg; in control group, −0.5 kg</td>
</tr>
<tr>
<td>Whybrow, 2006 (28)†</td>
<td>Scotland</td>
<td>Low-F/V consuming adults: n = 90 (45 couples); mean age: 43.6 y; mean BMI: 24.3</td>
<td>Simple RCT</td>
<td>8-wk intervention of 0 (control), 300, or 600 g added F/Vs/d (home delivery)</td>
<td>Eating behavior and BW</td>
<td>Complete case analysis excluding low-energy reporters; mean BW change within groups: +0.48 kg (control), −0.29 kg (300-g group), and −0.14 kg (600-g group); P = 0.242 (F test)</td>
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<tr>
<td>Bradbury, 2006 (32)†</td>
<td>Ireland</td>
<td>Edentulous adults receiving full dentures: n = 66; 56.9% F; mean age: 66.0 y; mean BMI: 26.8</td>
<td>Simple RCT</td>
<td>Post–random assignment, 2 individual counseling sessions [tailored nutrition education to increase F/V intake plus dental treatment compared with dental treatment alone (control) 1 wk apart and then 7 wk follow-up and weigh in]</td>
<td>Change in weight of F/Vs consumed from food-diary data</td>
<td>BMI change reported; P = 0.497 (ANCOVA)</td>
</tr>
<tr>
<td>Cox, 1998 (33)†</td>
<td>United Kingdom</td>
<td>Adults who were low F/V consumers at baseline: n = 170 randomly assigned; n = 125 completed; n = 66 analyzed, baseline data for completers only; 70.9% F; mean age: 34.5 y; mean BMI: 24.6</td>
<td>Simple RCT</td>
<td>8-wk intervention program combining 1) educational, 2) motivational, and 3) behavioral approaches</td>
<td>Self-reported servings per day and nutrient intake</td>
<td>Treatment-group (n = 42) mean; +1.3 kg (P = 0.032); control-group (n = 24) mean: +1.5 kg (P = 0.041); both 2-tailed t tests</td>
</tr>
<tr>
<td>John, 2002 (35)†</td>
<td>United Kingdom</td>
<td>Adults; n = 729 randomly assigned, n = 673 completed, and n = 690 analyzed (BOCF); 51% F; mean age: 45.9 y; mean BMI: 25.8</td>
<td>Simple RCT</td>
<td>Brief negotiation method to encourage an increase in consumption of F/Vs to ≥5 portions/d (one visit); follow-up phone call 2 wk later; letter and seasonal recipe booklet sent 3 mo later</td>
<td>F/V consumption, plasma antioxidants, and blood pressure</td>
<td>Both intervention and control groups gained a mean ± SD of 0.6 ± 2.6 kg at 6 mo</td>
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(Continued)
TABLE 1 (Continued)

<table>
<thead>
<tr>
<th>First author, year of publication (reference)</th>
<th>Location of study</th>
<th>Population</th>
<th>Study design</th>
<th>Intervention</th>
<th>Main outcomes</th>
<th>Main results</th>
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<tbody>
<tr>
<td>McCall, 2011 (27)</td>
<td>United Kingdom</td>
<td>Hypertensive overweight and obese adults; n = 112 analyzed; mean BMI: 28.9</td>
<td>Simple RCT</td>
<td>Simple RCT</td>
<td>Blood and urine markers of inflammation, endothelial dysfunction, oxidative stress</td>
<td>Mean change in BW at week 16: 0.9, +0.3, and +0.7 kg in 1-, 3-, and 6-serving/d groups, respectively.</td>
</tr>
<tr>
<td>Neville, 2013 (34)</td>
<td>Ireland</td>
<td>Older adults; n = 83 randomly assigned; mean age: 71 y; mean BMI: 28.3</td>
<td>Simple RCT</td>
<td>Simple RCT</td>
<td>Compared effects on muscle mass, fat mass, physical functioning, and muscle strength</td>
<td>Mean change in BW at week 16: 1.35 kg; 5-portions/d group (n = 41), 0.25 kg; 2-portions/d group (n = 39), and 0.21 kg; 1-portions/d group (n = 30), p = 0.19.</td>
</tr>
<tr>
<td>Whybrow et al (28)</td>
<td>United Kingdom</td>
<td>Hypertensive overweight and obese adults; n = 112 analyzed; mean BMI: 28.9</td>
<td>Simple RCT</td>
<td>Simple RCT</td>
<td>Immune function (per clinical trial registry), physical functioning, and muscle strength</td>
<td>Immune function per clinical trial registry, physical functioning, and muscle strength</td>
</tr>
</tbody>
</table>

BF, body fat; BOCF, baseline observation carried forward; BW, body weight; F, fruit; F/V, fruit and vegetable; RCT, randomized controlled trial; WC, waist circumference.

For Whybrow et al (28), the authors reported outcomes for participants who did not report implausibly low energy intakes [low-energy reporters (LERs)] as their primary analysis. We used the same method in Figure 2, A and B, but in an analysis of data for this study that included LER participants, we showed no significant effect on overall SMDs for our primary analysis [SMD: −0.03 (95% CI: −0.44, 0.39) when LERs were included] or secondary analysis [SMD: 0.03 (95% CI: −0.09, 0.15) when LERs were included]. An examination of the 2 groups of studies that was done by using fixed-effects models for forest plots also indicated no significant effect overall [−0.08 (95% CI: −0.51, 0.35) for the primary analysis; 0.03 (95% CI: −0.09, 0.15) for the secondary analysis].

**General comparison of included studies**

Interventions analyzed could be broadly divided into the following 2 categories: 1) studies in which F/Vs were supplied and 2) studies in which F/V consumption was encouraged through counseling or educational approaches. Both studies in the primary analysis supplied F/Vs to participants. Whybrow et al (28) weighed F/Vs and delivered them to the home 3 times/wk for the 300 and 600-g/d groups. Wagner (31) supplemented diets of participants with the equivalent of 1 serving fruit/d and 2 servings vegetables/d delivered at weekly meetings. Neville et al (34) used weekly home deliveries of F/Vs to examine effects on physical functioning. Other studies used methods including education, encouragement, recipes, and refrigerator magnets (33, 35); tailored nutrition education on the basis of the stage of change theory (32); school-wide interventions on the basis of the social learning theory (36); and social cognitive theory (37).

Subject inclusion and exclusion criteria and food forms of F/Vs differed in studies. For instance, Cox et al (33) excluded potatoes, cereal, desserts, and all but 200 mL fruit juice/d in their calculation of F/V consumption, whereas Whybrow et al (28) excluded potatoes and allowed for only one portion each of fruit juice, beans, and pulses per day in their calculation of habitual intakes. Bradbury et al (32) created modified recipes for denture wearers, such as focusing on F/V recipes that were seed free. Wagner (31) focused intake assessments on F/Vs that were high in antioxidants, whereas Neville et al (34) purchased and supplied foods that participants indicated that they liked with “no prescriptive list offered to participants at any point.”

The following notes highlight additional differences in designs and study approaches that made comparisons difficult with the goal of reaching generalizable conclusions. Wagner (31) had 3 experimental groups as follows: a small, no-attention control group, an education group, and an education plus F/V group. The first 2 groups were fairly balanced in the percentage of women, but the latter and largest group predominantly included women (44%, 58%, and 77%, respectively). Cox et al (33) had a normal-consumption control and 2 experimental groups who received F/V behavioral guidance; the 2 intervention groups differed only in the way dietary intake data were collected. However, when differences in weight were reported, the authors reported only data for the group who weighed food consumed and the control group, with the exclusion of data from the nonweighing experimental group. See Table 2 for other studies considered and reasons that they were...
<table>
<thead>
<tr>
<th>First author, year of publication (reference)</th>
<th>Location of study</th>
<th>Intervention</th>
<th>Study design</th>
<th>Main outcomes</th>
<th>Reason not included or not usable</th>
<th>Does increased F/V intake significantly reduce weight or prevent weight gain?</th>
</tr>
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<tbody>
<tr>
<td>Bandoni, 2010 (38)</td>
<td>Brazil</td>
<td>Adult workers; increased availability of F/Vs offered by company food programs</td>
<td>Cluster randomized trial of 29 companies</td>
<td>Self-reported weights</td>
<td>Mean weights preintervention and postintervention provided by author but not weight-change values</td>
<td>No. Group mean weight increased over time but samples were independent.</td>
</tr>
<tr>
<td>Djuric, 2006 (39)</td>
<td>United States</td>
<td>Premenopausal adult women with a family history of breast cancer; control, low-fat, and high F/V and a combination of low-fat and high-F/V diets</td>
<td>One year 2 × 2 factorial design</td>
<td>Plasma concentrations of carotenoids, tocopherols, and vitamin C</td>
<td>Mixed intervention with low fat, but comparisons between only high-FVs and control; no change data reported, only cross-sectional measures</td>
<td>No. Despite counseling efforts to maintain baseline energy intakes, mean body weight increased significantly by 6 lb in the high-FV diet group and decreased significantly by 5 lb in the low-fat diet group.</td>
</tr>
<tr>
<td>Hoffman, 2011 (36)</td>
<td>United States</td>
<td>Elementary school children; multicomponent, theory on the basis of an intervention for 2.5 y</td>
<td>Cluster randomized by schools</td>
<td>Persistent effects on knowledge but not on intake behavior; no effects on preferences or BMI</td>
<td>Cross-sectional between groups within 1 y; no longitudinal data reported</td>
<td>No: “no effects on body mass index throughout the study”</td>
</tr>
<tr>
<td>Maskarinec, 1999 (40)</td>
<td>United States</td>
<td>Adult women; tested the feasibility of increasing F/V intake in healthy women to 9 servings/d through individual dietary counseling and group activities</td>
<td>Simple RCT recruited from participants in an ongoing observational study</td>
<td>Plasma phenol concentrations and on thiobarbituric acid-reactive substances measured as malondialdehyde equivalents, a possible marker of oxidative damage</td>
<td>Body weight changed very little in either group. The mean in the control group was 127 lb at baseline and 128 lb after 3 and 6 mo, whereas the mean weight of the intervention group remained ~125 lb throughout the study.</td>
<td>No</td>
</tr>
<tr>
<td>Wallace, 2013 (41)</td>
<td>Ireland</td>
<td>Overweight adults at high risk for cardiovascular disease; comparing 1 to 2, 4, or 7 portions F/Vs/d for 12 wk</td>
<td>Simple RCT</td>
<td>Insulin resistance</td>
<td>Instructed to avoid weight change</td>
<td>No</td>
</tr>
<tr>
<td>Zino, 1997 (42)</td>
<td>New Zealand</td>
<td>Normal and overweight adults; comparing usual intake to 8 servings/d without alteration in the consumption of nuts, oil, butter, or margarine</td>
<td>Simple RCT</td>
<td>Plasma concentrations of lipids and antioxidants; reduced intake of saturated fatty acids</td>
<td>Wrote author to request weight outcomes; data no longer available</td>
<td>No: “Body mass index remained unchanged throughout the study.”</td>
</tr>
</tbody>
</table>

1 Noteworthy studies considered for inclusion but not meeting all inclusion and exclusion criteria. Summary of vote-count procedures indicated 100% of these interventions had no significant effect on reducing weight or preventing weight gain. F/V, fruit and vegetable; RCT, randomized controlled trial.
not meta-analyzed (tertiary analysis). We provide a qualitative synthesis on weight effects for each study on the basis of available information; none of the studies reported a significant effect on body weight.

Risk of bias assessment

An important design aspect of this type of study was that of an attention placebo or contact time with participants, but only one study addressed this issue in its design (31). Since nutritional interventions often involve participant education and counseling, interpersonal dynamics may be a source of bias or variance that can be minimized by the use of an attention placebo in the study design, similar to approaches used in psychological research (43).

See Figure 3 for a summary and detailed ratings of potential sources of bias. For the blinding of assessors or analysts, we showed that none of the studies reported measures to address this potential source of bias. As can be seen from ratings and the summary for this collection of studies, greatest apparent risks of bias in aggregate came from the lack of an attention placebo and incomplete outcomes (attrition bias) because of the almost exclusive use of completers-only analyses rather than intention-to-treat analyses. In general, most items were rated as unclear because of incomplete reporting.

A visual examination of the funnel plot in Figure 4 did not indicate overt evidence of a publication bias; however, this method is not reliable and the calculation of Egger’s regression with the low number of studies in our analysis is not recommended (44, 45).

DISCUSSION

There is currently a lack of empirical evidence that supports claims of a causal effect of F/V intake on body weight. We can conclude that the evidence that does exist is suggestive of no effect or an effect of a ≤0.16-SD reduction in body weight, which explains, at most, 0.56% of the variance (primary analysis) to as little as 0.04% of the variance (secondary analysis) for an increase in body weight. However, the lack of strong evidence for any single one of the intervention types leaves room for uncertainty as to whether there is a modality that may be effective but has not yet been sufficiently studied or implemented in an effective way. Strengths of this meta-analysis included the comprehensive search and approach to obtain unreported or incompletely reported data. We also used multiple raters and verification methods to assure agreement and reduce bias in the selection and data extraction. The low number of studies in our analysis (2 studies in the primary analysis and 7 studies in the secondary analysis) was a significant limitation, which may simply have been a result of the state of the literature. We searched and included what is considered gray literature [eg, the Wagner dissertation, which is recommended (46)]. We cannot say with high confidence that there is not some form of an F/V intervention that may have significant effects on weight loss or the prevention of weight gain. We can only say that studies to date that have tested increased F/V intake in isolation from other interventions indicated no significant effects on body weight.

Another notable uncertainty was the questionable comparability in the specific interventions as well as significant risk of bias inherent in the design and analysis of included studies. The variety of F/V definitions in the studies was a concern for comparing exposures. However, these interventions were as specific as the general recommendation we set out to evaluate.

Suggestions for future research

On the basis of our survey of the presently available best-quality data, there is no evidence that brief interventions are
effective; most of the interventions included were ≤16 wk duration (3 were 8 wk), which may not have been sufficient time to see an effect of increased F/V intake on body weight. In addition, it is unclear what the effective dose of this type of intervention is and what ratio of volume and macronutrients will have the greatest effect. Several of the interventions resulted in relatively small increases in F/V intake, possibly not enough to effect changes in body weight. However, one study (28) reported a greater magnitude of effect at 300 compared with 600 g/d (NS). A higher proportion of vegetables relative to fruit may favor weight loss because of the generally lower energy density of vegetables (excluding starchy vegetables). This possibility remains conjecture.

Beyond specifics about the volume and specific F/V items to be included in interventions, interventions that supply F/Vs to participants have not proven to be more effective in eliciting an effect (both studies were in this category in our primary analysis). Most of the interventions included were educational interventions to increase F/V consumption, which had no significant effect on weight as delivered in the currently analyzed group. Purchasing and preparation barriers need to be addressed. Interventions should provide more instruction on how to prepare vegetables in such a way as to not increase their energy contents (such as not preparing vegetables with fat (eg, not frying or serving with butter), along with methods to verify compliance. Alternatively, consumption studies in which participants consume most of the F/Vs at a study center (to address the limitation of self-reported F/V intakes) would be informative.

Most of the studies we included had primary outcomes other than body weight. Future studies should evaluate body-weight outcomes as a focus, and those studies with multiple time point, researcher-obtained measures would be preferred. Also, effects

![FIGURE 3. Summary of study-level risk-of-bias assessment.](image-url)
on participant perceptions of hunger and satiety would add to the understanding of mechanisms that underlie observed effects. Also needed is an adequate dietary assessment pre-intervention and postintervention to determine what foods, if any, may be displaced by an increased consumption of F/Vs. Measures of compliance beyond self-reported dietary assessment, such as nutrient biomarkers (e.g., vitamin C and carotenoids), might advance knowledge in the practicality and validity of tested interventions.

Implications

F/Vs promote health in many ways by contributing to intakes of micronutrients (including antioxidants) and dietary fiber; F/V intake may be inversely associated with risk of cancer, cardiovascular disease, and diabetes. However, the current evidence did not indicate that health benefits mediated solely by changes in body weight were likely to account for improved health because of F/V intake. Recommendations for increasing intake of F/Vs may be based on cohort studies (see, e.g., reference 47); however, the reliability of data in such data sets has recently been called into question in terms of total energy intake (48). Higher intake of F/Vs may be a marker of a generally healthier cohort, and this dietary pattern creates minimal health risk.

In conclusion, there is currently no empirical evidence that increasing a person’s intake of F/Vs will have a discernible effect on body weight for the duration of the study periods reported (most study periods were 8 wk). Although many F/Vs have demonstrable positive health benefits, recommending increased F/V consumption to treat or prevent obesity without explicitly combining with methods to reduce intake of other energy sources is unwarranted.

The authors’ responsibilities were as follows—KAK, DBA, JMS, and RDM: developed the search and inclusion and exclusion criteria; DBA, MMBB, AWB, and KAK conducted the literature search; MMBB, AWB, and KAK, extracted data from included papers; KAK and AWB: performed the statistical analysis; JMS, KAK, MMBB, and AWB: conducted the risk of bias assessment; and all authors: contributed equally to the review of candidate papers and wrote portions of the manuscript. DBA has received funds from Kraft Foods and the Kellogg Company. The University of Alabama at Birmingham has received grants, contracts, or donations from the following organizations: The Coca-Cola Company, Kellogg’s Corporate Citizenship Fund, FoodMinds LLC, Mars Inc, the World Sugar Research Organisation, Red Bull NA, Tate & Lyle, Alliance for Potato Research & Education, The Sugar Association, American Beverage Association, PepsiCo, and the National Restaurant Association. RDM is currently conducting studies supported by the Almond Board of California, is consulting for various companies including Con Agra, Proctor & Gamble, and Biofortis, and has received honoraria and travel expenses from many companies for speaking engagements. KAK has received a speaker honorarium from Coca-Cola Iberia. AWB, MMBB, and JMS reported no conflicts of interest.

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