Do Healthier Foods and Diet Patterns Cost More Than Less Healthy Options? A Systematic Review and Meta-Analysis

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2013-004277
Article Type:	Research
Date Submitted by the Author:	17-Oct-2013

Complete List of Authors:	Rao, Mayuree; The Warren Alpert Medical School of Brown University, Afshin, Ashkan; Harvard School of Public Health, Department of Epidemiology Singh, Gitanjali; Harvard School of Public Health, Department of Nutrition Mozaffarian, Dariush; Harvard School of Public Health, Department of Epidemiology; Brigham and Women's Hospital and Harvard Medical School, Division of Cardiovascular Medicine

Primary Subject Heading:	Public health
Secondary Subject Heading:	Nutrition and metabolism, Health policy, Health economics
Keywords:	HEALTH ECONOMICS, PREVENTIVE MEDICINE, PUBLIC HEALTH, SOCIAL MEDICINE

CLEAN VERSION

Do Healthier Foods and Diet Patterns Cost More Than Less Healthy Options? A Systematic Review and Meta-Analysis

Mayuree Rao[1,2], Ashkan Afshin[2], Gitanjali Singh[3], Dariush Mozaffarian[2-4]

[1]The Warren Alpert Medical School of Brown University, Providence, RI, USA; [2]Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA; [3]Department of Nutrition, Harvard School of Public Health, Boston, MA, USA; [4]Division of Cardiovascular Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA

Correspondence to:
Mayuree Rao
The Warren Alpert Medical School of Brown University
222 Richmond St
Box G-9230A
Providence, RI 02903
mayuree_rao@brown.edu

Keywords: food/economics, diet/economics, public health, chronic disease, primary prevention
Word count: 4,760

Objective-To conduct a systematic review and meta-analysis of prices of healthier vs. less healthy foods/diet patterns while accounting for key sources of heterogeneity.

Data sources-Medline (2000-2011), supplemented with expert consultations and hand-reviews of reference lists and related citations.

Design-Studies, reviewed independently and in duplicate, were included if reporting mean retail price of foods or diet patterns stratified by healthfulness. We extracted, in duplicate, mean prices and their uncertainties of healthier and less healthy foods/diet patterns, and rated the intensity of health differences for each comparison (range 1 to 10). Prices were adjusted for inflation and World Bank purchasing power parity, standardized to the international dollar (defined as one USD) in 2011. Using random-effects models, we quantified price differences of healthier vs. less healthy options for specific food types, diet patterns, and units of price (serving, day, calorie). Statistical heterogeneity was quantified using I^2 statistics.

Results-Twenty-seven studies from 10 countries met inclusion criteria. Among food groups, meats/protein had largest price differences: healthier options cost $0.29/serving (95% CI: $0.19 to $0.40) and $0.47/200 kcal ($0.42 to $0.53) more than less healthy options. Price differences per serving for healthier vs. less healthy foods were smaller among grains ($0.03), dairy (-$0.004), snacks/sweets ($0.12), and fats/oils ($0.02) (p<0.05 each), and not significant for soda/juice ($0.11, p=0.64). Comparing extremes (top vs. bottom quantile) of food-based diet patterns, healthier diets cost $1.48/day ($1.01 to $1.95) and $1.54/2000 kcal ($1.15 to $1.94) more. Comparing nutrient-based patterns, price per day was not significantly different (top vs. bottom quantile: $0.04; p=0.916), whereas price per 2000 kcal was $1.56 ($0.61 to $2.51) more. Adjustment for intensity of differences in healthfulness yielded similar results.

Conclusions-This meta-analysis provides the best evidence to-date of price differences of healthier vs. less healthy foods/diet patterns, highlighting challenges and opportunities for reducing financial barriers to healthy eating.

Article summary

Article focus

- To conduct a systematic review and meta-analysis of prices of healthier vs. less healthy foods and diet patterns, while also evaluating and accounting for key sources of heterogeneity.

Key messages

- Among 6 food groups, larger price differences were observed by healthfulness for meats/protein, as well as smaller but statistically significant differences for snacks/sweets, grains, fats/oils, and dairy.
- Comparing extremes of healthier food-based diet patterns, the healthiest diets cost an average of \$1.48/day (95% CI: \$1.01 to \$1.95) more than the least healthy diets.

Strengths and limitations of this study

- This systematic review and meta-analysis represents, to our knowledge, the most comprehensive examination of the evidence on prices of more vs. less healthy foods and diet patterns. Strengths include the systematic search; adjustment for inflation and purchasing power parity; separate analyses of food groups, diet patterns, and units of price; and evaluation of heterogeneity by food type, intensity of contrast, and unit of comparison.
- The study was limited by less available data on restaurant prices and prices from low- and middle-income countries. High statistical heterogeneity was evident, although the actual observed range of price differences was more modest.

INTRODUCTION

Consumption of a healthy diet is a priority for reducing chronic diseases including obesity, diabetes, cardiovascular diseases, and several cancers. This is especially crucial for socioeconomically disadvantaged populations, who have both less healthy diets and higher disease risk than higher socioeconomic groups.[1-4] Many factors, including the availability and cultural acceptability of healthy foods, pose obstacles to the promotion of healthy diets. One of the most commonly described barriers is cost: conventional wisdom holds that healthier foods and diets are more expensive than less healthy options, an assumption which has become "a reflexive part of how we explain why so many Americans are overweight."[5]

Yet, whereas several studies have evaluated whether healthier foods or diets cost more,[6-10] the evidence has never, to our knowledge, been systematically reviewed nor quantified to critically evaluate the relationship between healthfulness of foods or diet patterns and price. In addition, little is known about the potential heterogeneity of this relationship. For example, price differences may vary by the foods or diets being compared. Many studies compare healthier and less healthy versions of the same food (i.e. more vs. less healthy grains), while other studies examine the price differences of healthier vs. less healthy overall diet patterns. Price differences may also depend on how healthfulness is defined, ranging from definitions based on single nutrients (e.g., fat content, sugar content) to those based on foods or more complex diet patterns. The intensity of the health contrast could also affect the price difference; for example, a fast food meal vs. a healthier home-cooked meal is a more extreme comparison than a low-fat vs. high-fat cookie. Finally, price differences may vary by the unit of comparison, e.g., per serving, per calorie, etc. In particular, price differences per calorie may be limited by reverse causation, as healthier foods (e.g., fruits, vegetables) often have fewer calories; evaluation of price differences per serving may alter conclusions.[11]

To address each of these key gaps in knowledge, we performed a systematic review and meta-analysis of the evidence for relationships between the healthfulness of foods/diet patterns and their price, including consideration of different food groups and diet patterns, definitions of healthfulness, intensities of the contrast, and units of comparison (calorie, serving, daily diet).

METHODS

We followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines throughout all stages of design, implementation, and reporting.[12] The independent and dependent variables of interest were the healthfulness of foods or diet patterns and their price, respectively. The protocol, which was not altered after commencement of the study, is available from the authors upon request.

Search strategy and selection of articles

Systematic searches were conducted using Medline (via PubMed) for all eligible English-language articles published through December 2011. Additional articles were identified by expert consultations, and hand-reviews of reference lists and first 20 "Related citations" in PubMed for all studies included after full-text review. Because our focus was on contemporary price differences related to healthfulness, and because such price differences could vary in earlier decades, we focused our search on studies having collected price data in the year 2000 or later. The search query combined terms related to foods/diet patterns, price, setting, and time (**Supporting Appendix 1**).

Studies were included if they reported the mean retail prices of foods (including beverages) or diet patterns stratified by a specified measure of healthfulness, as well as sufficient (or obtainable by direct contact) data to derive or estimate the statistical uncertainty (i.e., standard error of difference in means). No foods or diet patterns were excluded. Studies reporting wholesale price or perceived rather than actual price, as well as reviews, letters, editorials, and commentaries, were excluded.

One investigator screened all identified studies based on these inclusion and exclusion criteria by title and abstract. Following screening, remaining full-text articles were obtained and reviewed independently and in duplicate by two investigators for final inclusion/exclusion using the same criteria.

Any differences were resolved by discussion among all of the investigators. A list of excluded citations is available from the authors upon request.

Data extraction and synthesis

For each included study, two investigators extracted data independently and in duplicate using a standardized electronic spreadsheet. Data extracted included first author, title, publication year, year of price data collection, source of price data, demographic variables of study participants and/or community from which price data was collected, definition(s) of healthfulness, food/diet pattern comparison(s), numbers of participants and/or numbers of foods, and mean prices and uncertainties (including unit, e.g., calorie, serving) of the healthier and less healthy foods/diet patterns compared. Because the magnitude of differences in healthfulness could influence price differences, we also rated the intensity of the contrast in health difference between the compared foods/diet patterns on an ordinal scale (1 to 10), with 1 representing a very small difference in healthfulness and 10 a marked difference in healthfulness. These ratings were based on growing evidence that different types of foods and food-based diet patterns predict chronic disease outcomes better than differences in single nutrients.[13] Thus, foods/diet patterns that differed by a single nutrient were rated as low intensity, while foods/diet patterns that differed across multiple nutrients (e.g., three home-cooked meals vs. three fast-food meals) were rated as high intensity. The intensity of contrast was rated independently and in duplicate by two investigators with good concordance (generally less than or equal to 2 points); discrepancies were resolved by group discussion. These ratings are available in the Supporting Information.

Statistical analysis

Our primary endpoint was the difference in mean price between the healthier and less healthy foods or diet patterns. When data on the variance of the difference in means or information to directly calculate this variance were not reported, we calculated it based on the variance of the mean prices in each category, based on standard formulas[14]:

$$SE_{diff} = \sqrt{SE^2_{healthier} + SE^2_{less\ healthy}}$$

$$SE_{diff} = \sqrt{\frac{SD^2_{healthier}}{n_{healthier}} + \frac{SD^2_{less\ healthy}}{n_{less\ healthy}}}$$

For 9 studies in which mean prices were reported without their uncertainty, the SEs were imputed from the number of observations in each category, based on linear regression of studies with complete data, performed separately for market surveys (6 studies comparing samples of foods) and individual dietary surveys (3 studies comparing diets across samples of participants) (**Supporting Figure 1**).

We recognized that price comparisons within food groups (i.e., healthier vs. less healthy options within the same category of food) may vary from price comparisons across overall diet patterns. Furthermore, price differences may vary for diet patterns largely based on foods vs. diet patterns largely based on one or a few isolated nutrients. Thus, we separately investigated price differences that compared options within a single similar category of food (e.g., meats/protein, grains, dairy), price differences that compared varying concordance to food-based diet patterns (e.g., Alternative Healthy Eating Index, Western, or Mediterranean diet patterns), and price differences that compared varying concordance to isolated nutrient-based (e.g., fat, sugar) diet patterns. For analyses of diet patterns, we evaluated price differences for the extreme categories (e.g., the top vs. bottom quartile or quintile) of diet, to enable comparisons of the largest differences in diet quality.

Because price differences could also vary by the unit of comparison, findings for foods were evaluated standardized both to one usual serving and to 200 kcal; and for diet patterns, standardized both to one day (3 meals) and to 2000 kcal. Standard serving sizes were based on 2011 USDA MyPlate guidelines or, if not available from MyPlate, on nutrition labels from a major grocery website.[15 16] Calorie conversions were derived from the USDA database.[17] For standardizing studies of food baskets to meals, one serving of any food was assigned as one-fourth of a meal, except for condiments, fats, or oils for which one serving was assigned one-eighth of a meal. All price differences were adjusted for inflation by country to reflect prices in 2011. In addition, to account for the varying values of currencies across countries, these prices were further adjusted for purchasing power parity by standardizing to 2011 international dollars; one international dollar is defined as one US dollar. Inflation rates and purchasing power parity conversion factors were obtained from the World Bank; 2011 is the latest year for which these data are available.[18] We also repeated all analyses with additional weighting for the intensity of the contrast in healthfulness (range 1 to 10), i.e. with greater differences (higher intensity values) carrying greater weights.

Summary estimates were quantified using inverse-variance weighted, random effects meta-analysis (*metan* command in Stata). Statistical heterogeneity was evaluated using the I^2 statistic. Meta-regression (*metareg* command in Stata) was performed on intensity, study location (USA/Canada vs. other), and type of survey (market survey vs. dietary survey) to explore potential sources of heterogeneity. Publication bias was assessed using the Egger test and visual inspection of funnel plots. Statistical analyses were performed using Stata 12 (StataCorp, College Station, Texas), with two-tailed alpha = 0.05.

RESULTS

Search results and study characteristics

Of 1,010 articles identified by the Medline search and screened for inclusion, 83 were selected for full-text review (**Figure 1**). Of these, 19 articles met inclusion criteria, and an additional 8 articles were identified from hand-searches of references lists, related citations in PubMed, and expert consultations. Among the final 27 studies, 14 were conducted in the US, 2 in Canada, 6 in Europe, and 5 in other countries including South Africa, New Zealand, Japan, and Brazil (**Table**). Twelve studies were market surveys, and 15 were dietary surveys. The number of foods evaluated by the market surveys ranged from 2 to 133, with prices collected from between 1 and 1,230 stores. The number of participants evaluated by the dietary surveys ranged from 30 to 78,191. Several studies reported prices for multiple food comparisons or from different types of stores and contributed more than one estimate to the analysis.

Price Differences of Foods

Evidence on price comparisons within similar food groups was available in 6 major food groups, including meats/protein, grains, dairy, snacks/sweets, fats/oils, and soda/juice.

Per serving, meats/protein exhibited the largest price difference by healthfulness (**Figure 2A**). On average, the healthier choice was $0.29 more expensive per serving than the less healthy choice (95% CI: $0.19 to $0.40). Considerable statistical heterogeneity was evident (I^2=99.4%) that appeared at least partly related to the type of comparison. For example, price differences by healthfulness appeared largest for chicken, intermediate for beef, and smallest for peanut butter. Healthier snacks/sweets, grains, and fats/oils were also more expensive per serving than less healthy options, but with smaller price differences: for snacks/sweets, $0.12/serving ($0.02 to $0.23); for grains, $0.03/serving ($0.01 to $0.05); and for fats/oils, $0.02/serving ($0.01 to $0.02). For dairy, healthier options were slightly less expensive per serving (-\$0.004/serving; 95% CI: -\$0.005 to -\$0.004), although pooled findings were driven by one study with reported high statistical certainty. Excluding this study, healthier dairy options were similar in price to less healthy options (-\$0.004/serving, p=0.389). No significant price differences per serving were seen between healthier and less healthy soda/juice (\$0.11; 95% CI: -\$0.34 to \$0.56; I^2=25.1%), but only two studies evaluated this comparison.

For most of these food groups, findings were similar or stronger for pooled price differences standardized per calorie (**Figure 2B**), rather than per serving. The largest price difference was again among meats/protein, with healthier options costing \$0.47 per 200 kcal more (\$0.42 to \$0.53) than less healthy options. The main exception was dairy foods, for which the pooled price difference per 200 kcal was much greater than the price difference per serving. Per 200 kcal, healthier dairy foods were \$0.21 more expensive than less healthy options (\$0.11 to \$0.31), consistent with the strong calorie effect of the metric (fat content) that was used to define healthfulness in this food group.

Price Differences of Diet Patterns

Twenty studies evaluated price differences according to concordance with overall healthful diet patterns, with 14 studies evaluating more food-based patterns and 7 studies evaluating more nutrient-based patterns (one study evaluated both[19]).

Comparing extreme categories of food-based diet patterns, the highest category of healthier diets cost \$1.48/day (\$1.01 to \$1.95) more than the lowest category (**Figure 3A**). Findings were broadly consistent across several different definitions of healthful diet patterns, including based on the Mediterranean dietary pattern, Western dietary pattern, Alternative Healthy Eating Index, fruit and vegetable intake, and energy density. Some food-based diet patterns exhibited smaller or no price differences, including based on the Healthy Eating Index, the Environmental Standards for Healthy Eating, and comparing home-cooked to fast food meals. When standardized to 2000 kcal, healthier food-based diet patterns cost $1.54 more than less healthy options ($1.15 to $1.94), with price differences modestly larger for patterns based on the Alternative Healthy Eating Index and energy density, smaller for patterns based on fruit and vegetable consumption alone, and no longer significant for the Mediterranean dietary pattern. (**Figure 3B**).

For diet patterns based largely on single or few isolated nutrients, the price of the highest category of diets meeting these criteria was not significantly different than the lowest when based on a day's intake (**Figure 4A**). In contrast, when standardized to 2000 kcal, the highest category of nutrient-based patterns cost $1.56 more than the lowest ($0.61 to $2.51) (**Figure 4B**). Price differences per 2000 kcal were larger relative to the per day estimates for patterns based on fat; sugar; and fiber, fat, and sugar combined.

We also performed analyses restricted to US studies. Results were similar: healthier food-based diet patterns cost an average of $1.49/day ($0.60 to $0.237; n=7 studies) and $1.79/2000 calories ($0.78 to $2.80; n=6 studies) more than less healthy patterns. Healthier nutrient-based diet patterns cost an average of $0.40/day ($0.17 to $0.63; n=3 studies) and $2.46/2000 calories (-$2.17 to $7.09; n=2 studies) more than less healthy patterns.

Intensity of the Contrast in Healthfulness

We repeated all analyses adjusting for differences in the intensity of contrast in healthfulness in each comparison. Within food groups, intensities of contrasts were generally rated in the 4 to 6 range, with smallest contrast of 3 (e.g., comparing different types of cookies) and largest of 9 (e.g., comparing fruits/vegetables to packaged snacks). For food groups, intensity-weighted price differences were generally similar to the unweighted findings (**Supporting Figure 2)**. Contrasts of diet patterns were most often rated 6 or 7, with smallest contrast of 1 (comparing patterns based on total fat alone) to largest of 10 (comparing 3 healthier home-cooked meals to 3 fast food meals). Compared with unweighted comparisons, the intensity-weighted price differences of healthier vs. less healthy food-based diet patterns were similar: $1.46/day ($1.00 to $1.92) and $1.53/2000 kcal ($1.14 to $1.93) (**Supporting Figure 3**). Intensity-weighted price differences were also similar to unweighted results for nutrient-based diet patterns: $0.11/day (-$0.64 to $0.85) and $1.66/2000 kcal ($0.55 to $2.78) (**Supporting Figure 4**).

Potential Sources of Heterogeneity

Statistical heterogeneity as quantified by the I^2 statistic was high in most analyses. Meta-regression did not identify significant effect modification based on study location (USA/Canada vs. other), intensity of the contrast in healthfulness, or study type (market survey vs. dietary survey). Meta-regression by study type (market survey vs. dietary survey) was not possible for the food group analyses due to collinearity.

Publication bias

Publication bias was assessed using the Egger test and funnel plots (**Supporting Figure 5**).[20] There was no significant bias identified by the Egger test. Visual inspection of funnel plots suggested asymmetrical distributions for dairy food, food-based diet patterns, and nutrient-based diet pattern comparisons, consistent with a larger number of smaller studies reporting greater price differences than the overall pooled estimate.

DISCUSSION

The findings from this systematic review and meta-analysis provide the most robust evidence to-date on price differences of healthier versus less healthy foods and diet patterns. The results by food group provide insight into the relationship between healthfulness and price among similar foods. The results by diet pattern inform price differences between greater extremes of healthfulness, comparing very different foods, e.g., diets rich in fruits and vegetables vs. diets rich in processed foods. Although statistical heterogeneity was high, this was at least partly related to relatively small uncertainty of each within-study price difference; the magnitude of clinically relevant heterogeneity was much lower, with comparatively similar price differences between studies. In addition, with a few exceptions, findings were similar across different units of price (per serving or day vs. calorie), intensity of contrast, study location, and type of survey, increasing confidence in the validity and consistency of the findings.

Price Differences of Foods

Among 6 food groups, relatively large price differences were observed for meats/protein, as well as smaller but statistically significant differences for snacks/sweets, grains, fats/oils, and dairy. According to the USDA, the farm share of proceeds of a one dollar expenditure on domestically produced food in the United States is 14.1 cents[21], suggesting that final retail prices are determined largely by other industries and procedures in the food supply chain. Additional cost of processing and manufacturing could explain some of the identified variation in price differences; for example, lean beef and skinless chicken require more processing, perhaps accounting for their higher price. Our findings highlight the need for more research on the underlying drivers of price differences of specific items within broad food categories.

Our findings also demonstrate that, for certain metrics of healthfulness, the selected unit of comparison alters the results. In particular, metrics based largely on fat content demonstrated greater price differences per calorie than per serving. The most striking example was for dairy foods: healthier options were $0.004 less expensive per serving but $0.21 more expensive per 200 kcal. Whole milk contains nearly twice the calories as fat-free milk,[17] so nearly double the amount of fat-free milk must be purchased to achieve equivalent calories. These findings highlight the dangers of circular reasoning (e.g., selecting a metric based on fat content and then evaluating price differences per calorie) and the importance of identifying the most relevant unit of comparison for any individual or public health decision about price differences of foods.[11]

Price Differences of Diet Patterns

On average, healthier food-based diet patterns were more expensive than less healthy patterns, whether based on an actual day's intake or per 2000 kcal. The price difference – about $1.50 per day – represents the price difference per person for consuming a much healthier vs. much less healthy overall diet, e.g., comparing Mediterranean-type diets rich in fruits, vegetables, fish, and nuts vs. diets rich in processed food, meats, and refined grains. Thus, this price difference is for a relatively extreme contrast, between the healthiest and least healthy diet pattern. Better adherence to such food-based diet patterns consistently relates to improved health and lower risk of chronic diseases.[22 23]

In contrast to the findings for food-based diet patterns, healthier vs. less healthy nutrient-based diet patterns were not significantly different in price when based on a day's actual intake, but only cost more when standardized to 2000 kcal. These results mirror those observed when comparing individual food groups, such as dairy, based on single-nutrient metrics of healthfulness. These findings emphasize the crucial role of the unit of comparison when comparing prices by nutrient-based metrics. Healthier diets defined based on fiber or fat content will, by definition, have fewer calories, so they will naturally cost more per calorie. Yet, such diets will not necessarily cost more per serving or per meal. In the setting of a global obesity pandemic, assessing price differences per calorie may make little sense when a healthier diet also leads to reductions in total calorie consumption. Growing evidence also indicates that single or selected nutrients are less useful for distinguishing healthfulness than types of foods and food-based diet patterns.[13]

Heterogeneity

In most comparisons, statistical heterogeneity as measured by I^2 was high. Yet, adjustment for intensity of differences in healthfulness had little effect on pooled price differences, and meta-regression revealed no significant effect modification by intensity, study location, or study type. The high I^2 values may be partly explained by the relatively small uncertainty for each within-study price difference. In many of the identified studies, the combination of a continuous outcome (price) and a relatively large number of samples (foods or individuals) resulted in low uncertainty of each study-specific price difference. Lower within-study uncertainty produces higher I^2 values, even when absolute magnitudes of price heterogeneity among studies may be modest from a public health or practical perspective. For example, the price differences among snacks/sweets studies fell within a relatively limited range (-\$0.04 to \$0.30/serving), with a reasonable summary estimate of \$0.12/serving, but statistical heterogeneity was high (I^2=85.9%) partly due to narrow within-study confidence intervals. Thus, the calculated heterogeneity in each summary estimate should be interpreted in light of the actual range of observed price differences across studies. Since clinically relevant heterogeneity was lower than statistical heterogeneity, the pooled results provide insight into average price differences between healthier and less healthy foods and diet patterns.

Although similar classes of foods and diet patterns were evaluated separately, the foods or diet patterns within each category were not exactly the same. Our aim – and the relevant public health question – was not whether one specific product costs more than another, but whether healthier foods in a broad class of foods cost more, on average, than less healthy foods in the same broad class.

Strengths and Limitations

Several strengths can be highlighted. This systematic review and meta-analysis represents, to our knowledge, the most comprehensive examination of the evidence on prices of more vs. less healthy foods and diet patterns. Our systematic search makes it unlikely that we missed any large reported studies. Error and bias were each minimized by independent, duplicate decisions on inclusion of studies and data extraction. Adjustment for inflation and purchasing power parity to 2011 prices accounted for the varying value of money across years and countries. Exclusion of price data prior to the year 2000 increased generalizability of the results to contemporary diets. A key strength of our analysis was evaluation of food groups separately from diet patterns. The former provides data to inform choices when comparing otherwise relatively similar foods, whereas the latter informs price differences across very different selections of foods. Additional strengths include the standardization of disparate metrics, foods, and units; the assessment of food-based and nutrient-based diet patterns; and the evaluation of heterogeneity by food type, intensity of contrast, and unit of comparison.

Potential limitations should be considered. Like all meta-analyses, our analysis was based on available data; for certain comparisons, relatively few studies were available. For example, only one study directly compared prices of restaurant foods to home-cooked foods; all other studies reported supermarket prices. Thus, our results summarize the best current data on price differences of foods and diet patterns while also highlighting gaps in knowledge that require further investigation. Definitions of healthfulness varied across food groups and diet patterns. Yet, our findings across a variety of diet patterns and definitions of healthfulness inform how such contrasts may influence price differences. Our assessment of publication bias suggested that price differences for dairy foods and diet patterns may be partly overestimated due to selective publication of smaller studies with more extreme estimates. Statistical heterogeneity was evident in most comparisons, a significant consideration in the interpretation of the results. All meta-analyses must strike a balance between the imperative for generalizability and the need to minimize heterogeneity. Additionally, the actual range of observed price differences for many comparisons was not extreme. The rating system for intensity of contrast was subjective; yet, the ratings were assigned independently and in duplicate with good concordance and provide important sensitivity analyses on the robustness of the results. Our findings on price differences per day and per 2000 calories reflect an adult diet; the summary estimates should be adjusted for other caloric intakes, e.g. in young children. Only English-language studies from PubMed were included, so some studies may have been missed. Given absence of accepted criteria for judging quality of observational studies, quality of studies was not formally assessed. Most comparisons were from high-income countries, highlighting the need for similar studies in low- and middle-income nations.

CONCLUSIONS

In sum, our findings provide the most robust evidence to-date on price differences of healthier foods and diet patterns, while also highlighting the importance of carefully considering the metric of healthfulness, intensity of contrast, and unit of comparison. Our results indicate that lowering the price of healthier diet patterns – on average ~$1.50/day more expensive – should be a goal of public health and policy efforts, and some studies suggest that this intervention can indeed reduce consumption of unhealthy foods.[24-26]

It remains an open question as to *why* healthier diets cost more. Some have argued that US agricultural subsidies for commodities (e.g. corn, soy) lower the price of less healthy, more processed foods compared with unprocessed foods.[27] However, careful economic analyses demonstrate that the main impact of such subsidies is direct income transfer to farmers, with little influence on retail prices; and that tariffs and other protectionist policies are actually raising the prices of many US commodities such as sugar.[28-30] Conversely, many decades of policies focused on producing inexpensive, high volume commodities have led to a complex network of farming, storage, transportation, processing, manufacturing, and marketing capabilities that favor sales of highly processed food products for maximal industry profit.[31] Based on these experiences, efforts to create an infrastructure and commercial framework that facilitates production, transportation, and marketing of healthier foods could increase availability and reduce prices of more healthful products.[31] Taxation of less healthy foods and subsidies for healthier foods would also be an evidence-based intervention to balance price differences.[31]

Other potential barriers to a healthier diet exist, such as availability and cultural acceptability. However, our findings suggest that for socioeconomically disadvantaged populations, the relatively higher cost of healthy foods may be an impediment to eating better. On the other hand, Americans at all income levels allocate too little of their food budgets toward healthy foods.[32] A daily price difference of ~$1.50 translates to ~$550 higher annual food costs per person. For many low-income families, this additional cost represents a genuine barrier to healthier eating. Yet, this daily price difference is trivial in comparison to the lifetime personal and societal financial burdens of diet-related chronic diseases.[33 34] For example, suboptimal diet quality was recently estimated to account for 14% of all disability-adjusted life years (DALYs) in 2010 in the United States;[35] if translated to a proportion of national health expenditures in 2012,[36] this corresponds to diet-related health care costs of $393 billion/year, or more than $1200/year for every American. Our findings highlight the nuanced challenges and the opportunities for reducing financial barriers to healthy eating.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted

work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Funding disclosure: Funding support was provided by a Genes and Environment Initiative (GENI) grant from the Harvard School of Public Health; by a National Heart, Lung, and Blood institute Cardiovascular Epidemiology Training Grant in Behavior, the Environment, and Global Health (T32 HL098048); and by a National Institute of Diabetes and Digestive and Kidney Diseases Training Grant in Academic Nutrition (T32 DK007703). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Ethics statement: Ethics approval was not required for this study.

Contributors: MR and DM conceived the study design and aims. MR, AA, and GS performed the systematic review and data extraction. MR performed the analysis. MR, AA, GS, and DM interpreted the results. MR and DM drafted the manuscript; AA and GS contributed to manuscript revisions. MR and DM are guarantors. All authors had full access to all of the data and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Data sharing: Technical appendix available upon request from corresponding author.

adaptations, reprints, include within collections and create summaries, extracts and/or, abstracts of the Contribution, iii) create any other derivative work(s) based on the Contribution, iv) to exploit all subsidiary rights in the Contribution, v) the inclusion of electronic links from the Contribution to third party material where-ever it may be located; and, vi) license any third party to do any or all of the above.

Figure legends

Figure 1. Search and screening of studies comparing prices of healthier and less healthy foods or diet patterns.

Figure 2. Price difference between healthier and less healthy foods per serving (A) and per 200 kcal (B). Price difference defined as the healthier category minus the less healthy category. Standardized serving sizes were derived from 2011 USDA MyPlate guidelines or, if not available from MyPlate, nutrition labels from a major grocery website. Calorie-adjustment of price differences based on the USDA database. Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

Figure 3. Price difference between healthier and less healthy food-based diet patterns per day (A) and per 2000 kcal (B). Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Mozaffarian RS, 2012.[37] Energy density was included as a food-based pattern since this metric represents a set of foods more than it represents any single nutrient.[19] For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Number of participants reported for dietary surveys (studies comparing diets across samples of participants), and number of foods reported for market surveys (studies comparing samples of foods). Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

Figure 4. Price difference between healthier and less healthy nutrient-based diet patterns per day (A) and per 2000 kcal (B). One outlying, implausible estimate from Aggarwal A, 2011 (mean adequacy ratio) was excluded ($17.23; 95% CI: $14.35, $20.11).[38] Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based

on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Temple NJ, 2009 and Krukowski RA, 2010.[39 40] For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Number of participants reported for dietary surveys (studies comparing diets across samples of participants), and number of foods reported for market surveys (studies comparing samples of foods). Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

REFERENCES

1. Banks J, Marmot M, Oldfield Z, Smith JP. Disease and disadvantage in the United States and in England. *JAMA : the journal of the American Medical Association* 2006;295(17):2037-45.
2. Kant AK, Graubard BI. Secular trends in the association of socio-economic position with self-reported dietary attributes and biomarkers in the US population: National Health and Nutrition Examination Survey (NHANES) 1971-1975 to NHANES 1999-2002. *Public health nutrition* 2007;10(2):158-67.
3. Mackenbach JP, Stirbu I, Roskam AJ, Schaap MM, Menvielle G, Leinsalu M, et al. Socioeconomic inequalities in health in 22 European countries. *The New England journal of medicine* 2008;358(23):2468-81.
4. Darmon N, Drewnowski A. Does social class predict diet quality? *The American journal of clinical nutrition* 2008;87(5):1107-17.
5. Bittman M. Is Junk Food Really Cheaper? *The New York Times* 2011 Sept 24.
6. Bernstein AM, Bloom DE, Rosner BA, Franz M, Willett WC. Relation of food cost to healthfulness of diet among US women. *Am J Clin Nutr* 2010;92(5):1197-203.
7. Jetter KM, Cassady DL. The availability and cost of healthier food alternatives. *Am J Prev Med* 2006;30(1):38-44.
8. McDermott AJ, Stephens MB. Cost of eating: whole foods versus convenience foods in a low-income model. *Fam Med* 2010;42(4):280-4.
9. Rehm CD, Monsivais P, Drewnowski A. The quality and monetary value of diets consumed by adults in the United States. *Am J Clin Nutr* 2011;94(5):1333-9.
10. Ryden PJ, Hagfors L. Diet cost, diet quality and socio-economic position: how are they related and what contributes to differences in diet costs? *Public Health Nutr* 2011;14(9):1680-92.
11. Carlson A, Frazao E. Are Healthy Foods Really More Expensive? It depends on How You Measure the Price: U.S. Department of Agriculture, Economic Research Service, 2012.
12. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA : the journal of the American Medical Association* 2000;283(15):2008-12.
13. Mozaffarian D, Ludwig DS. Dietary guidelines in the 21st century--a time for food. *JAMA : the journal of the American Medical Association* 2010;304(6):681-2.
14. Rosner B. *Fundamentals of Biostatistics*. 7 ed. Boston, MA: Brooks/Cole , Cengage Learning, 2011.
15. USDA. ChooseMyPlate.gov.
16. Peapod.
17. USDA. Food-a-Pedia.
18. Azevedo JP. "wbopendata: Stata module to access World Bank databases." Statistical Software Components S457234.: Boston College Department of Economics. http://ideas.repec.org/c/boc/bocode/s457234.html Accessed 5/9/2013, 2011.
19. Drewnowski A, Darmon N, Briend A. Replacing fats and sweets with vegetables and fruits--a question of cost. *Am J Public Health* 2004;94(9):1555-9.
20. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *Bmj* 1997;315(7109):629-34.
21. USDA Economic Research Service. Food Dollar Series., July 5, 2012.
22. Mozaffarian D, Appel LJ, Van Horn L. Components of a cardioprotective diet: new insights. *Circulation* 2011;123(24):2870-91.

23. Estruch R, Ros E, Salas-Salvado J, Covas MI, Corella D, Aros F, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. *The New England journal of medicine* 2013;368(14):1279-90.
24. Andreyeva T, Long MW, Brownell KD. The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. *American journal of public health* 2010;100(2):216-22.
25. Powell LM, Chriqui JF, Khan T, Wada R, Chaloupka FJ. Assessing the potential effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, demand and body weight outcomes. *Obesity reviews : an official journal of the International Association for the Study of Obesity* 2013;14(2):110-28.
26. Eyles H, Ni Mhurchu C, Nghiem N, Blakely T. Food pricing strategies, population diets, and non-communicable disease: a systematic review of simulation studies. *PLoS medicine* 2012;9(12):e1001353.
27. For a Healthier Country, Overhaul Farm Subsidies. *Scientific American*. May, 2012 ed.
28. Rickard BJ, Okrent AM, Alston JM. How Have Agricultural Policies Influenced Caloric Consumption in the United States? *Health economics* 2012.
29. Beghin JC, Jensen HH. Farm Policies and Added Sugars in US Diets: Center for Agricultural and Rural Development, Iowa State University.
30. Harvie A, Wise TA. Sweetening the Pot: Implicit Subsidies to Corn Sweeteners and the U.S. Obesity Epidemic: Global Development and Environment Institute, Tufts University.
31. Mozaffarian D, Afshin A, Benowitz NL, Bittner V, Daniels SR, Franch HA, et al. Population approaches to improve diet, physical activity, and smoking habits: a scientific statement from the American Heart Association. *Circulation* 2012;126(12):1514-63.
32. Volpe R, Okrent A. Assessing the Healthfulness of Consumers' Grocery Purchases: U.S. Department of Agriculture, Economic Research Service, November 2012.
33. American Diabetes A. Economic costs of diabetes in the U.S. In 2007. *Diabetes care* 2008;31(3):596-615.
34. Dall TM, Zhang Y, Chen YJ, Quick WW, Yang WG, Fogli J. The economic burden of diabetes. *Health affairs* 2010;29(2):297-303.
35. Collaborators USBoD. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. *JAMA : the journal of the American Medical Association* 2013;310(6):591-608.
36. National Health Expenditure Projections 2012-2022. The Office of the Actuary in the Centers for Medicare & Medicaid Services. <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Downloads/Proj2012.pdf> Accessed 10/15/2013.
37. Mozaffarian RS, Andry A, Lee RM, Wiecha JL, Gortmaker SL. Price and healthfulness of snacks in 32 YMCA after-school programs in 4 US metropolitan areas, 2006-2008. *Prev Chronic Dis* 2012;9:E38.
38. Aggarwal A, Monsivais P, Cook AJ, Drewnowski A. Does diet cost mediate the relation between socioeconomic position and diet quality? *Eur J Clin Nutr* 2011;65(9):1059-66.
39. Temple NJ, Steyn NP. Food Prices and Energy Density as Barriers to Healthy Food Patterns in Cape Town, South Africa. *Journal of Hunger & Environmental Nutrition* 2009;4:201-13.
40. Krukowski RA, West DS, Harvey-Berino J, Elaine Prewitt T. Neighborhood impact on healthy food availability and pricing in food stores. *J Community Health* 2010;35(3):315-20.
41. Cassady D, Jetter KM, Culp J. Is price a barrier to eating more fruits and vegetables for low-income families? *J Am Diet Assoc* 2007;107(11):1909-15.
42. Katz DL, Doughty K, Njike V, Treu JA, Reynolds J, Walker J, et al. A cost comparison of more and less nutritious food choices in US supermarkets. *Public Health Nutr* 2011;14(9):1693-9.

43. Liese AD, Weis KE, Pluto D, Smith E, Lawson A. Food store types, availability, and cost of foods in a rural environment. *J Am Diet Assoc* 2007;107(11):1916-23.
44. Lipsky LM. Are energy-dense foods really cheaper? Reexamining the relation between food price and energy density. *Am J Clin Nutr* 2009;90(5):1397-401.
45. Ricciuto L, Ip H, Tarasuk V. The relationship between price, amounts of saturated and trans fats, and nutrient content claims on margarines and oils. *Can J Diet Pract Res* 2005;66(4):252-5.
46. Ricciuto L, Lin K, Tarasuk V. A comparison of the fat composition and prices of margarines between 2002 and 2006, when new Canadian labelling regulations came into effect. *Public Health Nutr* 2009;12(8):1270-5.
47. Wang J, Williams M, Rush E, Crook N, Forouhi NG, Simmons D. Mapping the availability and accessibility of healthy food in rural and urban New Zealand--Te Wai o Rona: Diabetes Prevention Strategy. *Public Health Nutr* 2010;13(7):1049-55.
48. Wilson N, Mansoor O. Food pricing favours saturated fat consumption: supermarket data. *N Z Med J* 2005;118(1210):U1338.
49. Lopez CN, Martinez-Gonzalez MA, Sanchez-Villegas A, Alonso A, Pimenta AM, Bes-Rastrollo M. Costs of Mediterranean and western dietary patterns in a Spanish cohort and their relationship with prospective weight change. *J Epidemiol Community Health* 2009;63(11):920-7.
50. Monsivais P, Drewnowski A. Lower-energy-density diets are associated with higher monetary costs per kilocalorie and are consumed by women of higher socioeconomic status. *J Am Diet Assoc* 2009;109(5):814-22.
51. Monsivais P, Aggarwal A, Drewnowski A. Are socio-economic disparities in diet quality explained by diet cost? *J Epidemiol Community Health* 2010.
52. Murakami K, Miyake Y, Sasaki S, Tanaka K, Ohya Y, Hirota Y. Monetary Diet Cost is Associated with not only Favorable but also Unfavorable Aspects of Diet in Pregnant Japanese Women: The Osaka Maternal and Child Health Study. *Environ Health Insights* 2009;3:27-35.
53. Rauber F, Vitolo MR. Nutritional quality and food expenditure in preschool children. *J Pediatr (Rio J)* 2009;85(6):536-40.
54. Ryden P, Sydner YM, Hagfors L. Counting the cost of healthy eating: a Swedish comparison of Mediterranean-style and ordinary diets. *International Journal of Consumer Studies* 2008;32(2):138-46.
55. Schroder H, Marrugat J, Covas MI. High monetary costs of dietary patterns associated with lower body mass index: a population-based study. *Int J Obes (Lond)* 2006;30(10):1574-9.
56. Townsend MS, Aaron GJ, Monsivais P, Keim NL, Drewnowski A. Less-energy-dense diets of low-income women in California are associated with higher energy-adjusted diet costs. *Am J Clin Nutr* 2009;89(4):1220-6.
57. Waterlander WE, de Haas WE, van Amstel I, Schuit AJ, Twisk JW, Visser M, et al. Energy density, energy costs and income - how are they related? *Public Health Nutr* 2010;13(10):1599-608.

Table. **Characteristics of food price studies included in meta-analysis.**

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
Market studies				
Cassady D et al, 2007[41*]	June 2003, Sept-Oct 2003, March-April 2004	35 foods from 25 stores in Sacramento and Los Angeles, California	Fruit and vegetable basket meeting 2005 Dietary Guidelines vs. 1995 Thrifty Food Plan fruit and vegetable basket[†‡]	Cross-sectional price survey conducted across 3 time periods in chain supermarkets, small independent grocery stores, and supermarkets selling bulk food items with no membership fee
Jetter KM and DL Cassady, 2006[7]	June 2003, Sept 2003, March-April 2004	133 foods from 25 stores in Sacramento and Los Angeles, California	Market basket with four times the amount of fiber and one-fifth the grams of total fat vs. 1995 Thrifty Food Plan market basket[§]	Cross-sectional price survey conducted across 3 time periods in chain supermarkets, small independent grocery stores, and supermarkets selling bulk food items with no membership fee
Katz DL et al, 2011[42]	NR	131 foods in 8 food categories from 6 stores in Jackson County, Missouri	Nutrition Detectives program criteria for healthfulness (meeting vs. not meeting)[¥‡]	Prices collected from chain grocery stores accessible to research assistant
Krukowski RA et al, 2010[40]	Feb-April 2008	20 foods from 42 stores in Arkansas and Vermont	10 high-fiber, low-fat, low-sugar foods vs. 10 low-fiber, high-fat, high-sugar foods[β]	Overweight individuals entering a behavioral weight loss research program self-reported their primary grocery store. Trained data collectors assessed food prices at these stores
Liese AD et al, 2007[43]	2004	8 foods from 75 stores in Orangeburg County, South Carolina	Lean ground beef vs. high-fat ground beef; skinless and boneless chicken breasts vs. chicken drumsticks; high-fiber bread vs. low-fiber bread; low-fat/non-fat milk vs. whole milk	All food stores in county identified from Licensed Food Service Facilities Database and in-person verification. Prices recorded and reported by store type (supermarket, grocery store, convenience store)
Lipsky LM et al, 2009[44]	2008	2 food groups from 1 store in mid-Atlantic region	Produce (fruits, vegetables) vs. snacks (cookies, chips)	Price collected from online supermarket
McDermott AJ et al, 2010[8]	NR	34 foods from 4 stores in Baltimore, Maryland	3 c milk/dairy, 5 oz lean meat, 1.5 c fruit, 2.5 c vegetables, and 6 oz grains per day vs. breakfast, lunch, and dinner from fast-food restaurant	Prices for healthier foods obtained from 3 large supermarket chains. Prices for less healthy foods obtained from a large, multinational fast-food chain.

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
Ricciuto L et al, 2005[45]	Nov 2002	229 foods from 9 stores in Toronto, Canada	Margarine with vs. without label "low in saturated fat" or "cholesterol free"	Prices obtained from 9 stores of 3 major chain supermarkets
Ricciuto L et al, 2009[46]	Nov 2002 and Nov-Dec 2006	229 foods from 9 stores in 2002 and 274 foods from 10 stores in 2006 in Toronto, Canada	Trans fat-free vs. non trans fat-free margarine[£]	Prices obtained from 10 stores of 3 major chain supermarkets
Temple NJ and NP Steyn, 2009[39]	May 2006	24 foods from 1 store in each of 3 communities in Cape Town, South Africa	Higher-fiber, lower-fat, and lower-sugar daily menu vs. typical daily menu[¶]	Food prices obtained from supermarkets; price reported by community
Wang J et al, 2010[47]	June-Aug 2005	14 foods from 1230 stores in Waikato and Lakes Districts, New Zealand	Basket including bread, chicken, beef/pork, sugar-sweetened drinks, milk, snacks, spreads, and sugar meeting vs. not meeting New Zealand food-based dietary guidelines (i.e. less energy-dense; lower- fat, salt, and sugar; and higher-fiber)[‡]	Prices obtained from 1230 stores (including supermarkets, dairies, bakeries, service stations, restaurants and takeaways). Each food was not available in every store
Wilson N and O Mansoor, 2005[48]	Jan 23, 2005	18 foods from 2 stores in Wellington, New Zealand	Basket of foods including butter, butter/vegetable oil blend, margarine type spread, cream cheese, hard cheese, grated cheese, cream, biscuits & crackers, and chocolate with mean saturated fat of 14.9 g/100 g vs. basket of same foods with mean saturated fat of 29.0 g/100 g [‡**]	Within each of 9 food-types, items with highest and lowest levels of saturated fat identified and prices obtained from 2 large supermarkets
Dietary studies				
Aggarwal A et al, 2011[48]	April-June 2004 and May-July 2006	1266 participants in Seattle Obesity Study; 3 stores	Dietary energy density, kJ/g and mean adequacy ratio (quintile 1 vs. quintile 5)[††]	Diet cost calculated based on prices of FFQ component foods. Food prices obtained from 3 supermarket chains via in-store visits and websites
Bernstein AM et al, 2010[6]	2001-2002	78191 participants in Nurses' Health Study; 467 foods	Alternative Healthy Eating Index score (quintile 5 vs. quintile 1)[‡‡]	Diet cost calculated by merging FFQ database with USDA Center for Nutrition Policy and Promotion price database

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
Drewnowski A et al, 2004[19]	NR	837 participants in Val-de-Marne, France; 57 foods	Fats and sweets intake, fruit and vegetables intake, total fat intake, and sucrose intake (quintile 1 vs. quintile 5)	Diet cost calculated from food prices from French National Institute of Statistics
Lopez CN et al, 2009[49]	Dec 1999-May 2005	11195 participants in Spain; 136 foods	Western dietary pattern score and Mediterranean dietary pattern score (quintile 1 vs. quintile 5)[§§]	Diet cost calculated from food prices from Ministry of Industry, Tourism and Commerce of Spain. When data not available from ministry, food prices obtained from national supermarket websites
Monsivais P and A Drewnowski, 2009[50]	May-July 2006	164 participants; 384 foods from 3 stores in Seattle, Washington	Dietary energy density, kcal/g (tertile 1 vs. tertile 3)	Diet cost calculated based on prices of FFQ component foods. Prices obtained at supermarket chains. Price reported separately for men and women
Monsivais P et al, 2010[51]	April-June 2004 and May-July 2006	1295 participants; 384 foods from 3 stores in Seattle, Washington	Nutrient density of diet (quintile 5 vs. quintile 1 of diet cost)[¥¥ββ]	Diet cost calculated based on prices of FFQ component foods. Food prices obtained from 3 supermarket chains via in-store visits and websites
Mozaffarian RS et al, 2012[37]	2003-2004	1294 snack-days in 32 YMCA after-school programs in 4 metropolitan areas	Environmental Standards for Healthy Eating (meeting vs. not meeting)[££]	Prices from USDA Center for Nutrition Policy and Promotion price database
Murakami K et al, 2009[52]	2004	596 pregnant women in Neyagawa City, Osaka Prefecture, Japan; 150 foods	Dietary energy density, kcal/g (quartile 4 vs. quartile 1 of diet cost)[¥¥]	Diet cost based on National Retail Price Survey. For foods not in survey, prices obtained from websites of nationally distributed supermarket or fast-food restaurant chains
Rauber F and MR Vitolo, 2009[53]	NR	346 children aged 3-4 y; 3 brands each of 104 foods from 2 stores in São Leopoldo, Brazil	Calories from sugar-rich foods (<= 150 kcal vs. > 150 kcal) and calories from fat-rich foods (<= 150 kcal vs. > 150 kcal)	Diet cost based on prices obtained at a large establishment (supermarket or hypermarket) and a small establishment (market, minimart or bakery)
Rehm CD et al, 2011[9]	2001-2002	4744 participants in NHANES	Healthy Eating Index-2005 score (quintile 5 vs. quintile 1 of diet cost)[¥¥¶¶]	Diet cost calculated from USDA Center for Nutrition Policy and Promotion price database
Rydén PJ et al, 2008[54]	Autumn 2005	30 participants in Kalmar province, Sweden; 600 foods	Mediterranean diet vs. typical diet[***]	Diet cost calculated from prices from Statistics Sweden. For foods not reported by Statistics Sweden, prices

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
				obtained from 4 stores and 2 online stores
Rydén PJ and L Hagfors, 2011[10]	Spring 2010	2160 children ages 4, 8, and 11 y in Sweden; prices of 991 foods from Statistics Sweden, and stores when not available from Statistics Sweden	Healthy Eating Index-2005 score (> 70 vs. < 50)¶¶	Average national prices of 391 foods obtained from Statistics Sweden. Prices of remaining 600 foods were not available from Statistics Sweden; obtained from one online supermarket and one online grocery store
Schroder H et al, 2006[55]	May 2005	2847 participants in Girona, Spain; 165 foods	Mediterranean Diet Score and Healthy Eating Index score (quartile 4 vs. quartile 1)¶¶	Diet cost calculated from average national price database of the Secretaria de Estado de Turismo y Comercio de Espana
Townsend MS et al, 2009[56]	2006	112 participants; 8 stores in San Joaquin, Solano, Calavaras, and Tulare counties in California	Dietary energy density, kcal/g (tertile 1 vs. tertile 3)	Diet cost (with and without beverages) calculated based on prices of FFQ component foods. Prices obtained from a large supermarket chain store and a small independent market in each county
Waterlander WE et al, 2010[57]	Feb-April 2008	373 participants in Longitudinal Ageing Study Amsterdam and 200 participants in Amsterdam Growth and Health Longitudinal Study; 2 stores	Dietary energy density, kJ/g (quartile 1 vs. quartile 4)	Diet cost calculated from prices obtained from 2 market leader supermarkets. Price reported separately for men and women

* This study is not included in analysis since it is the only market survey on fruits and vegetables.
† Baskets include varying amounts of fruits, dark green vegetables, orange vegetables, legumes, starchy vegetables, and “other” vegetables.
‡ Components of baskets also compared.
§ Baskets include healthier vs. less healthy breads, canned fruit, cheese, chicken, cereal; cooking oil, egg noodles, evaporated milk, flour, potatoes; frozen fish; ground meat, milk, rice, salad dressing, spaghetti, margarine, and tuna fish. Baskets also include fresh fruits and vegetables, eggs, and beans which are unchanged between two baskets.
¥ Nutrition Detectives criteria: subjectively determined to not have excessive marketing-related claims or images on the front of the package; not have an unhealthy ingredient such as sugar or white flour listed first on ingredient list, does not contain partially hydrogenated oil or high-fructose corn syrup, and does not have a long ingredient list relative to other items in the same food category. For grain-based products only, more nutritious foods also contain at least 2 g fiber per serving.
β Baskets include healthy vs. less healthy juice, hot dogs, ground beef, chips, bread, soda, milk, frozen dinner, baked goods, and cereals.
£ Trans fat-free defined as containing 1) <= 0.2 g TFA per 10 g; 2) <= 2 g TFA and SFA combined per 10 g; and 3) <= 15% energy from TFA and SFA combined per 10 g.
¶ Typical menu includes corn flakes, whole milk, sugar, and cola drink in the morning; white bread, brick margarine, jam, and cookies for lunch; and regular hamburger, white rice, fried cabbage, and candied butternut for dinner. Healthier menu includes bran flakes, skim milk, banana, and orange juice in the morning, whole wheat bread, tub margarine, low-fat cottage cheese, and apple for lunch; and lean hamburger, brown rice, boiled cabbage, and boiled butternut for dinner.
**Average price at the 2 stores calculated and used in meta-analysis.

††Model 3 coefficients in Tables 4a and 4b used to calculate difference in price between quintiles 1 and 5. Mean adequacy ratio is a truncated index of the percent of daily recommended intakes for key nutrients. Computed by taking the average of nutrient adequacy ratio for 11 key nutrients: vitamins A, C, D, E, B12, calcium, iron, magnesium, potassium, folate and fiber. Expressed as percent of adequacy/day.
‡‡ The Alternative Healthy Eating Index reflects intake of fruit, vegetables, nuts, soy, beans, white and red meats, cereal fiber, trans unsaturated fatty acids, polyunsaturated fatty acids, saturated fatty acids, alcohol, and years of multivitamin use.
§§ Food items identified in Western pattern were red meat, processed meats, eggs, sauces, precooked food, fast-food, caloric soft drinks, whole-fat dairy and potatoes. Food items identified in the Mediterranean pattern included olive oil, poultry, fish, low-fat dairy, legumes, fruits, and vegetables.
¥¥ Healthfulness of diet stratified by quantile of diet cost.
ββ Nutrient density is defined as mean percentage daily value for vitamin A, vitamin C, vitamin E, calcium, magnesium, potassium, and dietary fiber in 2000 kcal of dietary energy.
££ Environmental Standards for Healthy Eating guidelines: do not serve sugar-sweetened beverages, serve water every day, serve a fruit and/or vegetable every day, do not serve foods with trans fat, and when serving grains (such as bread, crackers, and cereals), serve whole grains.
¶¶ Healthy Eating Index is a measure of overall diet quality based on consumption of sodium, saturated fat, total fruit, whole fruit, total vegetables, dark green and orange vegetables, milk, total grains, whole grains, meat and beans, oils, and empty calories.
*** Mediterranean diet included eating more fruit, vegetables and pulses; choosing whole-grain products; changing dietary fat intake to products containing less saturated fat and more unsaturated fat; avoiding meat and meat products; and limiting the intake of sweets, snacks and desserts.
††† Mediterranean diet based on intake of cereals, fruits, vegetables, legumes, fish, olive oil, nuts, and red wine.

TRACKED CHANGES VERSION

Do Healthier Foods and Diet Patterns Cost More Than Less Healthy Options? A Systematic Review and Meta-Analysis

Mayuree ~~Rao, Researcher~~[1]Rao[1,2], Ashkan ~~Afshin, Postdoctoral Fellow~~[2]Afshin[2], Gitanjali ~~Singh, Postdoctoral Fellow~~[2]Singh[3], Dariush ~~Mozaffarian, Associate Professor~~[2,3]Mozaffarian[2-4]

[1]The Warren Alpert Medical School of Brown University, Providence, RI, USA; [2]Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA; [3]~~Division~~[3]Department of Nutrition, Harvard School of Public Health, Boston, MA, USA; [4]Division of Cardiovascular Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA

Correspondence to:
Mayuree Rao
The Warren Alpert Medical School of Brown University
222 Richmond St
Box G-9230A
Providence, RI~~,~~ 02903
mayuree_rao@brown.edu

Formatted: Font: +Body (Calibri), 11 pt

Keywords: food/economics, diet/economics, public health, chronic disease, primary prevention

Formatted: No Spacing

Word count: 4,760

Background: Conventional wisdom holds that healthier foods cost more than less healthy options. Yet, this research question has not been systematically evaluated, including consideration of types of foods and diet patterns and definitions of healthfulness.

Objective: To conduct a systematic review and meta-analysis of prices of healthier vs. less healthy foods/diet patterns while evaluating and accounting for key sources of heterogeneity.

Data sources: Medline (2000-2011), supplemented with expert consultations and hand-reviews of reference lists and related citations.

Eligibility criteria for selecting studies: Studies were reviewed independently and in duplicate, and included if reporting mean retail price of foods or diet patterns stratified by a specified measure of healthfulness. Data before 2000 were excluded to maximize contemporary generalizability.

Design: Studies, were reviewed independently and in duplicate, , wereand included if reporting mean retail price of foods or diet patterns stratified by a specified measure of healthfulness. Data before 2000 were excluded to maximize contemporary generalizability. We extracted, in duplicate, mean prices and their uncertainties of healthier and less healthy foods/diet patterns, and rated the intensity of health differences for each comparison (range 1 to 10). Prices were adjusted for inflation and World Bank purchasing power parity, standardized to the international dollar (defined as one USD) in 2011. Using random-effects models, we quantified price differences of healthier vs. less healthy options for specific food types, diet patterns, and units of price (serving, day, calorie). Statistical heterogeneity was quantified using I^2 statistics.

Results: Twenty-seven studies from 10 countries met inclusion criteria. Among food groups, meats/protein had largest price differences: healthier options cost $0.29/serving (95% CI: $0.19 to 0.40) and $0.47/200 kcal ($0.42 to 0.53) more than less healthy options. Price differences per serving for healthier vs. less healthy foods were smaller among grains ($0.03), dairy (-$0.004), snacks/sweets ($0.12), and fats/oils ($0.02) (p<0.05 each), and not significant for soda/juice ($0.11, p=0.64). Comparing extremes (top vs. bottom quantile) of food-based diet patterns, healthier diets cost $1.48/day ($1.01 to 1.95) and $1.54/2000 kcal ($1.15 to 1.94) more. Comparing nutrient-based patterns, price per day was not significantly different (top vs. bottom quantile: $0.04; p=0.916), whereas price per 2000 kcal was $1.56 ($0.61 to 2.51) more. Results were similar after aAdjustment for intensity of differences in healthfulness yielded similar results.

Conclusions: ~~:~~ This meta-analysis provides the best evidence to-date of price differences of healthier vs. less healthy foods/diet patterns, highlighting ~~nuanced~~ challenges and opportunities for reducing financial barriers to healthy eating.

~~"What this paper adds" box~~

~~*What is already known on this subject:*~~

~~One commonly described barrier to promotion of healthy diets is cost: conventional wisdom holds that healthier foods and diets are more expensive than less healthy options. Yet, whereas several studies have evaluated whether healthier foods or diets cost more,[1-5] the evidence has never been systematically reviewed nor quantified to critically evaluate the relationship between healthfulness of foods or diet patterns and price. In addition, little is known about the potential heterogeneity of this relationship.~~

~~*What this study adds:*~~

~~Our study finds that healthier diet patterns cost more than less healthy diet patterns. This additional cost, while significant for many low-income families, is dwarfed by the lifetime financial burdens of diet-related chronic diseases. These findings highlight the nuanced challenges and opportunities for reducing financial barriers to healthy eating.~~ **Article summary**

Article focus

- To conduct a systematic review and meta-analysis of prices of healthier vs. less healthy foods and diet patterns, while also evaluating and accounting for key sources of heterogeneity.

Key messages

- Among 6 food groups, larger price differences were observed by healthfulness for meats/protein, as well as smaller but statistically significant differences for snacks/sweets, grains, fats/oils, and dairy.
- Comparing extremes of healthier food-based diet patterns, the healthiest diets cost an average of $1.48/day (95% CI: $1.01 to $1.95) more than the least healthy diets.

Strengths and limitations of this study

- This systematic review and meta-analysis represents, to our knowledge, the most comprehensive examination of the evidence on prices of more vs. less healthy foods and diet patterns. Strengths include the systematic search; adjustment for inflation and purchasing power parity; separate analyses of food groups, diet patterns, and units of price; and evaluation of heterogeneity by food type, intensity of contrast, and unit of comparison.
- The study was limited by less available data on restaurant prices and prices from low- and middle-income countries. High statistical heterogeneity was evident, although the actual observed range of price differences was more modest.

INTRODUCTION

Consumption of a healthy diet is a priority for reducing chronic diseases including obesity, diabetes, cardiovascular diseases, and several cancers. This is especially crucial for socioeconomically disadvantaged populations, who have both less healthy diets and higher disease risk than higher socioeconomic groups.[6-9] One commonly described barrier[1-4] Many factors, including the availability and cultural acceptability of healthy foods, pose obstacles to the promotion of healthy diets. One of the most commonly described barriers is cost: conventional wisdom holds that healthier foods and diets are more expensive than less healthy options, and thisan assumption which has become "a reflexive part of how we explain why so many Americans are overweight."[105]

Field Code Changed

Yet, whereas several studies have evaluated whether healthier foods or diets cost more,[1-56-10] the evidence has never, to our knowledge, been systematically reviewed nor quantified to critically evaluate the relationship between healthfulness of foods or diet patterns and price. In addition, little is known about the potential heterogeneity of this relationship. For example, price differences may vary by the foods or diets being compared. Many studies compare healthier and less healthy versions of the same food (i.e. more vs. less healthy grains), while other studies examine the price differences of a healthier vs. less healthy overall diet patterns. Price differences may also depend on how healthfulness is defined, ranging from definitions based on single nutrients (e.g., fat content, sugar content) to those based on foods or more complex diet patterns. The intensity of the health contrast could also affect the price difference; for example, a fast food meal vs. a healthier home-cooked meal is a more extreme comparison than a low-fat vs. high-fat cookie. Finally, price differences may vary by the unit of comparison, e.g., per serving, per calorie, etc. In particular, price differences per calorie may be limited by reverse causation, as healthier foods (e.g., fruits, vegetables) often have fewer calories; evaluation of price differences per serving may alter conclusions.[11]

To address each of these key gaps in knowledge, we performed a systematic review and meta-analysis of the evidence for relationships between the healthfulness of foods/diet patterns and their price, including consideration of different food groups and diet patterns, definitions of healthfulness, intensities of the contrast, and units of comparison (calorie, serving, daily diet).

METHODS

We followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines throughout all stages of design, implementation, and reporting.[12] The independent and dependent variables of interest were the healthfulness of foods or diet patterns and their price, respectively. The protocol, which was not altered after commencement of the study, is available from the authors upon request.

Search strategy and selection of articles

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

Systematic searches were conducted using Medline (via PubMed) for all eligible English-language articles published through December 2011. Additional articles were identified by expert consultations, and hand-reviews of reference lists and first 20 "Related citations" in PubMed for all studies included after full-text review. Because our focus was on contemporary price differences related to healthfulness, and because such price differences could vary in earlier decades, we focused our search on studies having collected price data in the year 2000 or later. The search query combined terms related to foods/diet patterns, price, setting, and time (**Supporting Appendix 1**).

Studies were included if they reported the mean retail prices of foods (including beverages) or diet patterns stratified by a specified measure of healthfulness, as well as sufficient (or obtainable by direct contact) data to derive or estimate the statistical uncertainty (i.e., standard error of difference in means). No foods or diet patterns were excluded. Studies reporting wholesale price or perceived rather than actual price, as well as reviews, letters, editorials, and commentaries, were excluded.

One investigator screened all identified studies ~~for~~based on these inclusion and exclusion criteria by title and abstract. Following screening, remaining full-text articles were obtained and reviewed independently and in duplicate by two investigators for final inclusion/exclusion~~.~~ using the same criteria. Any differences were resolved by discussion among all of the investigators. A list of excluded citations is available from the authors upon request.

Data extraction and synthesis

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

For each included study, two investigators extracted data independently and in duplicate using a standardized electronic spreadsheet. Data extracted included first author, title, publication year, year of price data collection, source of price data, demographic variables of study participants and/or community from which price data was collected, definition(s) of healthfulness, food/diet pattern comparison(s), numbers of participants and/or numbers of foods, and mean prices and uncertainties (including unit, e.g., calorie, serving) of the healthier and less healthy foods/diet patterns compared. Because the magnitude of differences in healthfulness could influence price differences, we also rated the intensity of the contrast in health difference between the compared foods/diet patterns on an ordinal scale (1 to 10), with 1 representing a very small difference in healthfulness and 10 a marked difference in healthfulness. ~~These ratings are available in the Supporting Information. The intensity of contrast was rated independently and in duplicate by two investigators, with discrepancies resolved by group discussion~~These ratings were based on growing evidence that different types of foods and food-based diet patterns predict chronic disease outcomes better than differences in single nutrients.[13] Thus, foods/diet patterns that differed by a single nutrient were rated as low intensity, while foods/diet patterns that differed across multiple nutrients (e.g., three home-cooked meals vs. three fast-food meals) were rated as high intensity. The intensity of contrast was rated independently and in duplicate by two investigators with good concordance (generally less than or equal to 2 points); discrepancies were resolved by group discussion. These ratings are available in the Supporting Information.

Statistical analysis

Formatted: Font: Bold, Not Italic

Our primary endpoint was the difference in mean price between the healthier and less healthy foods or diet patterns. When data on the variance of the difference in means or information to directly calculate this variance were not reported, we calculated it based on the variance of the mean prices in each category, based on standard formulas[1314]:

Field Code Changed

$$SE_{diff} = \sqrt{SE^2_{healthier} + SE^2_{less\ healthy}}$$

$$SE_{diff} = \sqrt{\frac{SD^2_{healthier}}{n_{healthier}} + \frac{SD^2_{less\ healthy}}{n_{less\ healthy}}}$$

For 9 studies in which mean prices were reported without their uncertainty, the SEs were imputed from the number of observations in each category, based on linear regression of studies with complete data, performed separately for market surveys (6 studies comparing samples of foods) and individual dietary surveys (3 studies comparing diets across samples of participants) (**Supporting Figure 1**).

We recognized that price comparisons within food groups (i.e., healthier vs. less healthy options within the same category of food) may vary from price comparisons across overall diet patterns. Furthermore, price differences may vary for diet patterns largely based on foods vs. diet patterns largely based on one or a few isolated nutrients. Thus, we separately investigated price differences that compared options within a single similar category of food (e.g., meats/protein, grains, dairy), price differences that compared varying concordance to food-based diet patterns (e.g., Alternative Healthy Eating Index, Western, or Mediterranean diet patterns), and price differences that compared varying concordance to isolated nutrient-based (e.g., fat, sugar) diet patterns. For analyses of diet patterns, we evaluated price differences for the extreme categories (e.g., the top vs. bottom quartile or quintile) of diet, to enable comparisons of the largest differences in diet quality.

Because price differences could also vary by the unit of comparison, findings for foods were evaluated standardized both to one usual serving and to 200 kcal; and for diet patterns, standardized both to one day (3 meals) and to 2000 kcal. Standard serving sizes were based on 2011 USDA MyPlate guidelines or, if not available from MyPlate, on nutrition labels from a major grocery website.[15 16] Calorie conversions were derived from the USDA database.[17] For standardizing studies of food baskets to meals, one serving of any food was assigned as one-fourth of a meal, except for condiments, fats, or oils for which one serving was assigned one-eighth of a meal. All price differences were adjusted for inflation by country to reflect prices in 2011. In addition, to account for the varying values of currencies across countries, these prices were further adjusted for purchasing power parity by standardizing to 2011 international dollars; one international dollar is defined as one US dollar. Inflation rates and purchasing power parity conversion factors were obtained from the World Bank; 2011 is the latest year for which these data are available.[18] We also repeated all analyses with additional weighting for the intensity of the contrast in healthfulness (range 1 to 10), i.e. with greater differences (higher intensity values) carrying greater weights.

Summary estimates were quantified using inverse-variance weighted, random effects meta-analysis (*metan* command in Stata). Statistical heterogeneity was evaluated using the I^2 statistic. Meta-regression (*metareg* command in Stata) was performed on intensity, study location (USA/Canada vs. other), and type of survey (market survey vs. dietary survey) to explore potential sources of heterogeneity. Publication bias was assessed using the Egger test and visual inspection of funnel plots. Statistical analyses were performed using Stata 12 (StataCorp, College Station, Texas), with two-tailed alpha = 0.05.

RESULTS

Search results and study characteristics

Formatted: Font: Bold, Not Italic
Formatted: Font: Bold

Of 1,010 articles identified by the Medline search and screened for inclusion, 83 were selected for full-text review (**Figure 1**). Of these, 19 articles met inclusion criteria, and an additional 8 articles were identified from hand-searches of references lists, related citations in PubMed, and expert consultations. Among the final 27 studies, 14 were conducted in the US, 2 in Canada, 6 in Europe, and 5 in other countries including South Africa, New Zealand, Japan, and Brazil (**Table**). Twelve studies were market surveys, and 15 were dietary surveys. The number of foods evaluated by the market surveys ranged from 2 to 133, with prices collected from between 1 and 1,230 stores. The number of participants evaluated by the dietary surveys ranged from 30 to 78,191. Several studies reported prices for multiple food comparisons or from different types of stores and contributed more than one estimate to the analysis.

Price Differences of Foods

Formatted: Font: Bold, Not Italic

Evidence on price comparisons within similar food groups was available in 6 major food groups, including meats/protein, grains, dairy, snacks/sweets, fats/oils, and soda/juice.

Per serving, meats/protein exhibited the largest price difference by healthfulness (**Figure 2A**). On average, the healthier choice was $0.29 more expensive per serving than the less healthy choice (95% CI: $0.19 to $0.40). Considerable statistical heterogeneity was evident (I^2=99.4%) that appeared at least partly related to the type of comparison. For example, price differences by healthfulness appeared largest for chicken, intermediate for beef, and smallest for peanut butter. Healthier snacks/sweets, grains, and fats/oils were also more expensive per serving than less healthy options, but with smaller price differences: for snacks/sweets, $0.12/serving ($0.02 to $0.23); for grains, $0.03/serving ($0.01 to $0.05); and for fats/oils, $0.02/serving ($0.01 to $0.02). For dairy, healthier options were slightly less expensive per serving (-$0.004/serving; 95% CI: -$0.005 to -$0.004), although pooled findings were driven by one study with reported high statistical certainty. Excluding this study, healthier dairy options were similar in price to less healthy options (-$0.004/serving, p=0.389). No significant price differences per serving were seen between healthier and less healthy soda/juice ($0.11; 95% CI: -$0.34 to $0.56; I^2=25.1%), but only two studies evaluated this comparison.

For most of these food groups, findings were similar or stronger for pooled price differences standardized per calorie (**Figure 2B**), rather than per serving. The largest price difference was again among meats/protein, with healthier options costing $0.47 per 200 kcal more ($0.42 to $0.53) than less healthy options. The main exception was dairy foods, for which the pooled price difference per 200 kcal was much greater than the price difference per serving. Per 200 kcal, healthier dairy foods were $0.21 more expensive than less healthy options ($0.11 to $0.31), consistent with the strong calorie effect of the metric (fat content) that was used to define healthfulness in this food group.

Price Differences of Diet Patterns

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

Twenty studies evaluated price differences according to concordance with overall healthful diet patterns, with 14 studies evaluating more food-based patterns and 7 studies evaluating more nutrient-based patterns (one study evaluated both[18][19]).

Comparing extreme categories of food-based diet patterns, the highest category of healthier diets cost $1.48/day ($1.01 to $1.95) more than the lowest category (**Figure 3A**). Findings were broadly consistent across several different definitions of healthful diet patterns, including based on the Mediterranean dietary pattern, Western dietary pattern, Alternative Healthy Eating Index, fruit and vegetable intake, and energy density. Some food-based diet patterns exhibited smaller or no price differences, including based on the Healthy Eating Index, the Environmental Standards for Healthy Eating, and comparing home-cooked to fast food meals. When standardized to 2000 kcal, healthier food-based diet patterns cost $1.54 more than less healthy options ($1.15 to $1.94), with price differences modestly larger for patterns based on the Alternative Healthy Eating Index and energy density, smaller for patterns based on fruit and vegetable consumption alone, and no longer significant for the Mediterranean dietary pattern. (**Figure 3B**).

For diet patterns based largely on single or few isolated nutrients, the price of the highest category of diets meeting these criteria was not significantly different than the lowest when based on a day's intake (**Figure 4A**). In contrast, when standardized to 2000 kcal, the highest category of nutrient-based patterns cost $1.56 more than the lowest ($0.61 to $2.51) (**Figure 4B**). Price differences per 2000 kcal were larger relative to the per day estimates for patterns based on fat; sugar; and fiber, fat, and sugar combined.

We also performed analyses restricted to US studies. Results were similar: healthier food-based diet patterns cost an average of $1.49/day ($0.60 to $0.237; n=7 studies) and $1.79/2000 calories ($0.78 to $2.80; n=6 studies) more than less healthy patterns. Healthier nutrient-based diet patterns cost an average of $0.40/day ($0.17 to $0.63; n=3 studies) and $2.46/2000 calories (-$2.17 to $7.09; n=2 studies) more than less healthy patterns.

Intensity of the Contrast in Healthfulness

Formatted: Font: Bold, Not Italic

We repeated all analyses adjusting for differences in the intensity of contrast in healthfulness in each comparison. Within food groups, intensities of contrasts were generally rated in the 4 to 6 range, with smallest contrast of 3 (e.g., comparing different types of cookies) and largest of 9 (e.g., comparing fruits/vegetables to packaged snacks). For food groups, intensity-weighted price differences were generally similar to the unweighted findings (**Supporting Figure 2)**. Contrasts of diet patterns were most often rated 6 or 7, with smallest contrast of 1 (comparing patterns based on total fat alone) to largest of 10 (comparing 3 healthier home-cooked meals to 3 fast food meals). Compared with unweighted comparisons, the intensity-weighted price differences of healthier vs. less healthy food-based diet patterns were similar: $1.46/day ($1.00 to $1.92) and $1.53/2000 kcal ($1.14 to $1.93) (**Supporting Figure 3**). Intensity-weighted price differences were also similar to unweighted results for nutrient-based diet patterns: $0.11/day (-$0.64 to $0.85) and $1.66/2000 kcal ($0.55 to $2.78) (**Supporting Figure 4**).

Potential Sources of Heterogeneity

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

Statistical heterogeneity as quantified by the I^2 statistic was high in most analyses. Meta-regression did not identify significant effect modification based on study location (USA/Canada vs. other), intensity of the contrast in healthfulness, or study type (market survey vs. dietary survey). Meta-regression by study type (market survey vs. dietary survey) was not possible for the food group analyses due to collinearity.

Publication bias

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

Publication bias was assessed using the Egger test and funnel plots (**Supporting Figure 5**).[20] There was no significant bias identified by the Egger test. Visual inspection of funnel plots suggested asymmetrical distributions for dairy food, food-based diet patterns, and nutrient-based diet pattern comparisons, consistent with a larger number of smaller studies reporting greater price differences than the overall pooled estimate.

DISCUSSION

The findings from this systematic review and meta-analysis provide the most robust evidence to-date on price differences of healthier versus less healthy foods and diet patterns. The results by food group provide insight into the relationship between healthfulness and price among similar foods. The results by diet pattern inform price differences between greater extremes of healthfulness, comparing very different foods, e.g., diets rich in fruits and vegetables vs. diets rich in processed foods. ~~With~~Although statistical heterogeneity was high, this was at least partly related to relatively small uncertainty of each within-study price difference; the magnitude of clinically relevant heterogeneity was much lower, with comparatively similar price differences between studies. In addition, with a few exceptions, findings were similar across different units of price (per serving or day vs. calorie), intensity of contrast, study location, and type of survey, increasing confidence in the validity and consistency of the findings.

Price Differences of Foods

Formatted: Font: Bold, Not Italic

Among 6 food groups, relatively large price differences were observed for meats/protein, as well as smaller but statistically significant differences for snacks/sweets, grains, fats/oils, and dairy. According to the USDA, the farm share of proceeds of a one dollar expenditure on domestically produced food in the United States is 14.1 cents[2021], suggesting that final retail prices are determined largely by other industries and procedures in the food supply chain. Additional cost of processing and manufacturing could explain some of the identified variation in price differences; for example, lean beef and skinless chicken require more processing, perhaps accounting for their higher price. Our findings highlight the need for more research on the underlying drivers of price differences of specific items within broad food categories.

Our findings also demonstrate that, for certain metrics of healthfulness, the selected unit of comparison alters the results. In particular, metrics based largely on fat content demonstrated greater price differences per calorie than per serving. The most striking example was for dairy foods: healthier options were $0.004 less expensive per serving but $0.21 more expensive per 200 kcal. Whole milk contains nearly twice the calories as fat-free milk,[~~16~~17] so nearly double the amount of fat-free milk must be purchased to achieve equivalent calories. These findings highlight the dangers of circular reasoning (e.g., selecting a metric based on fat content and then evaluating price differences per calorie) and the importance of identifying the most relevant unit of comparison for any individual or public health decision about price differences of foods.[11]

Price Differences of Diet Patterns

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

On average, healthier food-based diet patterns were more expensive than less healthy patterns, whether based on an actual day's intake or per 2000 kcal. The price difference – about $1.50 per day – represents the price difference per person for consuming a much healthier vs. much less healthy overall diet, e.g., comparing Mediterranean-type diets rich in fruits, vegetables, fish, and nuts vs. diets rich in processed food, meats, and refined grains. Thus, ~~the results represent~~this price ~~differences~~difference is for a relatively extreme ~~contrasts~~contrast, between the ~~highest~~healthiest and ~~lowest categories of an overall~~least healthy diet pattern. Better adherence to such food-based diet patterns consistently relates to improved health and lower risk of chronic diseases.[~~21~~22 ~~22~~23]

In contrast to the findings for food-based diet patterns, healthier vs. less healthy nutrient-based diet patterns were not significantly different in price when based on a day's actual intake, but only cost more when standardized to 2000 kcal. These results mirror those observed when comparing individual food groups, such as dairy, based on single-nutrient metrics of healthfulness. These findings emphasize the crucial role of the unit of comparison when comparing prices by nutrient-based metrics. Healthier diets defined based on fiber or fat content will, by definition, have fewer calories, so they will naturally cost more per calorie. Yet, such diets will not necessarily cost more per serving or per meal. In the setting of a global obesity pandemic, assessing price differences per calorie may make little sense when a healthier diet also leads to reductions in total calorie consumption. Growing evidence also indicates that single or selected nutrients are less useful for distinguishing healthfulness than types of foods and food-based diet patterns.[2313]

Field Code Changed

Heterogeneity

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

In most comparisons, statistical heterogeneity as measured by I^2 was high. Yet, adjustment for intensity of differences in healthfulness had little effect on pooled price differences, and meta-regression revealed no significant effect modification by intensity, study location, or study type. The high I^2 values may be partly explained by the relatively small uncertainty for each within-study price difference. In many of the identified studies, the combination of a continuous outcome (price) and a relatively large number of samples (foods or individuals) resulted in low uncertainty of each study-specific price difference. Lower within-study uncertainty produces higher I^2 values, even when absolute magnitudes of price heterogeneity among studies may be modest from a public health or practical perspective. For example, the price differences among snacks/sweets studies fell within a relatively limited range (-$0.04 to $0.30/serving), with a reasonable summary estimate of $0.12/serving, but statistical heterogeneity was high (I^2=85.9%) partly due to narrow within-study confidence intervals. Thus, the calculated heterogeneity in each summary estimate should be interpreted in light of the actual range of observed price differences across studies. Since clinically relevant heterogeneity was lower than statistical heterogeneity, the pooled results provide insight into average price differences between healthier and less healthy foods and diet patterns.

Although similar classes of foods and diet patterns were evaluated separately, the foods or diet patterns within each category were not exactly the same. Our aim – and the relevant public health question – was not whether one specific product costs more than another, but whether healthier foods in a broad class of foods cost more, on average, than less healthy foods in the same broad class.

Strengths and Limitations

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

Several strengths can be highlighted. This systematic review and meta-analysis represents, to our knowledge, the most comprehensive examination of the evidence on prices of more vs. less healthy foods and diet patterns. Our systematic search makes it unlikely that we missed any large reported studies. Error and bias were each minimized by independent, duplicate decisions on inclusion of studies and data extraction. Adjustment for inflation and purchasing power parity to 2011 prices accounted for the varying value of money across years and countries. Exclusion of price data prior to the year 2000 increased generalizability of the results to contemporary diets. A key strength of our analysis was evaluation of food groups separately from diet patterns. The former provides data to inform choices when comparing otherwise relatively similar foods, whereas the latter informs price differences across very different selections of foods. Additional strengths include the standardization of disparate metrics, foods, and units; the assessment of food-based and nutrient-based diet patterns; and the evaluation of heterogeneity by food type, intensity of contrast, and unit of comparison.

Potential limitations should be considered. Like all meta-analyses, our analysis was based on available data; for certain comparisons, relatively few studies were available. For example, only one study directly compared prices of restaurant foods to home-cooked foods; all other studies reported supermarket prices. Thus, our results summarize the best current data on price differences of foods and diet patterns while also highlighting gaps in knowledge that require further investigation. Definitions of healthfulness varied across food groups and diet patterns. Yet, our findings across a variety of diet patterns and definitions of healthfulness inform how such contrasts may influence price differences. Our assessment of publication bias suggested that price differences for dairy foods and diet patterns may be partly overestimated due to selective publication of smaller studies with more extreme estimates. Statistical heterogeneity was evident in most comparisons, although the range of observed price differences for many comparisons was not extreme. Statistical heterogeneity was evident in most comparisons, a significant consideration in the interpretation of the results. All meta-analyses must strike a balance between the imperative for generalizability and the need to minimize heterogeneity. Additionally, the actual range of observed price differences for many comparisons was not extreme. The rating system for intensity of contrast was subjective; yet, the ratings were assigned independently and in duplicate with good concordance and provide important sensitivity analyses on the robustness of the results. Our findings on price differences per day and per 2000 calories reflect an adult diet; the summary estimates should be adjusted for other caloric intakes, e.g. in young children. Only English-language studies from PubMed were included, so some studies may have been missed. Given absence of accepted criteria for judging quality of observational studies, quality of studies was not formally assessed. Most comparisons were from high-income countries, highlighting the need for similar studies in low- and middle-income nations.

ConclusionsCONCLUSIONS

Formatted: Font: Bold, Not Italic

Formatted: Font: Bold

In sum, our findings provide the most robust evidence to-date on price differences of healthier foods and diet patterns, while also highlighting the importance of carefully considering the metric of healthfulness, intensity of contrast, and unit of comparison. Our results indicate that lowering the price of healthier diet patterns – on average ~$1.50/day more expensive – should be a goal of public health and policy efforts, and some studies suggest that this intervention can indeed reduce consumption of unhealthy foods.[24-26]

It remains an open question as to *why* healthier diets cost more. Some have argued that US agricultural subsidies for commodities (e.g. corn, soy) lower the price of less healthy, more processed foods compared with unprocessed foods.[27] However, careful economic analyses demonstrate that the main impact of such subsidies is direct income transfer to farmers, with little influence on retail prices; and that tariffs and other protectionist policies are actually raising the prices of many US commodities such as sugar.[28-30] Conversely, many decades of policies focused on producing inexpensive, high volume commodities have led to a complex network of farming, storage, transportation, processing, manufacturing, and marketing capabilities that favor sales of highly processed food products for maximal industry profit.[31] Based on these experiences, efforts to create an infrastructure and commercial framework that facilitates production, transportation, and marketing of healthier foods could increase availability and reduce prices of more healthful products.[31] Taxation of less healthy foods and subsidies for healthier foods would also be an evidence-based intervention to balance price differences.[31]

~~For~~ Other potential barriers to a healthier diet exist, such as availability and cultural acceptability. However, our findings suggest that for socioeconomically disadvantaged populations, the relatively higher cost of healthy foods may be an impediment to eating better. On the other hand, Americans at all income levels allocate too little of their food budgets toward healthy foods.[32] A daily price difference of ~$1.50 translates to ~$550 higher annual food costs per person. For many low-income families, this additional cost ~~might represent~~represents a genuine barrier to healthier eating. Yet, this daily price difference is ~~also similar to the price of a cup of coffee and quite~~ trivial in comparison to the lifetime personal and societal financial burdens of diet-related chronic diseases.[33 34] ~~Our findings highlight the nuanced challenges and the opportunities for reducing financial barriers to healthy eating.~~For example, suboptimal diet quality was recently estimated to account for 14% of all disability-adjusted life years (DALYs) in 2010 in the United States;[35] if translated to a proportion of national health expenditures in 2012,[36] this corresponds to diet-related health care costs of $393 billion/year, or more than $1200/year for every American. Our findings highlight the nuanced challenges and the opportunities for reducing financial barriers to healthy eating.

Formatted: Space After: 0 pt, Line spacing: Double

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Formatted: Font color: Auto
Field Code Changed
Formatted: Font color: Auto
Formatted: Font color: Auto

Funding disclosure: Funding support was provided by a Genes and Environment Initiative (GENI) grant from the Harvard School of Public Health; by a National Heart, Lung, and Blood institute Cardiovascular Epidemiology Training Grant in Behavior, the Environment, and Global Health (T32 HL098048); and by a National Institute of Diabetes and Digestive and Kidney Diseases Training Grant in Academic Nutrition (T32 DK007703). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Ethics statement: Ethics approval was not required for this study.

Contributors: MR and DM conceived the study design and aims. MR, AA, and GS performed the systematic review and data extraction. MR performed the analysis. MR, AA, GS, and DM interpreted the results. MR and DM drafted the manuscript; AA and GS contributed to manuscript revisions. MR and DM are guarantors. All authors had full access to all of the data and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Data sharing: Technical appendix available upon request from corresponding author.

Formatted: Font color: Auto

Formatted: Font color: Auto

Figure 1. Search and screening of studies comparing prices of healthier and less healthy foods or diet patterns.

Formatted: Font: Not Bold

Figure 2. Price difference between healthier and less healthy foods per serving (A) and per 200 kcal (B). Price difference defined as the healthier category minus the less healthy category. Standardized serving sizes were derived from 2011 USDA MyPlate guidelines or, if not available from MyPlate, nutrition labels from a major grocery website. Calorie-adjustment of price differences based on the USDA database. Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

Figure 3. Price difference between healthier and less healthy food-based diet patterns per day (A) and per 2000 kcal (B). Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Mozaffarian RS, 2012.[37] Energy density was included as a food-based pattern since this metric represents a set of foods more than it represents any single nutrient.[19] For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Number of participants reported for dietary surveys (studies comparing diets across samples of participants), and number of foods reported for market surveys (studies comparing samples of foods). Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

Figure 4. Price difference between healthier and less healthy nutrient-based diet patterns per day (A) and per 2000 kcal (B). One outlying, implausible estimate from Aggarwal A, 2011 (mean adequacy ratio) was excluded ($17.23; 95% CI: $14.35, $20.11).[38] Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Temple NJ, 2009 and Krukowski RA, 2010.[39 40] For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Number of participants reported for dietary surveys (studies comparing diets across samples of participants), and number of foods reported for market surveys (studies comparing samples of foods). Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

~~References~~REFERENCES

1. Banks J, Marmot M, Oldfield Z, Smith JP. Disease and disadvantage in the United States and in England. *JAMA : the journal of the American Medical Association* 2006;295(17):2037-45.
2. Kant AK, Graubard BI. Secular trends in the association of socio-economic position with self-reported dietary attributes and biomarkers in the US population: National Health and Nutrition Examination Survey (NHANES) 1971-1975 to NHANES 1999-2002. *Public health nutrition* 2007;10(2):158-67.
3. Mackenbach JP, Stirbu I, Roskam AJ, Schaap MM, Menvielle G, Leinsalu M, et al. Socioeconomic inequalities in health in 22 European countries. *The New England journal of medicine* 2008;358(23):2468-81.
4. Darmon N, Drewnowski A. Does social class predict diet quality? *The American journal of clinical nutrition* 2008;87(5):1107-17.
5. Bittman M. Is Junk Food Really Cheaper? *The New York Times* 2011 Sept 24.
6. Bernstein AM, Bloom DE, Rosner BA, Franz M, Willett WC. Relation of food cost to healthfulness of diet among US women. *Am J Clin Nutr* 2010;92(5):1197-203.
7. Jetter KM, Cassady DL. The availability and cost of healthier food alternatives. *Am J Prev Med* 2006;30(1):38-44.
8. McDermott AJ, Stephens MB. Cost of eating: whole foods versus convenience foods in a low-income model. *Fam Med* 2010;42(4):280-4.
9. Rehm CD, Monsivais P, Drewnowski A. The quality and monetary value of diets consumed by adults in the United States. *Am J Clin Nutr* 2011;94(5):1333-9.
10. Ryden PJ, Hagfors L. Diet cost, diet quality and socio-economic position: how are they related and what contributes to differences in diet costs? *Public Health Nutr* 2011;14(9):1680-92.
11. Carlson A, Frazao E. Are Healthy Foods Really More Expensive? It depends on How You Measure the Price: U.S. Department of Agriculture, Economic Research Service, 2012.
12. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA : the journal of the American Medical Association* 2000;283(15):2008-12.
13. Mozaffarian D, Ludwig DS. Dietary guidelines in the 21st century--a time for food. *JAMA : the journal of the American Medical Association* 2010;304(6):681-2.
14. Rosner B. *Fundamentals of Biostatistics*. 7 ed. Boston, MA: Brooks/Cole , Cengage Learning, 2011.
15. USDA. ChooseMyPlate.gov.
16. Peapod.
17. USDA. Food-a-Pedia.
18. Azevedo JP. "wbopendata: Stata module to access World Bank databases." Statistical Software Components S457234.: Boston College Department of Economics. http://ideas.repec.org/c/boc/bocode/s457234.html Accessed 5/9/2013, 2011.
19. Drewnowski A, Darmon N, Briend A. Replacing fats and sweets with vegetables and fruits--a question of cost. *Am J Public Health* 2004;94(9):1555-9.
20. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *Bmj* 1997;315(7109):629-34.
21. USDA Economic Research Service. Food Dollar Series., July 5, 2012.
22. Mozaffarian D, Appel LJ, Van Horn L. Components of a cardioprotective diet: new insights. *Circulation* 2011;123(24):2870-91.

23. Estruch R, Ros E, Salas-Salvado J, Covas MI, Corella D, Aros F, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. *The New England journal of medicine* 2013;368(14):1279-90.
24. Andreyeva T, Long MW, Brownell KD. The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. *American journal of public health* 2010;100(2):216-22.
25. Powell LM, Chriqui JF, Khan T, Wada R, Chaloupka FJ. Assessing the potential effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, demand and body weight outcomes. *Obesity reviews : an official journal of the International Association for the Study of Obesity* 2013;14(2):110-28.
26. Eyles H, Ni Mhurchu C, Nghiem N, Blakely T. Food pricing strategies, population diets, and non-communicable disease: a systematic review of simulation studies. *PLoS medicine* 2012;9(12):e1001353.
27. For a Healthier Country, Overhaul Farm Subsidies. *Scientific American*. May, 2012 ed.
28. Rickard BJ, Okrent AM, Alston JM. How Have Agricultural Policies Influenced Caloric Consumption in the United States? *Health economics* 2012.
29. Beghin JC, Jensen HH. Farm Policies and Added Sugars in US Diets: Center for Agricultural and Rural Development, Iowa State University.
30. Harvie A, Wise TA. Sweetening the Pot: Implicit Subsidies to Corn Sweeteners and the U.S. Obesity Epidemic: Global Development and Environment Institute, Tufts University.
31. Mozaffarian D, Afshin A, Benowitz NL, Bittner V, Daniels SR, Franch HA, et al. Population approaches to improve diet, physical activity, and smoking habits: a scientific statement from the American Heart Association. *Circulation* 2012;126(12):1514-63.
32. Volpe R, Okrent A. Assessing the Healthfulness of Consumers' Grocery Purchases: U.S. Department of Agriculture, Economic Research Service, November 2012.
33. American Diabetes A. Economic costs of diabetes in the U.S. In 2007. *Diabetes care* 2008;31(3):596-615.
34. Dall TM, Zhang Y, Chen YJ, Quick WW, Yang WG, Fogli J. The economic burden of diabetes. *Health affairs* 2010;29(2):297-303.
35. Collaborators USBoD. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. *JAMA : the journal of the American Medical Association* 2013;310(6):591-608.
36. National Health Expenditure Projections 2012-2022. The Office of the Actuary in the Centers for Medicare & Medicaid Services. <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Downloads/Proj2012.pdf> Accessed 10/15/2013.
37. Mozaffarian RS, Andry A, Lee RM, Wiecha JL, Gortmaker SL. Price and healthfulness of snacks in 32 YMCA after-school programs in 4 US metropolitan areas, 2006-2008. *Prev Chronic Dis* 2012;9:E38.
38. Aggarwal A, Monsivais P, Cook AJ, Drewnowski A. Does diet cost mediate the relation between socioeconomic position and diet quality? *Eur J Clin Nutr* 2011;65(9):1059-66.
39. Temple NJ, Steyn NP. Food Prices and Energy Density as Barriers to Healthy Food Patterns in Cape Town, South Africa. *Journal of Hunger & Environmental Nutrition* 2009;4:201-13.
40. Krukowski RA, West DS, Harvey-Berino J, Elaine Prewitt T. Neighborhood impact on healthy food availability and pricing in food stores. *J Community Health* 2010;35(3):315-20.
41. Cassady D, Jetter KM, Culp J. Is price a barrier to eating more fruits and vegetables for low-income families? *J Am Diet Assoc* 2007;107(11):1909-15.
42. Katz DL, Doughty K, Njike V, Treu JA, Reynolds J, Walker J, et al. A cost comparison of more and less nutritious food choices in US supermarkets. *Public Health Nutr* 2011;14(9):1693-9.

43. Liese AD, Weis KE, Pluto D, Smith E, Lawson A. Food store types, availability, and cost of foods in a rural environment. *J Am Diet Assoc* 2007;107(11):1916-23.
44. Lipsky LM. Are energy-dense foods really cheaper? Reexamining the relation between food price and energy density. *Am J Clin Nutr* 2009;90(5):1397-401.
45. Ricciuto L, Ip H, Tarasuk V. The relationship between price, amounts of saturated and trans fats, and nutrient content claims on margarines and oils. *Can J Diet Pract Res* 2005;66(4):252-5.
46. Ricciuto L, Lin K, Tarasuk V. A comparison of the fat composition and prices of margarines between 2002 and 2006, when new Canadian labelling regulations came into effect. *Public Health Nutr* 2009;12(8):1270-5.
47. Wang J, Williams M, Rush E, Crook N, Forouhi NG, Simmons D. Mapping the availability and accessibility of healthy food in rural and urban New Zealand--Te Wai o Rona: Diabetes Prevention Strategy. *Public Health Nutr* 2010;13(7):1049-55.
48. Wilson N, Mansoor O. Food pricing favours saturated fat consumption: supermarket data. *N Z Med J* 2005;118(1210):U1338.
49. Lopez CN, Martinez-Gonzalez MA, Sanchez-Villegas A, Alonso A, Pimenta AM, Bes-Rastrollo M. Costs of Mediterranean and western dietary patterns in a Spanish cohort and their relationship with prospective weight change. *J Epidemiol Community Health* 2009;63(11):920-7.
50. Monsivais P, Drewnowski A. Lower-energy-density diets are associated with higher monetary costs per kilocalorie and are consumed by women of higher socioeconomic status. *J Am Diet Assoc* 2009;109(5):814-22.
51. Monsivais P, Aggarwal A, Drewnowski A. Are socio-economic disparities in diet quality explained by diet cost? *J Epidemiol Community Health* 2010.
52. Murakami K, Miyake Y, Sasaki S, Tanaka K, Ohya Y, Hirota Y. Monetary Diet Cost is Associated with not only Favorable but also Unfavorable Aspects of Diet in Pregnant Japanese Women: The Osaka Maternal and Child Health Study. *Environ Health Insights* 2009;3:27-35.
53. Rauber F, Vitolo MR. Nutritional quality and food expenditure in preschool children. *J Pediatr (Rio J)* 2009;85(6):536-40.
54. Ryden P, Sydner YM, Hagfors L. Counting the cost of healthy eating: a Swedish comparison of Mediterranean-style and ordinary diets. *International Journal of Consumer Studies* 2008;32(2):138-46.
55. Schroder H, Marrugat J, Covas MI. High monetary costs of dietary patterns associated with lower body mass index: a population-based study. *Int J Obes (Lond)* 2006;30(10):1574-9.
56. Townsend MS, Aaron GJ, Monsivais P, Keim NL, Drewnowski A. Less-energy-dense diets of low-income women in California are associated with higher energy-adjusted diet costs. *Am J Clin Nutr* 2009;89(4):1220-6.
57. Waterlander WE, de Haas WE, van Amstel I, Schuit AJ, Twisk JW, Visser M, et al. Energy density, energy costs and income - how are they related? *Public Health Nutr* 2010;13(10):1599-608.

Table. Characteristics of food price studies included in meta-analysis.

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
Market studies				
Cassady D et al, 2007[35*]Cassady D et al, 2007[41*]	June 2003, Sept-Oct 2003, March-April 2004	35 foods from 25 stores in Sacramento and Los Angeles, California	Fruit and vegetable basket meeting 2005 Dietary Guidelines vs. 1995 Thrifty Food Plan fruit and vegetable basket[†‡]	Cross-sectional price survey conducted across 3 time periods in chain supermarkets, small independent grocery stores, and supermarkets selling bulk food items with no membership fee
Jetter KM and DL Cassady, 2006[2]Jetter KM and DL Cassady, 2006[7]	June 2003, Sept 2003, March-April 2004	133 foods from 25 stores in Sacramento and Los Angeles, California	Market basket with four times the amount of fiber and one-fifth the grams of total fat vs. 1995 Thrifty Food Plan market basket[§]	Cross-sectional price survey conducted across 3 time periods in chain supermarkets, small independent grocery stores, and supermarkets selling bulk food items with no membership fee
Katz DL et al, 2011[36]Katz DL et al, 2011[42]	NR	131 foods in 8 food categories from 6 stores in Jackson County, Missouri	Nutrition Detectives program criteria for healthfulness (meeting vs. not meeting)[¥‡]	Prices collected from chain grocery stores accessible to research assistant
Krukowski RA et al, 2010[37]Krukowski RA et al, 2010[40]	Feb-April 2008	20 foods from 42 stores in Arkansas and Vermont	10 high-fiber, low-fat, low-sugar foods vs. 10 low-fiber, high-fat, high-sugar foods[β]	Overweight individuals entering a behavioral weight loss research program self-reported their primary grocery store. Trained data collectors assessed food prices at these stores
Liese AD et al, 2007[38]Liese AD et al, 2007[43]	2004	8 foods from 75 stores in Orangeburg County, South Carolina	Lean ground beef vs. high-fat ground beef; skinless and boneless chicken breasts vs. chicken drumsticks; high-fiber bread vs. low-fiber bread; low-fat/non-fat milk vs. whole milk	All food stores in county identified from Licensed Food Service Facilities Database and in-person verification. Prices recorded and reported by store type (supermarket, grocery store, convenience store)
Lipsky LM et al, 2009[39]Lipsky LM et al, 2009[44]	2008	2 food groups from 1 store in mid-Atlantic region	Produce (fruits, vegetables) vs. snacks (cookies, chips)	Price collected from online supermarket
McDermott AJ et al, 2010[3]McDermott AJ et al, 2010[8]	NR	34 foods from 4 stores in Baltimore, Maryland	3 c milk/dairy, 5 oz lean meat, 1.5 c fruit, 2.5 c vegetables, and 6 oz grains per day vs. breakfast, lunch, and dinner from fast-food	Prices for healthier foods obtained from 3 large supermarket chains. Prices for less healthy foods obtained from a large, multinational fast-food chain.

Formatted Table

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
			restaurant	
~~Ricciuto L et al, 2005~~[40] Ricciuto L et al, 2005[45]	Nov 2002	229 foods from 9 stores in Toronto, Canada	Margarine with vs. without label "low in saturated fat" or "cholesterol free"	Prices obtained from 9 stores of 3 major chain supermarkets
~~Ricciuto L et al, 2009~~[41] Ricciuto L et al, 2009[46]	Nov 2002 and Nov-Dec 2006	229 foods from 9 stores in 2002 and 274 foods from 10 stores in 2006 in Toronto, Canada	Trans fat-free vs. non trans fat-free margarine£	Prices obtained from 10 stores of 3 major chain supermarkets
~~Temple NJ and NP Steyn, 2009~~[42] Temple NJ and NP Steyn, 2009[39]	May 2006	24 foods from 1 store in each of 3 communities in Cape Town, South Africa	Higher-fiber, lower-fat, and lower-sugar daily menu vs. typical daily menu¶	Food prices obtained from supermarkets; price reported by community
~~Wang J et al, 2010~~[43] Wang J et al, 2010[47]	June-Aug 2005	14 foods from 1230 stores in Waikato and Lakes Districts, New Zealand	Basket including bread, chicken, beef/pork, sugar-sweetened drinks, milk, snacks, spreads, and sugar meeting vs. not meeting New Zealand food-based dietary guidelines (i.e. less energy-dense; lower- fat, salt, and sugar; and higher-fiber)‡	Prices obtained from 1230 stores (including supermarkets, dairies, bakeries, service stations, restaurants and takeaways). Each food was not available in every store
~~Wilson N and O Mansoor, 2005~~[44] Wilson N and O Mansoor, 2005[48]	Jan 23, 2005	18 foods from 2 stores in Wellington, New Zealand	Basket of foods including butter, butter/vegetable oil blend, margarine type spread, cream cheese, hard cheese, grated cheese, cream, biscuits & crackers, and chocolate with mean saturated fat of 14.9 g/100 g vs. basket of same foods with mean saturated fat of 29.0 g/100 g ‡**	Within each of 9 food-types, items with highest and lowest levels of saturated fat identified and prices obtained from 2 large supermarkets
Dietary studies				
Aggarwal A et al, 2011[4538]	April-June 2004 and May-July 2006	1266 participants in Seattle Obesity Study; 3 stores	Dietary energy density, kJ/g and mean adequacy ratio (quintile 1 vs. quintile 5)††	Diet cost calculated based on prices of FFQ component foods. Food prices obtained from 3 supermarket chains via in-store visits and websites
~~Bernstein AM et al, 2010~~[1] Bernstein AM et al,	2001-2002	78191 participants in Nurses'	Alternative Healthy Eating Index score	Diet cost calculated by merging FFQ database with USDA Center for Nutrition Policy and Promotion price

Formatted Table

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
2010[6]		Health Study; 467 foods	(quintile 5 vs. quintile 1)‡‡	database
Drewnowski A et al, 2004[~~18~~19]	NR	837 participants in Val-de-Marne, France; 57 foods	Fats and sweets intake, fruit and vegetables intake, total fat intake, and sucrose intake (quintile 1 vs. quintile 5)	Diet cost calculated from food prices from French National Institute of Statistics
~~Lopez CN et al, 2009~~[~~46~~]Lopez CN et al, 2009[49]	Dec 1999-May 2005	11195 participants in Spain; 136 foods	Western dietary pattern score and Mediterranean dietary pattern score (quintile 1 vs. quintile 5)§§	Diet cost calculated from food prices from Ministry of Industry, Tourism and Commerce of Spain. When data not available from ministry, food prices obtained from national supermarket websites
Monsivais P and A Drewnowski, 2009[~~47~~50]	May-July 2006	164 participants; 384 foods from 3 stores in Seattle, Washington	Dietary energy density, kcal/g (tertile 1 vs. tertile 3)	Diet cost calculated based on prices of FFQ component foods. Prices obtained at supermarket chains. Price reported separately for men and women
~~Monsivais P et al, 2010~~[~~48~~]Monsivais P et al, 2010[51]	April-June 2004 and May-July 2006	1295 participants; 384 foods from 3 stores in Seattle, Washington	Nutrient density of diet (quintile 5 vs. quintile 1 of diet cost)¥¥ßß	Diet cost calculated based on prices of FFQ component foods. Food prices obtained from 3 supermarket chains via in-store visits and websites
~~Mozaffarian RS et al, 2012~~[~~49~~]Mozaffarian RS et al, 2012[37]	2003-2004	1294 snack-days in 32 YMCA after-school programs in 4 metropolitan areas	Environmental Standards for Healthy Eating (meeting vs. not meeting)££	Prices from USDA Center for Nutrition Policy and Promotion price database
~~Murakami K et al, 2009~~[~~50~~]Murakami K et al, 2009[52]	2004	596 pregnant women in Neyagawa City, Osaka Prefecture, Japan; 150 foods	Dietary energy density, kcal/g (quartile 4 vs. quartile 1 of diet cost)¥¥	Diet cost based on National Retail Price Survey. For foods not in survey, prices obtained from websites of nationally distributed supermarket or fast-food restaurant chains
~~Rauber F and MR Vitolo, 2009~~[~~51~~]Rauber F and MR Vitolo, 2009[53]	NR	346 children aged 3-4 y; 3 brands each of 104 foods from 2 stores in São Leopoldo, Brazil	Calories from sugar-rich foods (<= 150 kcal vs. > 150 kcal) and calories from fat-rich foods (<= 150 kcal vs. > 150 kcal)	Diet cost based on prices obtained at a large establishment (supermarket or hypermarket) and a small establishment (market, minimart or bakery)
~~Rehm CD et al, 2011~~[~~4~~]Rehm CD et al, 2011[9]	2001-2002	4744 participants in NHANES	Healthy Eating Index-2005 score (quintile 5 vs. quintile 1 of diet cost)¥¥¶¶	Diet cost calculated from USDA Center for Nutrition Policy and Promotion price database

Formatted Table

Author, year	Time of price data collection	Participants or foods, setting	Assessment of healthfulness	Price assessment
~~Rydén PJ et al, 2008~~[52]Rydén PJ et al, 2008[54]	Autumn 2005	30 participants in Kalmar province, Sweden; 600 foods	Mediterranean diet vs. typical diet***	Diet cost calculated from prices from Statistics Sweden. For foods not reported by Statistics Sweden, prices obtained from 4 stores and 2 online stores
~~Rydén PJ and L Hagfors, 2011~~[5]Rydén PJ and L Hagfors, 2011[10]	Spring 2010	2160 children ages 4, 8, and 11 y in Sweden; prices of 991 foods from Statistics Sweden, and stores when not available from Statistics Sweden	Healthy Eating Index-2005 score (> 70 vs. < 50)¶¶	Average national prices of 391 foods obtained from Statistics Sweden. Prices of remaining 600 foods were not available from Statistics Sweden; obtained from one online supermarket and one online grocery store
Schröder H et al, 2006[~~53~~55]	May 2005	2847 participants in Girona, Spain; 165 foods	Mediterranean Diet Score and Healthy Eating Index score (quartile 4 vs. quartile 1)¶¶	Diet cost calculated from average national price database of the Secretaria de Estado de Turismo y Comercio de Espana
Townsend MS et al, 2009[~~54~~56]	2006	112 participants; 8 stores in San Joaquin, Solano, Calavaras, and Tulare counties in California	Dietary energy density, kcal/g (tertile 1 vs. tertile 3)	Diet cost (with and without beverages) calculated based on prices of FFQ component foods. Prices obtained from a large supermarket chain store and a small independent market in each county
Waterlander WE et al, 2010[~~55~~57]	Feb-April 2008	373 participants in Longitudinal Ageing Study Amsterdam and 200 participants in Amsterdam Growth and Health Longitudinal Study; 2 stores	Dietary energy density, kJ/g (quartile 1 vs. quartile 4)	Diet cost calculated from prices obtained from 2 market leader supermarkets. Price reported separately for men and women

Formatted Table

* This study is not included in analysis since it is the only market survey on fruits and vegetables.
† Baskets include varying amounts of fruits, dark green vegetables, orange vegetables, legumes, starchy vegetables, and "other" vegetables.
‡ Components of baskets also compared.
§ Baskets include healthier vs. less healthy breads, canned fruit, cheese, chicken, cereal; cooking oil, egg noodles, evaporated milk, flour, potatoes; frozen fish; ground meat, milk, rice, salad dressing, spaghetti, margarine, and tuna fish. Baskets also include fresh fruits and vegetables, eggs, and beans which are unchanged between two baskets.
¥ Nutrition Detectives criteria: subjectively determined to not have excessive marketing-related claims or images on the front of the package; not have an unhealthy ingredient such as sugar or white flour listed first on ingredient list, does not contain partially hydrogenated oil or high-fructose corn syrup, and does not have a long ingredient list relative to other items in the same food category. For grain-based products only, more nutritious foods also contain at least 2 g fiber per serving.
β Baskets include healthy vs. less healthy juice, hot dogs, ground beef, chips, bread, soda, milk, frozen dinner, baked goods, and cereals.
£ Trans fat-free defined as containing 1) <= 0.2 g TFA per 10 g; 2) <= 2 g TFA and SFA combined per 10 g; and 3) <= 15% energy from TFA and SFA combined per 10 g.

¶ Typical menu includes corn flakes, whole milk, sugar, and cola drink in the morning; white bread, brick margarine, jam, and cookies for lunch; and regular hamburger, white rice, fried cabbage, and candied butternut for dinner. Healthier menu includes bran flakes, skim milk, banana, and orange juice in the morning, whole wheat bread, tub margarine, low-fat cottage cheese, and apple for lunch; and lean hamburger, brown rice, boiled cabbage, and boiled butternut for dinner.

**Average price at the 2 stores calculated and used in meta-analysis.

††Model 3 coefficients in Tables 4a and 4b used to calculate difference in price between quintiles 1 and 5. Mean adequacy ratio is a truncated index of the percent of daily recommended intakes for key nutrients. Computed by taking the average of nutrient adequacy ratio for 11 key nutrients: vitamins A, C, D, E, B12, calcium, iron, magnesium, potassium, folate and fiber. Expressed as percent of adequacy/day.

‡‡ The Alternative Healthy Eating Index reflects intake of fruit, vegetables, nuts, soy, beans, white and red meats, cereal fiber, trans unsaturated fatty acids, polyunsaturated fatty acids, saturated fatty acids, alcohol, and years of multivitamin use.

§§ Food items identified in Western pattern were red meat, processed meats, eggs, sauces, precooked food, fast-food, caloric soft drinks, whole-fat dairy and potatoes. Food items identified in the Mediterranean pattern included olive oil, poultry, fish, low-fat dairy, legumes, fruits, and vegetables.

¥¥ Healthfulness of diet stratified by quantile of diet cost.

ββ Nutrient density is defined as mean percentage daily value for vitamin A, vitamin C, vitamin E, calcium, magnesium, potassium, and dietary fiber in 2000 kcal of dietary energy.

££ Environmental Standards for Healthy Eating guidelines: do not serve sugar-sweetened beverages, serve water every day, serve a fruit and/or vegetable every day, do not serve foods with trans fat, and when serving grains (such as bread, crackers, and cereals), serve whole grains.

¶¶ Healthy Eating Index is a measure of overall diet quality based on consumption of sodium, saturated fat, total fruit, whole fruit, total vegetables, dark green and orange vegetables, milk, total grains, whole grains, meat and beans, oils, and empty calories.

*** Mediterranean diet included eating more fruit, vegetables and pulses; choosing whole-grain products; changing dietary fat intake to products containing less saturated fat and more unsaturated fat; avoiding meat and meat products; and limiting the intake of sweets, snacks and desserts.

††† Mediterranean diet based on intake of cereals, fruits, vegetables, legumes, fish, olive oil, nuts, and red wine.

("Diet/economics"[Mesh] OR "Food/economics"[Mesh] OR "Health food/economics"[Mesh]) AND (healthy[tw] OR unhealthy[tw] OR nutritious[tw] OR market basket [tw] OR thrifty food plan [tw] OR food stamps [tw] OR dietary guidelines [tw] OR price [tw] OR cost [tw] OR affordable [tw] OR fast food [tw] OR restaurant [tw] OR supermarket [tw] OR grocery [tw] OR store [tw]) AND ("2000"[Date - Publication] : "3000"[Date - Publication]) AND English[Language].

Supporting Appendix 1. PubMed search query used to identify studies comparing prices of healthier and less healthy foods/diet patterns.

Reporting of background should include
- Problem definition
- Hypothesis statement
- Description of study outcome(s)
- Type of exposure or intervention used
- Type of study designs used
- Study population

Reporting of search strategy should include
- Qualifications of searchers (eg, librarians and investigators)
- Search strategy, including time period included in the synthesis and keywords
- Effort to include all available studies, including contact with authors
- Databases and registries searched
- Search software used, name and version, including special features used (eg, explosion)
- Use of hand searching (eg, reference lists of obtained articles)
- List of citations located and those excluded, including justification
- Method of addressing articles published in languages other than English
- Method of handling abstracts and unpublished studies
- Description of any contact with authors

Reporting of methods should include
- Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested
- Rationale for the selection and coding of data (eg, sound clinical principles or convenience)
- Documentation of how data were classified and coded (eg, multiple raters, blinding, and interrater reliability)
- Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)
- Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results
- Assessment of heterogeneity
- Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated
- Provision of appropriate tables and graphics

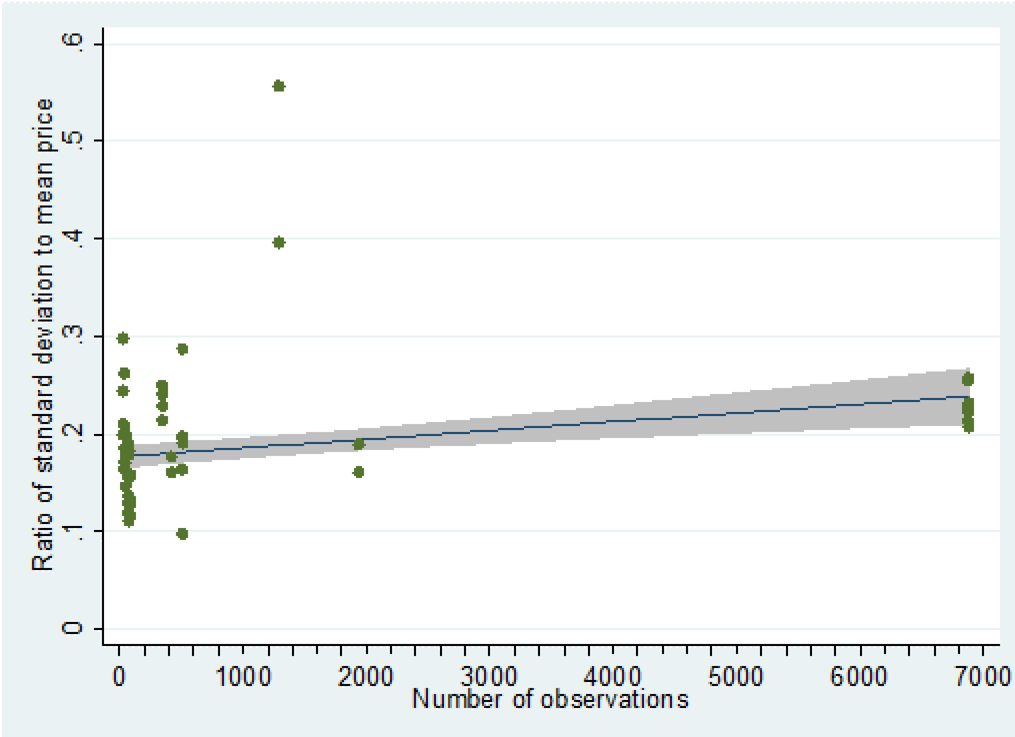
Reporting of results should include
- Graphic summarizing individual study estimates and overall estimate
- Table giving descriptive information for each study included
- Results of sensitivity testing (eg, subgroup analysis)
- Indication of statistical uncertainty of findings

Reporting of discussion should include
- Quantitative assessment of bias (eg, publication bias)
- Justification for exclusion (eg, exclusion of non-English-language citations)
- Assessment of quality of included studies

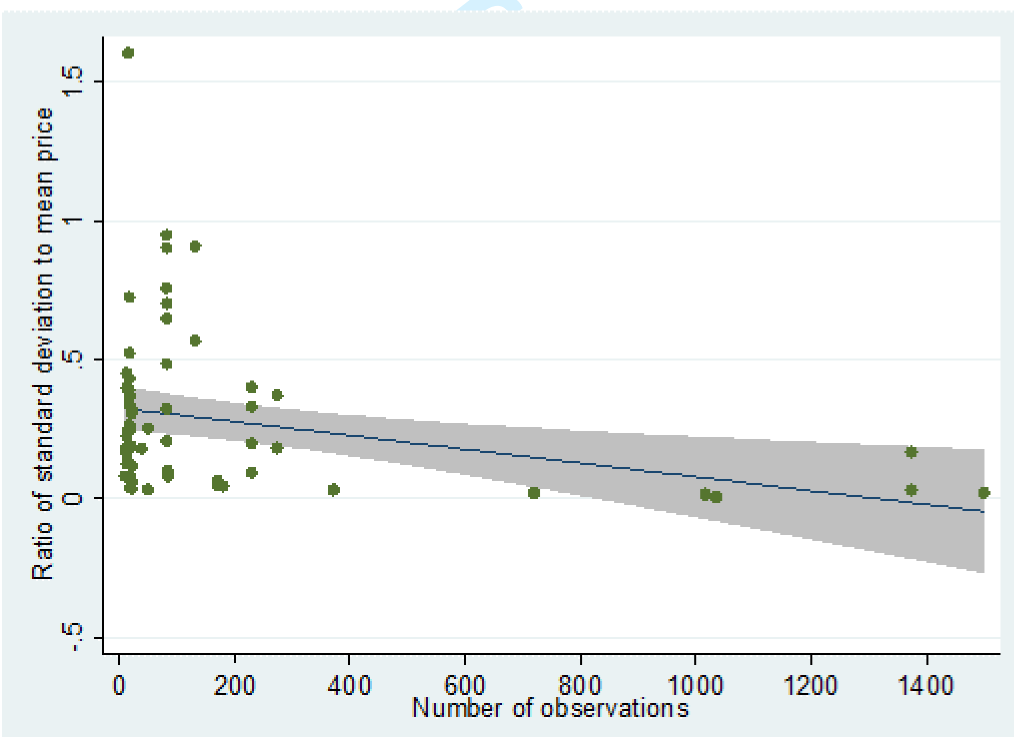
Reporting of conclusions should include
- Consideration of alternative explanations for observed results
- Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)
- Guidelines for future research
- Disclosure of funding source

Supporting Appendix 2. **Meta-analysis Of Observational Studies in Epidemiology checklist.** We followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines throughout all stages of design, implementation, and reporting.[12]

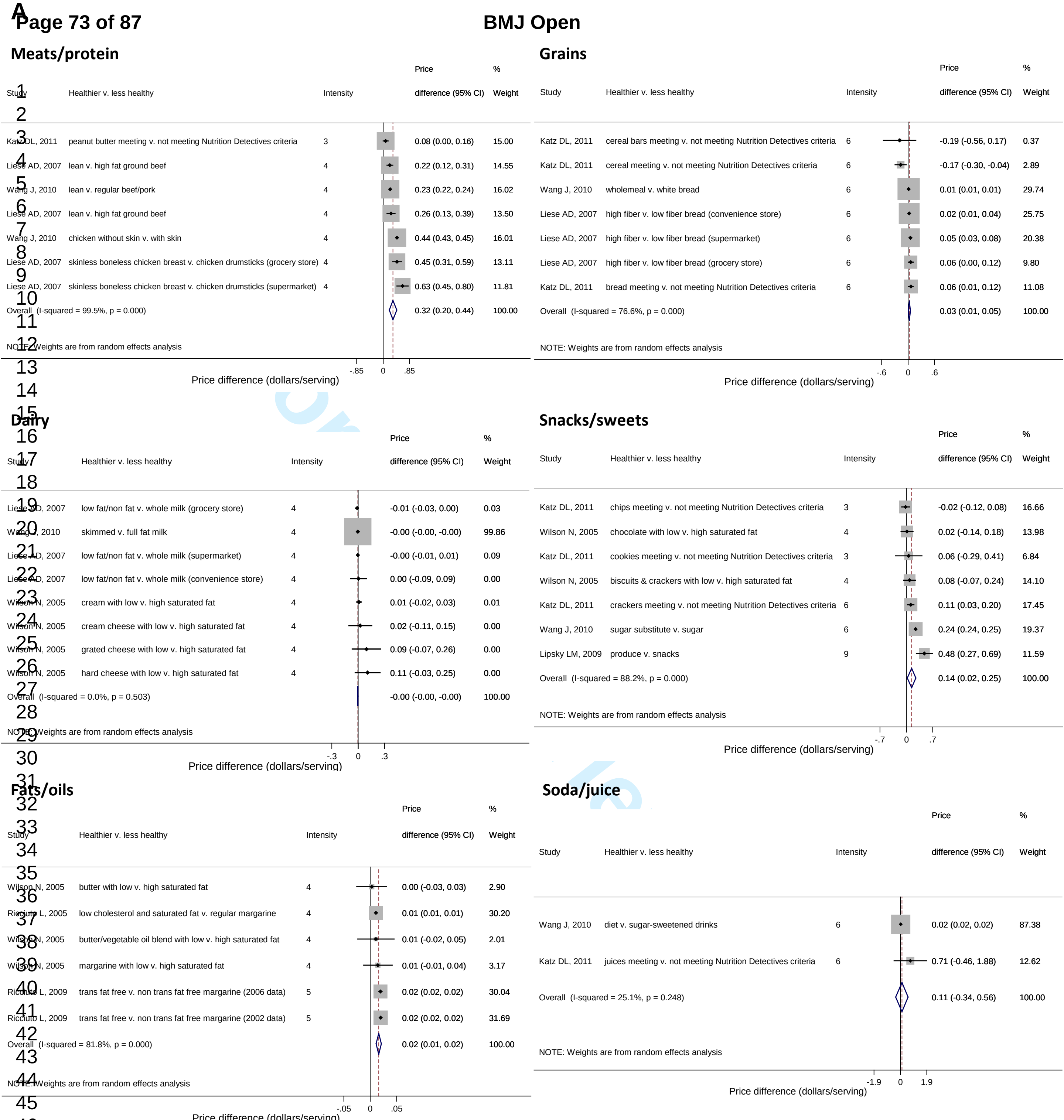
Dietary surveys



Market surveys

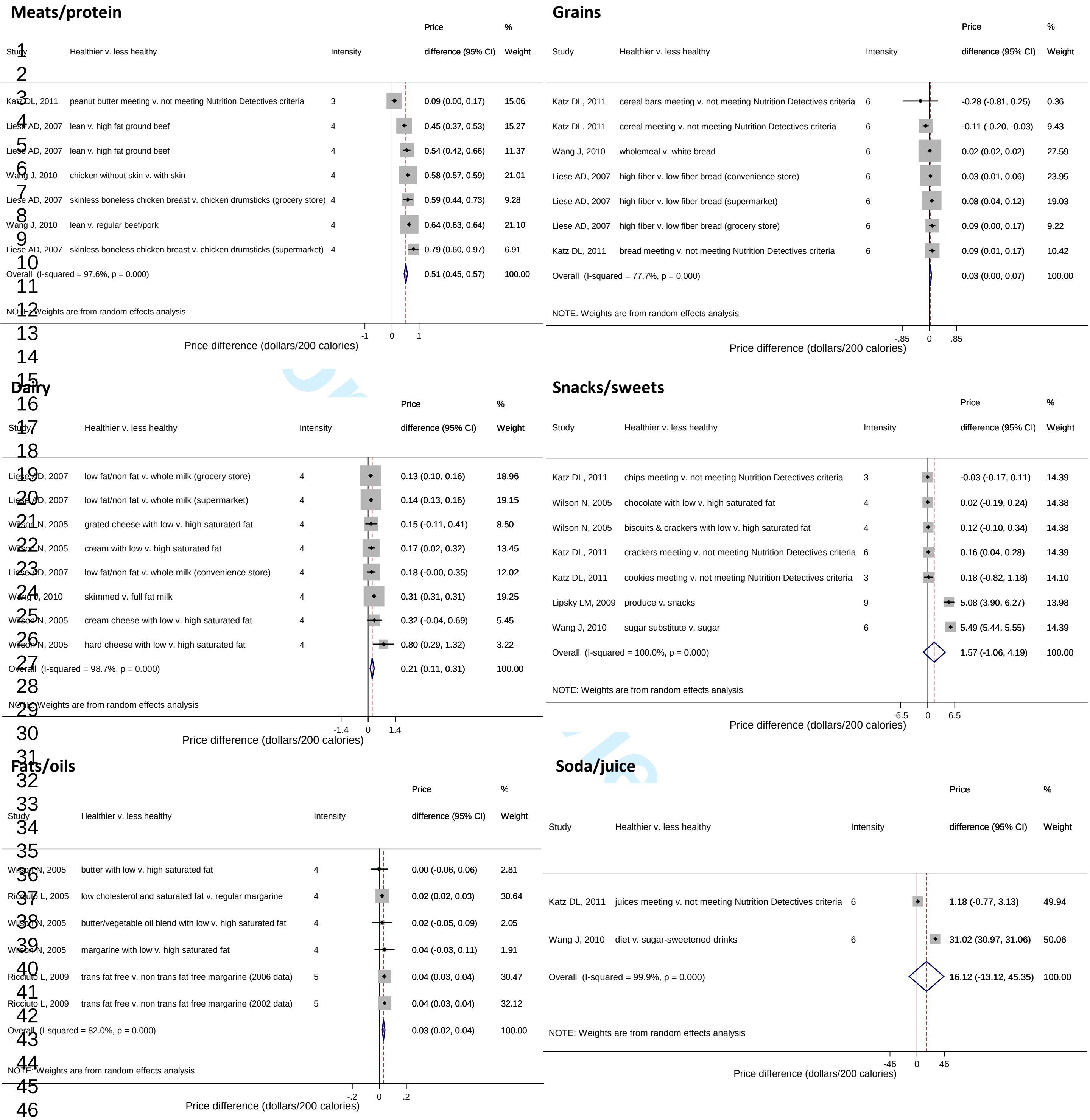


Supporting Figure 1. Linear regression of ratios of SD to mean price vs. number of observations for studies with complete data. Regression results were used to impute the SE of the price difference from the number of observations in each category for nine studies (3 dietary surveys and 6 market surveys) in which the mean price was reported without its uncertainty. Imputations were performed separately for dietary surveys and market surveys. Regression coefficients were 8.99 x 10^{-6} (95%CI 4.43 x 10^{-6}, 1.35 x 10^{-5}) for dietary surveys and -2.486 x 10^{-4} (-4.14 x 10^{-4}, -8.33 x 10^{-5}) for market surveys.

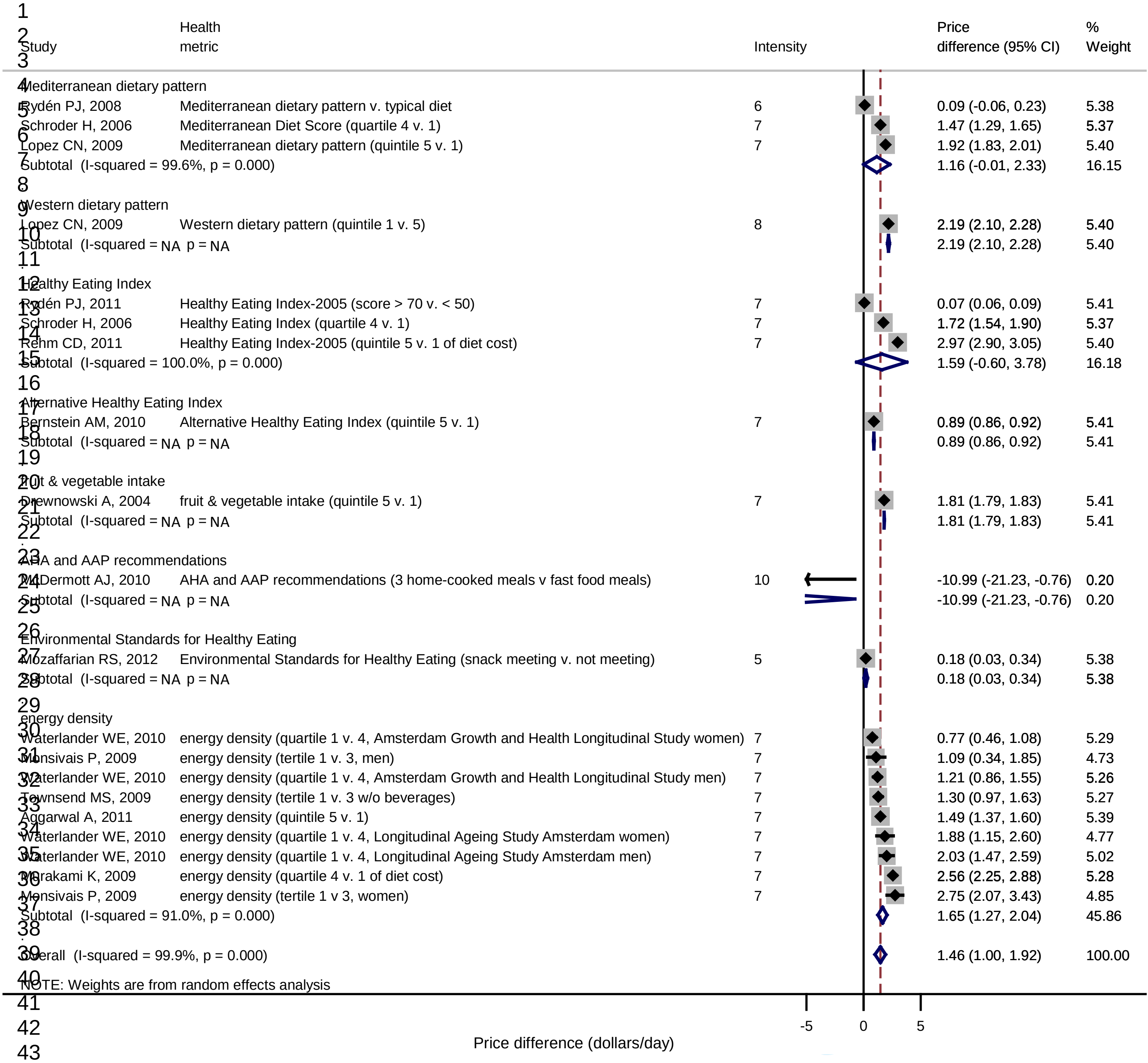


Supporting Figure 2. Price difference between healthier and less healthy foods per serving (A) and per 200 kcal (B), standardized to mean intensity. Price difference defined as the healthier category minus the less healthy category. Each comparison was assigned an intensity between 1 and 10, with 1 signifying that the healthfulness of the two foods was almost the same and 10 signifying that the healthfulness of the foods was extremely different. Each price difference was multiplied by the ratio of the intensity of the study comparison to the mean intensity of the food group. Standardized serving sizes were derived from 2011 USDA MyPlate guidelines or, if not available from MyPlate, nutrition labels from a major grocery website. Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

B


Meats/protein
Study | Healthier v. less healthy | Intensity | Price difference (95% CI) | % Weight
Katz DL, 2011 | peanut butter meeting v. not meeting Nutrition Detectives criteria | 3 | 0.09 (0.00, 0.17) | 15.06
Liese AD, 2007 | lean v. high fat ground beef | 4 | 0.45 (0.37, 0.53) | 15.27
Liese AD, 2007 | lean v. high fat ground beef | 4 | 0.54 (0.42, 0.66) | 11.37
Wang J, 2010 | chicken without skin v. with skin | 4 | 0.58 (0.57, 0.59) | 21.01
Liese AD, 2007 | skinless boneless chicken breast v. chicken drumsticks (grocery store) | 4 | 0.59 (0.44, 0.73) | 9.28
Wang J, 2010 | lean v. regular beef/pork | 4 | 0.64 (0.63, 0.64) | 21.10
Liese AD, 2007 | skinless boneless chicken breast v. chicken drumsticks (supermarket) | 4 | 0.79 (0.60, 0.97) | 6.91
Overall (I-squared = 97.6%, p = 0.000) | 0.51 (0.45, 0.57) | 100.00
NOTE: Weights are from random effects analysis
-1 0 1
Price difference (dollars/200 calories)
Grains
Study | Healthier v. less healthy | Intensity | Price difference (95% CI) | % Weight
Katz DL, 2011 | cereal bars meeting v. not meeting Nutrition Detectives criteria | 6 | -0.28 (-0.81, 0.25) | 0.36
Katz DL, 2011 | cereal meeting v. not meeting Nutrition Detectives criteria | 6 | -0.11 (-0.20, -0.03) | 9.43
Wang J, 2010 | wholemeal v. white bread | 6 | 0.02 (0.02, 0.02) | 27.59
Liese AD, 2007 | high fiber v. low fiber bread (convenience store) | 6 | 0.03 (0.01, 0.06) | 23.95
Liese AD, 2007 | high fiber v. low fiber bread (supermarket) | 6 | 0.08 (0.04, 0.12) | 19.03
Liese AD, 2007 | high fiber v. low fiber bread (grocery store) | 6 | 0.09 (0.00, 0.17) | 9.22
Katz DL, 2011 | bread meeting v. not meeting Nutrition Detectives criteria | 6 | 0.09 (0.01, 0.17) | 10.42
Overall (I-squared = 77.7%, p = 0.000) | 0.03 (0.00, 0.07) | 100.00
NOTE: Weights are from random effects analysis
-.85 0 .85
Price difference (dollars/200 calories)
Dairy
Study | Healthier v. less healthy | Intensity | Price difference (95% CI) | % Weight
Liese AD, 2007 | low fat/non fat v. whole milk (grocery store) | 4 | 0.13 (0.10, 0.16) | 18.96
Liese AD, 2007 | low fat/non fat v. whole milk (supermarket) | 4 | 0.14 (0.13, 0.16) | 19.15
Wilson N, 2005 | grated cheese with low v. high saturated fat | 4 | 0.15 (-0.11, 0.41) | 8.50
Wilson N, 2005 | cream with low v. high saturated fat | 4 | 0.17 (0.02, 0.32) | 13.45
Liese AD, 2007 | low fat/non fat v. whole milk (convenience store) | 4 | 0.18 (-0.00, 0.35) | 12.02
Wang J, 2010 | skimmed v. full fat milk | 4 | 0.31 (0.31, 0.31) | 19.25
Wilson N, 2005 | cream cheese with low v. high saturated fat | 4 | 0.32 (-0.04, 0.69) | 5.45
Wilson N, 2005 | hard cheese with low v. high saturated fat | 4 | 0.80 (0.29, 1.32) | 3.22
Overall (I-squared = 98.7%, p = 0.000) | 0.21 (0.11, 0.31) | 100.00
NOTE: Weights are from random effects analysis
-1.4 0 1.4
Price difference (dollars/200 calories)
Snacks/sweets
Study | Healthier v. less healthy | Intensity | Price difference (95% CI) | % Weight
Katz DL, 2011 | chips meeting v. not meeting Nutrition Detectives criteria | 3 | -0.03 (-0.17, 0.11) | 14.39
Wilson N, 2005 | chocolate with low v. high saturated fat | 4 | 0.02 (-0.19, 0.24) | 14.38
Wilson N, 2005 | biscuits & crackers with low v. high saturated fat | 4 | 0.12 (-0.10, 0.34) | 14.38
Katz DL, 2011 | crackers meeting v. not meeting Nutrition Detectives criteria | 6 | 0.16 (0.04, 0.28) | 14.39
Katz DL, 2011 | cookies meeting v. not meeting Nutrition Detectives criteria | 3 | 0.18 (-0.82, 1.18) | 14.10
Lipsky LM, 2009 | produce v. snacks | 9 | 5.08 (3.90, 6.27) | 13.98
Wang J, 2010 | sugar substitute v. sugar | 6 | 5.49 (5.44, 5.55) | 14.39
Overall (I-squared = 100.0%, p = 0.000) | 1.57 (-1.06, 4.19) | 100.00
NOTE: Weights are from random effects analysis
-6.5 0 6.5
Price difference (dollars/200 calories)
Fats/oils
Study | Healthier v. less healthy | Intensity | Price difference (95% CI) | % Weight
Wilson N, 2005 | butter with low v. high saturated fat | 4 | 0.00 (-0.06, 0.06) | 2.81
Ricciuto L, 2005 | low cholesterol and saturated fat v. regular margarine | 4 | 0.02 (0.02, 0.03) | 30.64
Wilson N, 2005 | butter/vegetable oil blend with low v. high saturated fat | 4 | 0.02 (-0.05, 0.09) | 2.05
Wilson N, 2005 | margarine with low v. high saturated fat | 4 | 0.04 (-0.03, 0.11) | 1.91
Ricciuto L, 2009 | trans fat free v. non trans fat free margarine (2006 data) | 5 | 0.04 (0.03, 0.04) | 30.47
Ricciuto L, 2009 | trans fat free v. non trans fat free margarine (2002 data) | 5 | 0.04 (0.03, 0.04) | 32.12
Overall (I-squared = 82.0%, p = 0.000) | 0.03 (0.02, 0.04) | 100.00
NOTE: Weights are from random effects analysis
-.2 0 .2
Price difference (dollars/200 calories)
Soda/juice
Study | Healthier v. less healthy | Intensity | Price difference (95% CI) | % Weight
Katz DL, 2011 | juices meeting v. not meeting Nutrition Detectives criteria | 6 | 1.18 (-0.77, 3.13) | 49.94
Wang J, 2010 | diet v. sugar-sweetened drinks | 6 | 31.02 (30.97, 31.06) | 50.06
Overall (I-squared = 99.9%, p = 0.000) | 16.12 (-13.12, 45.35) | 100.00
NOTE: Weights are from random effects analysis
-46 0 46
Price difference (dollars/200 calories)

A

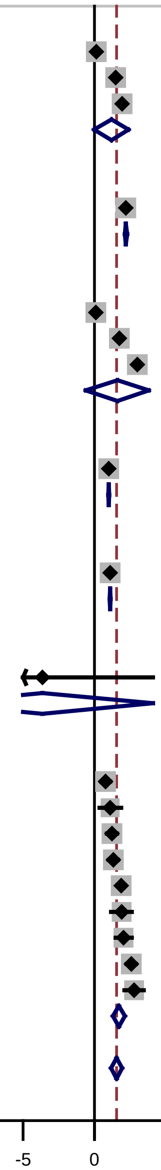


Supporting Figure 3. Price difference between healthier and less healthy food-based diet patterns per day (A) and per 2000 kcal (B), standardized to mean intensity. Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Mozaffarian RS, 2012.[37] Energy density was included as a food-based pattern since this metric represents a set of foods more than it represents any single nutrient.[19] Each comparison was assigned an intensity between 1 and 10, with 1 signifying that the healthfulness of the two diet patterns was almost the same and 10 signifying that the healthfulness of the two diet patterns was extremely different. Each price difference was multiplied by the ratio of the intensity of the study comparison to the mean intensity across all studies. For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

B

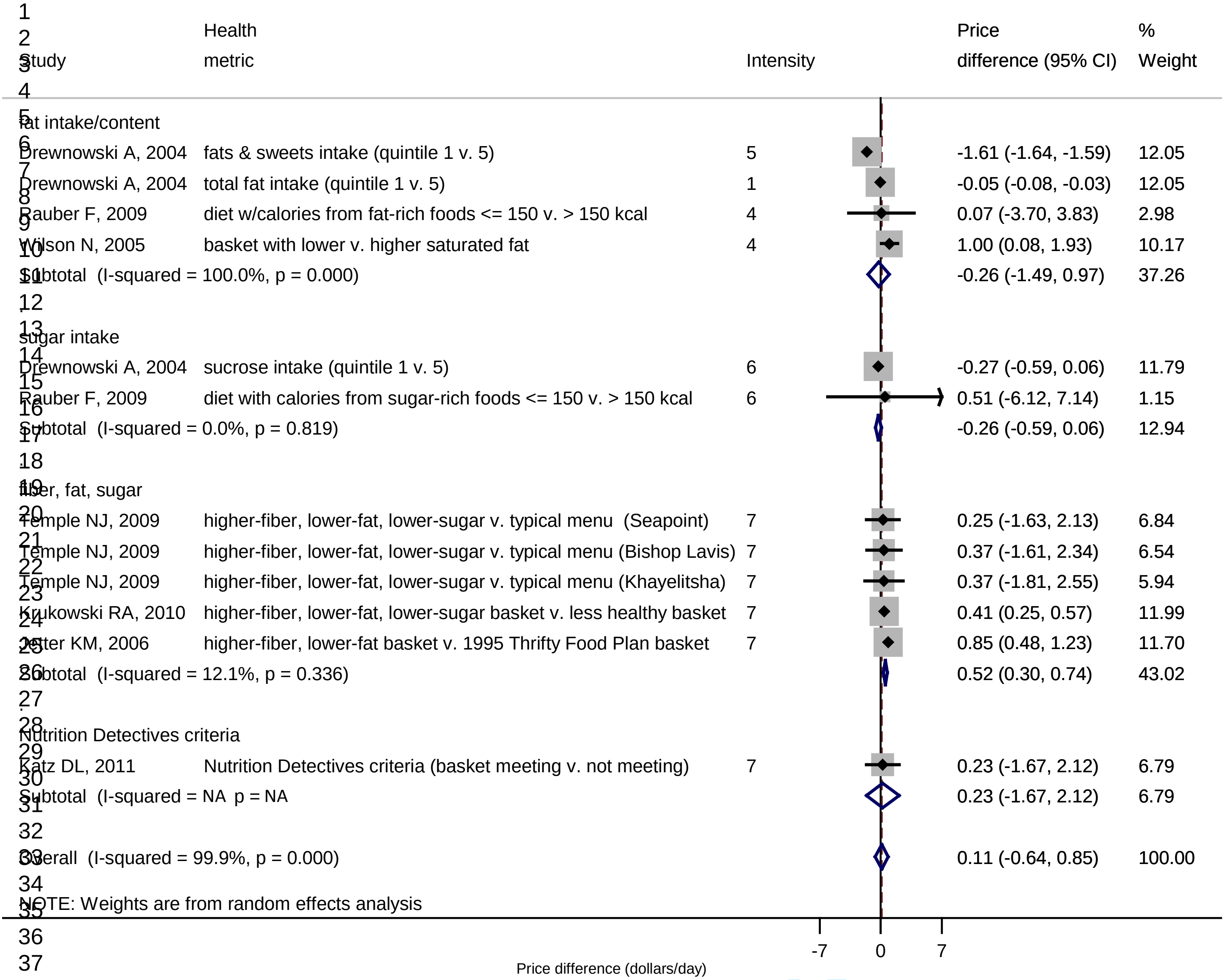
Study	Health metric	Intensity	Price difference (95% CI)	% Weight
Mediterranean dietary pattern				
Rydén PJ, 2008	Mediterranean dietary pattern v. typical diet	6	0.13 (0.01, 0.25)	5.76
Schroder H, 2006	Mediterranean Diet Score (quartile 4 v. 1)	7	1.47 (1.29, 1.65)	5.72
Lopez CN, 2009	Mediterranean dietary pattern (quintile 5 v. 1)	7	1.92 (1.83, 2.01)	5.78
Subtotal (I-squared = 99.6%, p = 0.000)			1.17 (-0.03, 2.37)	17.27
.				
Western dietary pattern				
Lopez CN, 2009	Western dietary pattern (quintile 1 v. 5)	8	2.19 (2.10, 2.28)	5.78
Subtotal (I-squared = NA p = NA			2.19 (2.10, 2.28)	5.78
.				
Healthy Eating Index				
Rydén PJ, 2011	Healthy Eating Index-2005 (score > 70 v. < 50)	7	0.07 (0.06, 0.09)	5.79
Schroder H, 2006	Healthy Eating Index (quartile 4 v. 1)	7	1.72 (1.54, 1.90)	5.72
Rehm CD, 2011	Healthy Eating Index-2005 (quintile 5 v. 1 of diet cost)	7	2.97 (2.90, 3.05)	5.78
Subtotal (I-squared = 100.0%, p = 0.000)			1.59 (-0.60, 3.78)	17.30
.				
Alternative Healthy Eating Index				
Bernstein AM, 2010	Alternative Healthy Eating Index (quintile 5 v. 1)	7	0.99 (0.96, 1.02)	5.79
Subtotal (I-squared = NA p = NA			0.99 (0.96, 1.02)	5.79
.				
fruit & vegetable intake				
Drewnowski A, 2004	fruit & vegetable intake (quintile 5 v. 1)	7	1.08 (1.05, 1.10)	5.79
Subtotal (I-squared = NA p = NA			1.08 (1.05, 1.10)	5.79
.				
AHA and AAP recommendations				
McDermott AJ, 2010	AHA and AAP recommendations (3 home-cooked meals v fast food meals)	10	-3.64 (-11.36, 4.07)	0.25
Subtotal (I-squared = NA p = NA			-3.64 (-11.36, 4.07)	0.25
.				
energy density				
Waterlander WE, 2010	energy density (quartile 1 v. 4, Amsterdam Growth and Health Longitudinal Study women)	7	0.77 (0.46, 1.08)	5.60
Monsivais P, 2009	energy density (tertile 1 v. 3, men)	7	1.09 (0.34, 1.85)	4.78
Waterlander WE, 2010	energy density (quartile 1 v. 4, Amsterdam Growth and Health Longitudinal Study men)	7	1.21 (0.86, 1.55)	5.55
Townsend MS, 2009	energy density (tertile 1 v. 3 w/o beverages)	7	1.30 (0.97, 1.63)	5.57
Aggarwal A, 2011	energy density (quintile 5 v. 1)	7	1.86 (1.71, 2.01)	5.75
Waterlander WE, 2010	energy density (quartile 1 v. 4, Longitudinal Ageing Study Amsterdam women)	7	1.88 (1.15, 2.60)	4.84
Waterlander WE, 2010	energy density (quartile 1 v. 4, Longitudinal Ageing Study Amsterdam men)	7	2.03 (1.47, 2.59)	5.19
Murakami K, 2009	energy density (quartile 4 v. 1 of diet cost)	7	2.56 (2.25, 2.88)	5.59
Monsivais P, 2009	energy density (tertile 1 v 3, women)	7	2.75 (2.07, 3.43)	4.95
Subtotal (I-squared = 91.6%, p = 0.000)			1.70 (1.29, 2.12)	47.82
.				
Overall (I-squared = 99.9%, p = 0.000)			1.53 (1.14, 1.93)	100.00

NOTE: Weights are from random effects analysis



Price difference (dollars/2000 calories)

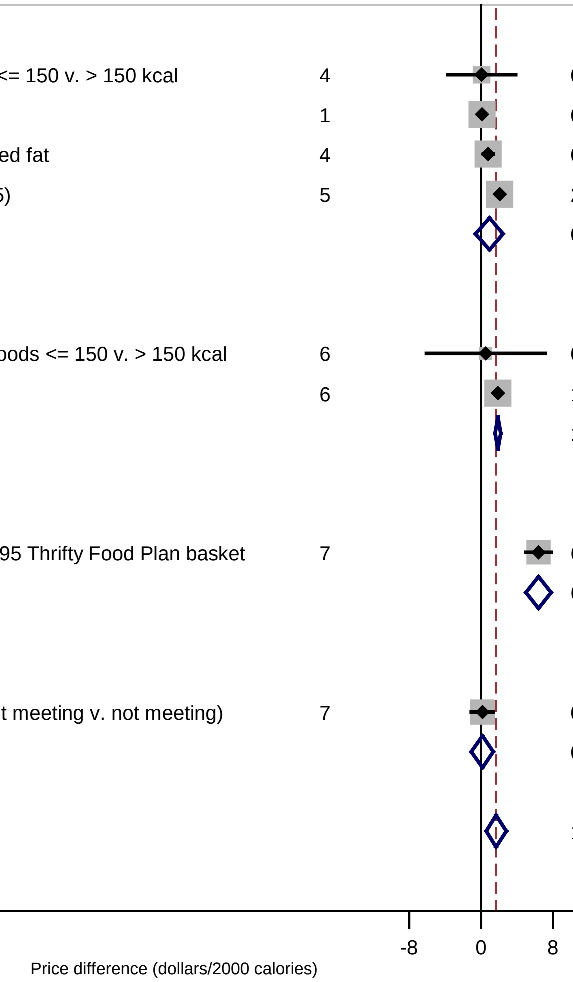
A

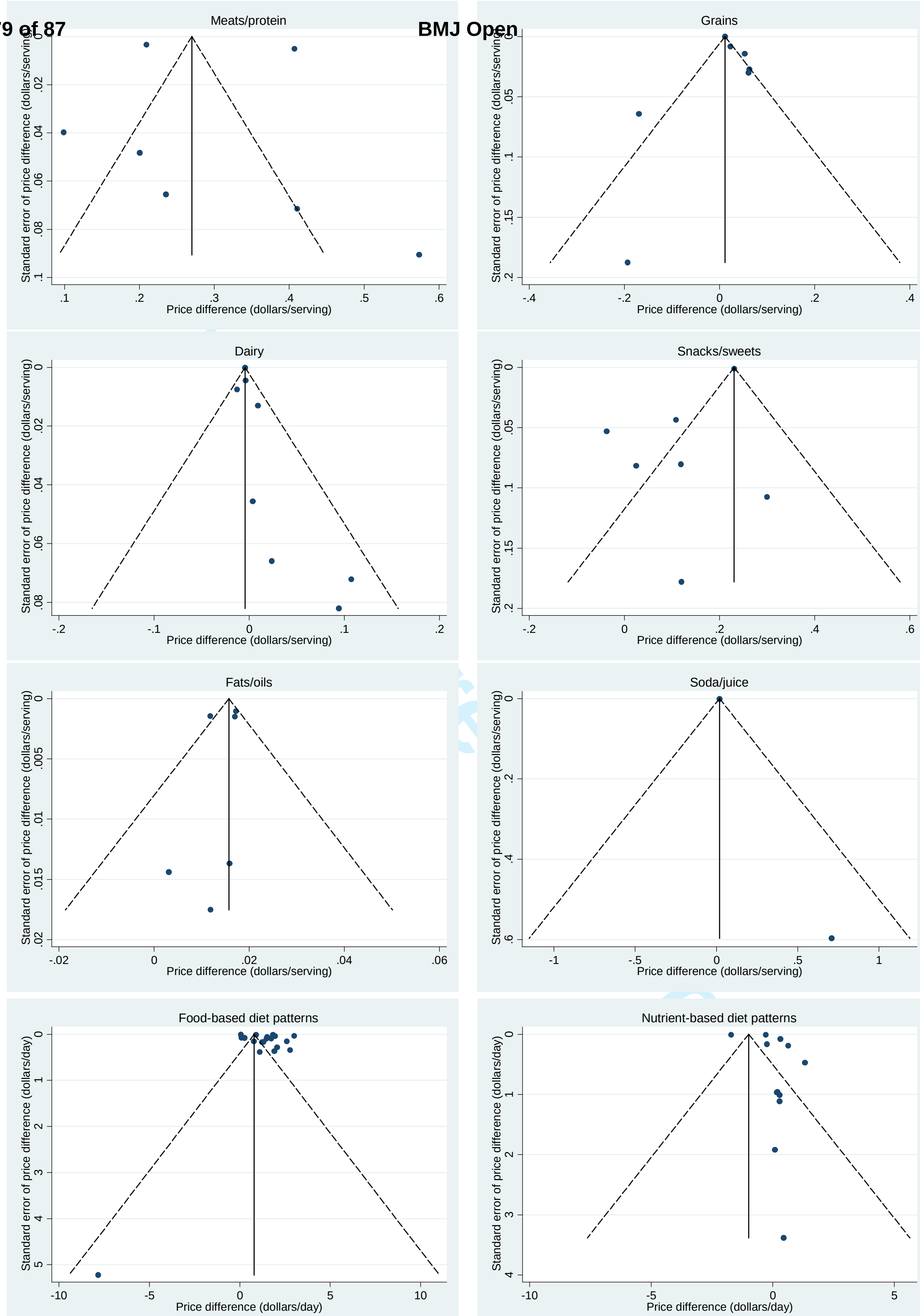


Supporting Figure 4. Price difference between healthier and less healthy nutrient-based diet patterns per day (A) and per 2000 kcal (B), standardized to mean intensity. One outlying, implausible estimate from Aggarwal A, 2011 (mean adequacy ratio) was excluded ($17.23; 95% CI: $14.35, $20.11).[38] Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Temple NJ, 2009 and Krukowski RA, 2010.[39,40] Each comparison was assigned an intensity between 1 and 10, with 1 signifying that the healthfulness of the two diet patterns was almost the same and 10 signifying that the healthfulness of the two diet patterns was extremely different. Each price difference was multiplied by the ratio of the intensity of the study comparison to the mean intensity across all studies. For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

Study	Health metric	Intensity	Price difference (95% CI)	% Weight
fat intake/content				
Rauber F, 2009	diet w/calories from fat-rich foods <= 150 v. > 150 kcal	4	0.07 (-3.70, 3.83)	5.74
Drewnowski A, 2004	total fat intake (quintile 1 v. 5)	1	0.11 (0.08, 0.13)	16.46
Wilson N, 2005	basket with lower v. higher saturated fat	4	0.80 (0.26, 1.34)	15.85
Drewnowski A, 2004	fats & sweets intake (quintile 1 v. 5)	5	2.10 (2.08, 2.12)	16.46
Subtotal (I-squared = 100.0%, p = 0.000)			0.91 (-0.61, 2.42)	54.51
.				
sugar intake				
Rauber F, 2009	diet with calories from sugar-rich foods <= 150 v. > 150 kcal	6	0.51 (-6.12, 7.14)	2.42
Drewnowski A, 2004	sucrose intake (quintile 1 v. 5)	6	1.86 (1.55, 2.17)	16.26
Subtotal (I-squared = 0.0%, p = 0.690)			1.86 (1.55, 2.16)	18.68
.				
fiber, fat, sugar				
Jetter KM, 2006	higher-fiber, lower-fat basket v. 1995 Thrifty Food Plan basket	7	6.41 (5.00, 7.82)	13.04
Subtotal (I-squared = NA p = NA			6.41 (5.00, 7.82)	13.04
.				
Nutrition Detectives criteria				
Katz DL, 2011	Nutrition Detectives criteria (basket meeting v. not meeting)	7	0.14 (-1.07, 1.36)	13.76
Subtotal (I-squared = NA p = NA			0.14 (-1.07, 1.36)	13.76
.				
Overall (I-squared = 99.9%, p = 0.000)			1.66 (0.55, 2.78)	100.00

NOTE: Weights are from random effects analysis





Supporting Figure 5. Funnel plots of standard error vs price difference, per serving for food groups and per day for diet patterns. Egger test was performed to assess publication bias; p-values for per serving and per day analyses were 0.797 for meats/protein, 0.498 for grains, 0.190 for dairy, 0.061 for snacks/sweets, 0.582 for fats/oils, 0.197 for food-based diet patterns, and 0.621 for nutrient-based diet patterns with one outlier removed from Aggarwal A, 2011 (quintile 5 v. 1 of mean adequacy ratio). P-values for per 200 kcal and per 2000 kcal analyses were 0.206 for meats/protein, 0.533 for grains, 0.162 for dairy, 0.139 for snacks/sweets, 0.621 for fats/oils, 0.053 for food-based diet patterns, and 0.962 for nutrient-based diet patterns. There were too few soda/juice studies to perform the Egger test for this food group.

- Problem definition
- Hypothesis statement
- Description of study outcome(s)
- Type of exposure or intervention used
- Type of study designs used
- Study population

Reporting of search strategy should include

- Qualifications of searchers (eg, librarians and investigators)
- Search strategy, including time period included in the synthesis and keywords
- Effort to include all available studies, including contact with authors
- Databases and registries searched
- Search software used, name and version, including special features used (eg, explosion)
- Use of hand searching (eg, reference lists of obtained articles)
- List of citations located and those excluded, including justification
- Method of addressing articles published in languages other than English
- Method of handling abstracts and unpublished studies
- Description of any contact with authors

Reporting of methods should include

- Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested
- Rationale for the selection and coding of data (eg, sound clinical principles or convenience)
- Documentation of how data were classified and coded (eg, multiple raters, blinding, and interrater reliability)
- Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)
- Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results
- Assessment of heterogeneity
- Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated
- Provision of appropriate tables and graphics

Reporting of results should include

- Graphic summarizing individual study estimates and overall estimate
- Table giving descriptive information for each study included
- Results of sensitivity testing (eg, subgroup analysis)
- Indication of statistical uncertainty of findings

Reporting of discussion should include

- Quantitative assessment of bias (eg, publication bias)
- Justification for exclusion (eg, exclusion of non-English-language citations)
- Assessment of quality of included studies

Reporting of conclusions should include

- Consideration of alternative explanations for observed results
- Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)
- Guidelines for future research
- Disclosure of funding source

Meta-analysis Of Observational Studies in Epidemiology checklist. We followed the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines throughout all stages of design, implementation, and reporting.[12]

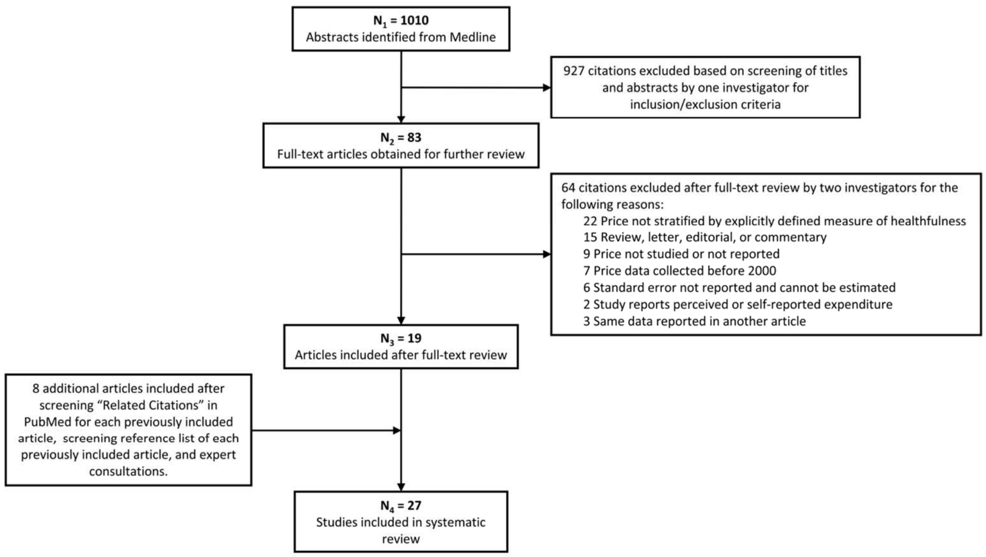


Figure 1. Search and screening of studies comparing prices of healthier and less healthy foods or diet patterns.

119x90mm (300 x 300 DPI)

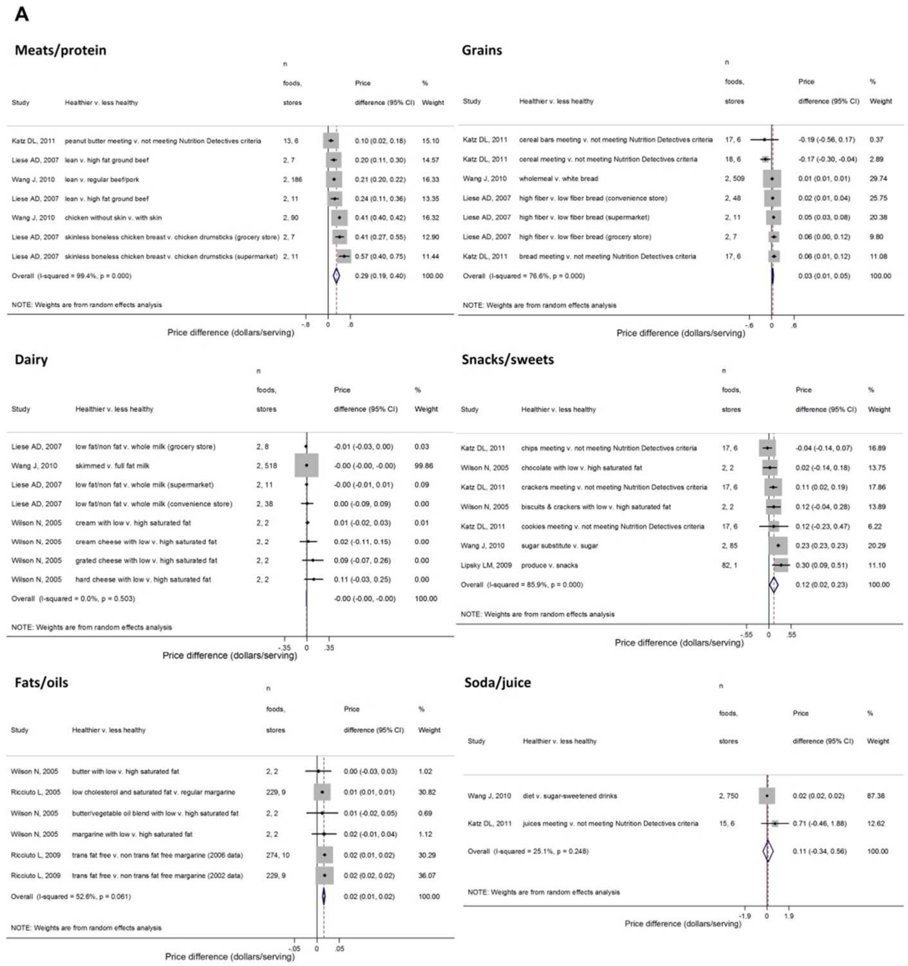
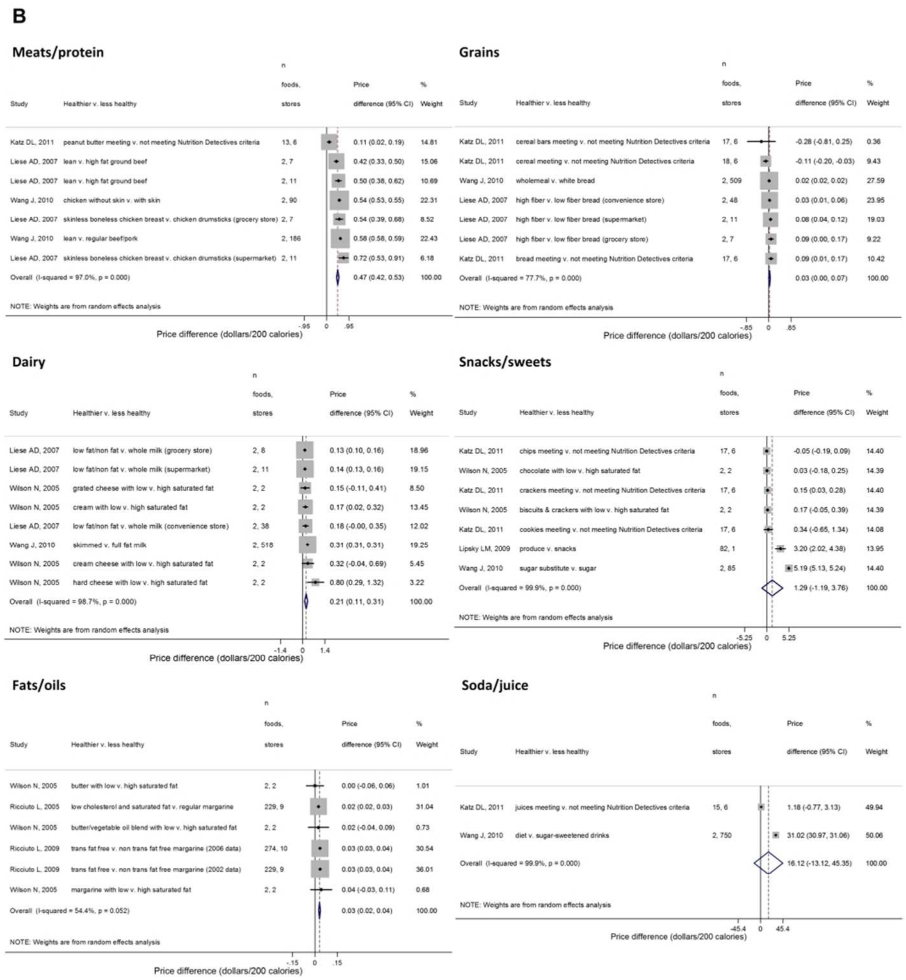


Figure 2. Price difference between healthier and less healthy foods per serving (A) and per 200 kcal (B). Price difference defined as the healthier category minus the less healthy category. Standardized serving sizes were derived from 2011 USDA MyPlate guidelines or, if not available from MyPlate, nutrition labels from a major grocery website. Calorie-adjustment of price differences based on the USDA database. Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

90x119mm (300 x 300 DPI)



90x119mm (300 x 300 DPI)

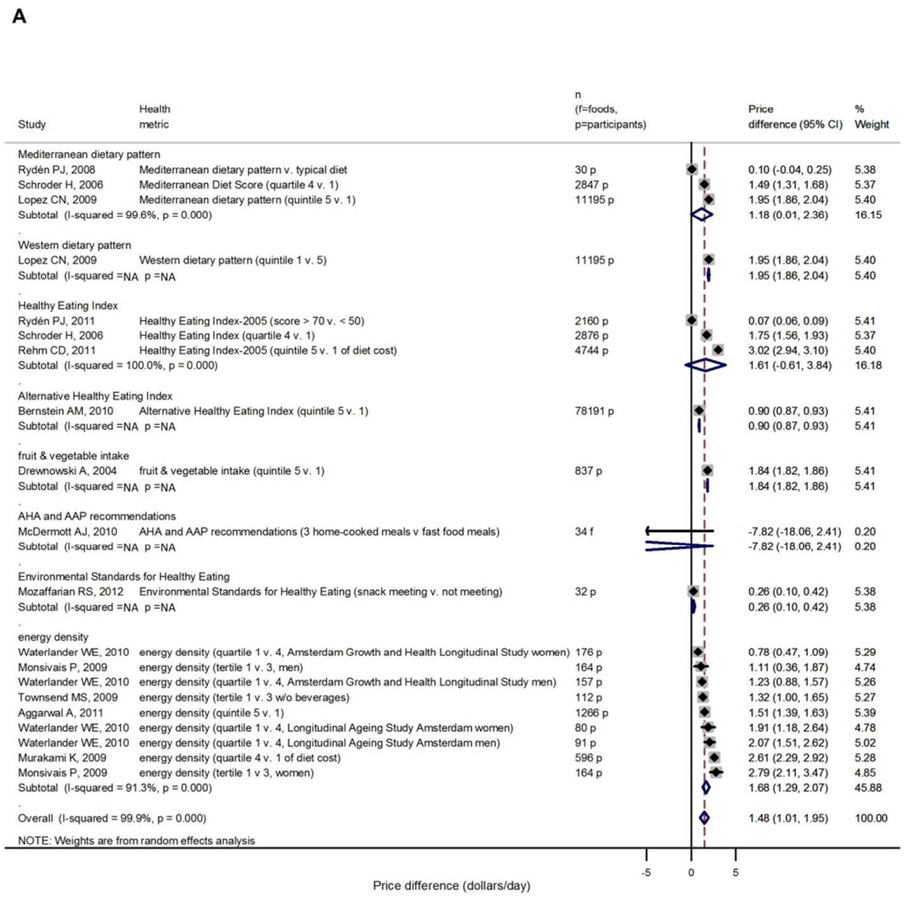
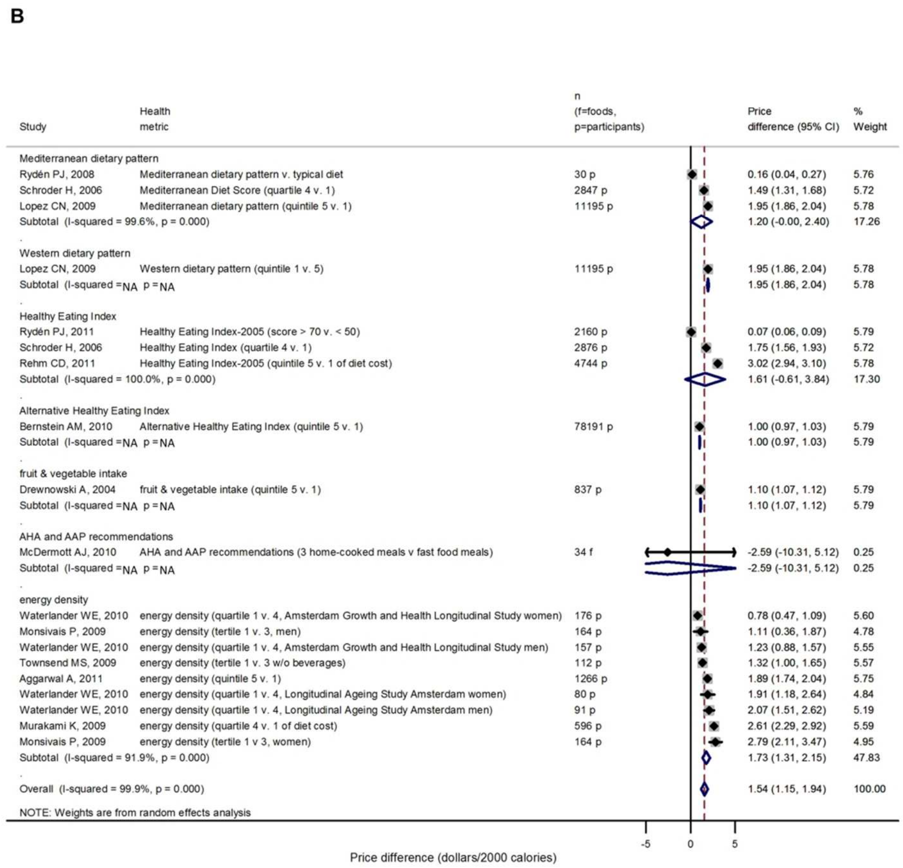


Figure 3. Price difference between healthier and less healthy food-based diet patterns per day (A) and per 2000 kcal (B). Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Mozaffarian RS, 2012.[37] Energy density was included as a food-based pattern since this metric represents a set of foods more than it represents any single nutrient.[19] For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Number of participants reported for dietary surveys (studies comparing diets across samples of participants), and number of foods reported for market surveys (studies comparing samples of foods). Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

90x119mm (300 x 300 DPI)



90x119mm (300 x 300 DPI)

A

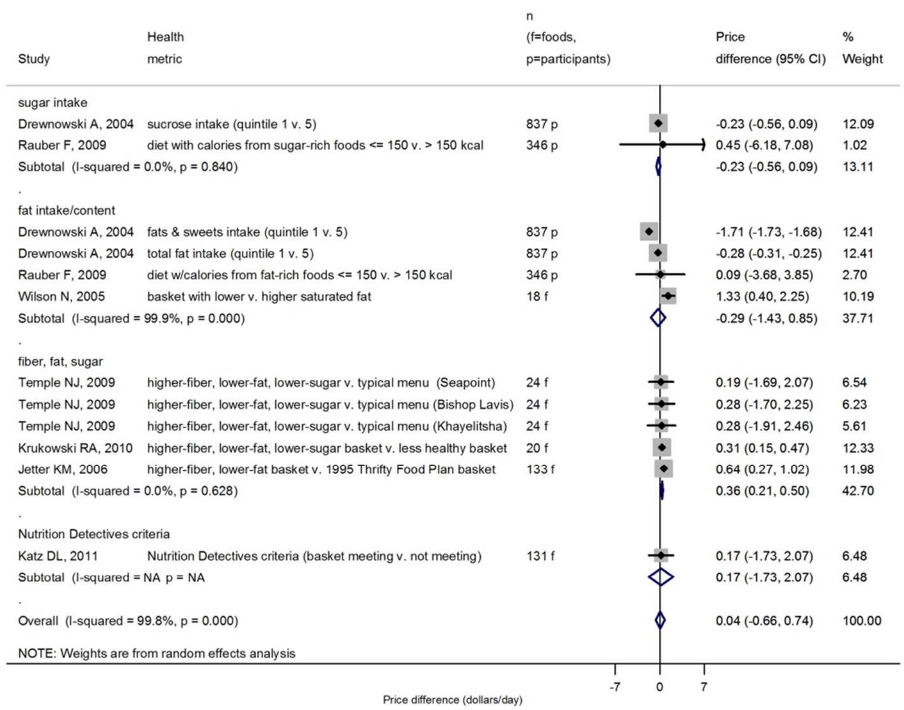
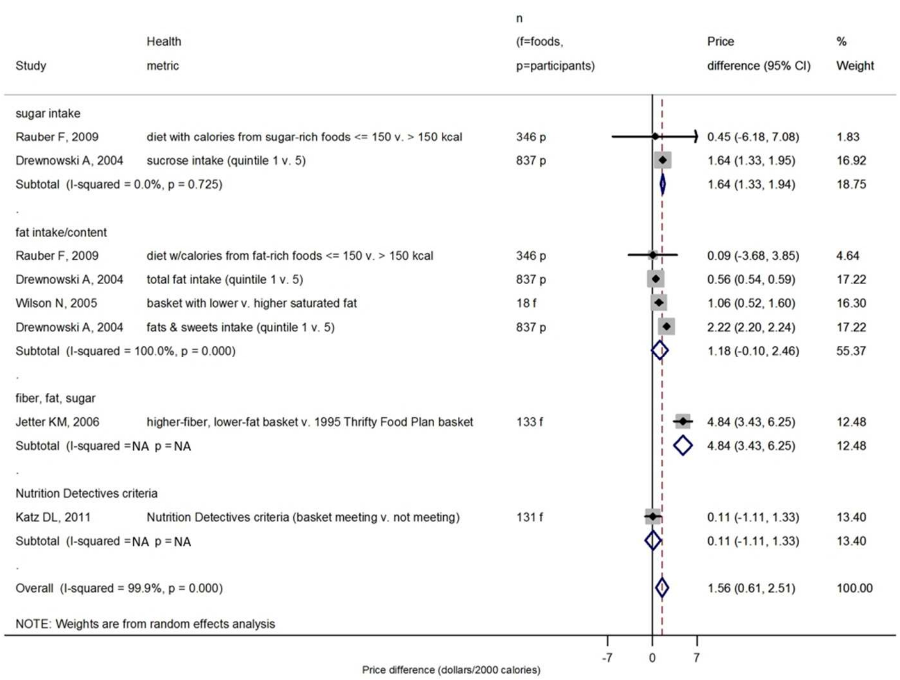


Figure 4. Price difference between healthier and less healthy nutrient-based diet patterns per day (A) and per 2000 kcal (B). One outlying, implausible estimate from Aggarwal A, 2011 (mean adequacy ratio) was excluded ($17.23; 95% CI: $14.35, $20.11).[38] Price difference defined as the healthier category minus the less healthy category. Dollars/day was defined as dollars/3 meals. One serving of any food was assumed to comprise one-fourth of a meal, except for condiments, fats, and oils for which one serving was assumed to comprise one-eighth of a meal. Calorie-adjustment of price differences based on the USDA database. Information reported was not sufficient to perform calorie-adjustment for Temple NJ, 2009 and Krukowski RA, 2010.[39,40] For studies reporting price across quantiles of healthfulness, the most extreme quantile comparison was selected for meta-analysis. Number of participants reported for dietary surveys (studies comparing diets across samples of participants), and number of foods reported for market surveys (studies comparing samples of foods). Summary estimates were generated using a random effects model in which studies were weighted according to the inverse variance of the price difference. All estimates were adjusted for inflation and purchasing power parity – standardized to the international dollar, defined as one US dollar – by country to reflect prices in 2011.

90x119mm (300 x 300 DPI)

B



90x119mm (300 x 300 DPI)