Healthy Food Pricing Incentives:

A systematic review of current evidence

Introduction

Increasing access to healthy foods by making them more affordable is an important strategy for improving nutrition and health. Poor nutrition is the largest contributor to chronic conditions such as obesity, diabetes, cancer, heart, liver and dental disease[1, 2] that are major causes of death and poor health in the United States. As a nation, we are far from meeting dietary recommendations.[3] More than 75% of Americans fall short of desired intake of fruits and vegetables and more than 60% of Americans exceed recommended levels of added sugars, saturated fats and sodium.[3] People with low-incomes and black and Hispanic people are less able to afford healthy foods such as fruits and vegetables compared to more affluent, white people.[4] Poor nutrition is therefore an important contributor to persistent chronic disease health inequities.[5]

In recent years, healthy food pricing incentives have emerged as a promising approach for increasing the affordability of healthy foods. Incentives reduce the cost to consumers of healthy foods through subsidies, discounts, rebates and matches. Numerous reviews have demonstrated that incentives increase consumption, purchases and sales of healthy foods, especially of fruits and vegetables.[6-18]

While the evidence is clear that pricing incentives work, the most recent reviews are current only through 2017 and it remains unknown what *specific attributes and program design features* of healthy food pricing incentives make them effective in increasing healthy food consumption. We therefore conducted a systematic literature review to update prior reviews by summarizing current knowledge and describing which attributes of incentive interventions (e.g. incentive

amount, type of incentive, site of use, etc.) are associated with greater effectiveness. We hope that this information will help practitioners and policy makers implement effective evidence-based and best practice approaches to incentives to increase affordability and consumption of healthy foods among people with limited resources.

Methodology

We briefly summarize the methods we used for this review, which were based on guidelines from the Cochrane Collaborative[19] and the Institute of Medicine.[20] More detailed methodology including the systematic review protocol, study inclusion and exclusion criteria and search hedge is available in the Healthy Food Pricing Incentive Protocol document, available upon request.

Research Questions

Our primary research question was: "What are the specific attributes of a healthy food pricing incentive that are associated with increasing purchases, sales and consumption of healthy foods?" More specifically, we explored the following:

a. What is the relationship of size and frequency of the incentive to changes in outcomes?
b. Does effect vary by the type of food subsidized?
c. Does effect vary by source of food (e.g. supermarket/grocery, farmers market, restaurant, etc.)?
d. Does effect vary by the type of incentive (discount, subsidy, rebate or match)?
e. What are the best mechanisms (i.e. EBT/ debit cards, paper vouchers, tokens) for providing incentives?

Identification and selection of articles for systematic review

We searched the PubMed database to identify peer-reviewed healthy food pricing incentive studies published between January 1, 2000 and January 3, 2019. We defined a healthy food pricing incentive as a financial incentive that encourages the purchase of healthy foods by reducing the cost to the consumer through discounts, matches, subsidies, or rebates (see definitions below). All articles were imported into Covidence. The title and abstract of each article was screened by two reviewers to select articles for full-text review to determine the final set of articles for inclusion. Reviewers met to resolve disagreements. Data from each included article was then extracted by one reviewer into a customized Excel spreadsheet. The second reviewer subsequently checked the entered data against the full-text publication. Each study was scored for quality based on eight, pre-defined criteria. Conflicts were resolved through consensus.

We sought additional articles by searching the Cochrane library and Google using a limited set of keywords, asking experts in the field, and scanning reference lists of the healthy food pricing incentive review articles cited above and articles included in this review.

Inclusion/Exclusion Criteria and Search Hedge

We used the following criteria to select studies:

1. *Population:* Human participants of any age.
2. *Publication Type and Language:* Peer-reviewed, full-length, English-language articles with original data. If there were multiple publications reporting on the same study, we selected the publication based on following criteria in the order listed: the study with the largest sample size, the study that is clearly identified by authors as the primary or main outcomes report, or the study with the earliest publication date.
3. *Study Design:* Controlled trial, quasi-experiment, natural experiment, single-group pre/post, time series, and prospective cohort. We excluded qualitative, systematic and other reviews; meta-analyses; cross-sectional designs; simulation or modelling studies; and studies with a short intervention duration (less than three weeks).
4. *Setting:* Any country and most food purchasing settings (stores, restaurants, cafeterias, and farmers markets but not vending and online sales or free fruit and vegetable programs offered in primary schools). We excluded lab-based and simulation studies.
5. *Intervention*: Healthy food pricing incentive strategy, including studies that combined multiple interventions, if the pricing incentive was a primary component.
6. *Outcome:* Must include outcome measure of healthy food consumption, purchase, sales, or expenditure data at the consumer level.
7. *Search Dates:* We searched databases from 01/01/2000 to 1/3/2019 (PubMed), from 1/1/2000 to 4/2/18 (Cochrane) and from 1/1/2000 to 10/14/18 (Google).

A medical librarian developed a PubMed search hedge based on these criteria using MeSH headings and key words (available upon request).

Assessment of study quality

A simple quality assessment tool was developed for use in Excel. Each study received a composite score ranging from 0-8 based on the following 8 criteria (each scored a "0" or "1"): pre/post data (scored 1 if available), comparison group (scored 1 if present), strong primary outcome measure (scored 1 if used electronic sales data or 24 hour dietary recalls), power > 80% (scored 1), participant study completion rate >80% or attrition rate < 20% (scored 1), missing data < 10% or adequately addressed by study methods (scored 1), intervention fidelity (scored 1 if authors mentioned fidelity and gave reasons why it was good, if the discount was automatically applied, or if the incentive usage rate was > 60%), and confounding addressed (scored 1 if appropriate covariates were used).

Analysis

Interventions

The analysis focused on the outcomes of the pricing intervention. Some studies included additional interventions, such as education, promotional activities, messaging, product placement, and purchasing restrictions. In some cases, these studies assessed the effects of the pricing incentive independent of any co-interventions and we could assess the specific effect of the pricing intervention. In other studies, the additional intervention was combined with the pricing intervention and we were only able to examine the joint effects. As part of the analysis, we separated those studies in which the effects of the pricing intervention could be assessed

independent of other interventions from those in which the pricing intervention was combined with other(s) and analyzed these two groups separately.

Primary outcomes

The primary outcomes were consumption and purchase of and expenditures on fruits and vegetables combined, fruits alone, vegetables alone and also healthy food choices in cafeterias. As available, we included both within-group change in the pricing intervention arm and the difference in differences between the intervention arm relative to a comparison group between the end of intervention and the baseline. The primary analysis was based on whether a study reported a statistically significant effect on any of the outcomes(s) reported in the publication, defined as $p < 0.05$. If a study reported multiple comparisons, we adjusted the significance of reported p-values using the Holm-Bonferroni method if the authors had not done so.[21]

Information extracted

In addition to primary outcomes, we extracted information on (1) population (including inclusion/exclusion criteria, recruitment methods, participation rate among those recruited, completion rate among those enrolled, age, gender, race, socio-economic status; (2) features of primary pricing intervention and of any co-interventions such as consumer education, promotion, marketing, etc. (including primary incentive intervention components, type of incentive, duration, fidelity of implementation, costs of intervention, unintended consequences, and equity considerations such as features intended to address inequities in healthy food access); (3) comparator (including any interventions received by the comparison group); (4) primary outcomes including difference in differences and/or within-group changes in means or odds ratios along with 95% CI, SD or SE, and p-values, when available, and differential effects based on income or race/ethnicity, if any; (5) qualitative findings, if any (6) duration of data collection (including any post-intervention follow-up); (7) setting and other study characteristics (including country, sponsorship source, intervention dates, study design, analytic model and adjustments for confounding, approach to missing data, statistical power); and (7) author's statement of objectives, conclusions, limitations and suggestions for future research.

Synthesizing the results

We first assessed variation across the full set of included studies for each extracted variable. We then selected a subset of variables for further analysis – those contained in the summary table. We selected them using systematic review guideline recommendatinos[19, 20, 22] and whether we deemed them of interest for explaining intervention effectiveness, generalizability, directness (applicability to specific populations), and precision.

Next, we determined whether a study reported a statistically significant effect on at least one primary outcome of interest. If a study looked at multiple outcomes, settings, or incentive amounts, we classified it as having a significant outcome if at least one outcome was significant. If there were more than one significant outcome, then we used the one with the greatest magnitude. We then coded intervention features to facilitate analysis of studies by these features. The code definitions are available upon request. For example, we coded interventions lasting less than 8 weeks as "short," 8-23.9 weeks as "medium," and 24 or more weeks as "long."

We then examined the association of study significance with intervention features (incentive amount, presence of cap on incentives awarded, type of incentive, mechanism of incentive distribution, frequency of incentive provision, site where incentive was provided and used, duration of incentive provision, presence of co-intervention(s), income and race of participants, and study design) and categories of each feature (e.g. types of sites at which incentive was used). We first grouped studies by whether they reported at least one significant outcome. We then qualitatively assessed whether a specific feature was found more or less commonly in significant studies relative to insignificant ones. For example, we reviewed sites where the incentives were redeemed to make a qualitative assessment of whether specific sites were found more frequently in the studies that significantly increased healthy food consumption compared to those that did not. We then divided studies into groups based on presence of a given feature, and assessed whether the frequency of significant studies differed by feature. For example, we compared the frequency of significant findings among studies takig place in different redemption sites. These approaches are roughly analogous to a case-control analysis (exposure in relation to outcome) and to a cohort analysis (outcome in relation to exposure), respectively. Note that the limited number of studies available for analysis and lack of common outcome measures precluded any quantitative assessment with statistical testing. Table 1 provides a summary of these analyses.

Results

We identified 3,793 distinct articles, selected 149 articles for full-text review, and included 29 studies described in 33 articles in the review (Figure 1).[23-55]

Descriptions of representative studies

We provide descriptions of a few studies representative of those included in this review. Space limitations preclude us from including all.

Olsho 2016[41] This large (n = 2784), well-designed randomized controlled trial evaluated the USDA Healthy Incentives Pilot (HIP). HIP offered 30% rebates (up to $60 per household per month) to Supplemental Nutrition Assistance Program (SNAP) participants for purchasing fruits and vegetables (fresh, frozen or canned) at supermarkets, groceries, convenience stores and farmers markets. Rebates were deposited to electronic benefit transfer (EBT) accounts. Total fruit and vegetable intake increased by 0.24 cup/day, a 26% increase - enough to close the gap between current and recommended daily intake by 20%. The authors suggest that more marketing, promotion and nutrition education activities as well as inclusion of more retailers (only 60% of SNAP expenditures occurred in participating retailers) might lead to greater impacts.[56]

Smith-Drelich 2016[46] This well-designed randomized controlled trial (n = 144) studied a substantial direct subsidy (reimbursement after submitting purchase receipts) of up to $50 during a 3 week period for purchases of fresh vegetables from any retail source among a largely white population that likely included many students associated with an elite university. Spending on vegetables increased significantly by $8.16/week while consumption (1.3 servings/week) did not increase significantly, raising the possibility that people shifted to more expensive vegetables

while not changing the quantity consumed or that the sample size may have been too small to detect a significant change in consumption.

Waterlander 2013[51] This factorial design randomized controlled trial with 199 supermarket shoppers assessed the effect of a 50% fruit and vegetable (mostly fresh, some canned and frozen) pricing discount via coupon sent by mail every two weeks, nutrition education consisting of telephone counseling by a dietician and 2 recipe books, or both. The pricing discount significantly increased purchases of fruits and vegetables among discount-only participants relative to controls by 238 grams per week, while nutrition education alone had no effect. The combination of discounts with education was no more effective than discounts alone.

Ball 2015[25] This supermarket-based factorial design randomized controlled trial with 641 women offered a 20% discount on all fruits and vegetables (fresh, canned and frozen) at the time of purchase by swiping a loyalty card rather than providing a coupon in advance. A second study arm received a behavioral intervention that included mailed skill-building nutrition information and tools, recipes and an online nutrition discussion forum that included peer-to-peer discussions and support from a dietician. The discount-only group increased fruit purchases by 364 grams/week (35%) relative to controls and vegetables by 233 grams/week (15%). The behavioral intervention had no effect.

Herman 2008[34] This nonequivalent controlled three-arm study of 602 WIC participants offered $10 weekly fruit and vegetables voucher at WIC centers for purchase of fresh fruits and vegetables at farmers markets in one group or supermarkets in a second group. Both groups saw an increase in fruit and vegetable consumption relative to a control group: 1.4 servings per 4186 kJ per day in famers markets and 0.8 servings per 4186 kJ per day in supermarkets (1.0 servings per 4186 kJ per day overall).

Michels 2008.[39] The price of healthy food items in a hospital cafeteria was discounted by 20% for 5 weeks along with distribution of education materials in a single group pre/post study. Purchases of healthful foods increased by 6% and less-healthy foods decreased by 2% relative to baseline. However, calories purchased did not change significantly.

Synthesis of study and incentive characteristics

Targeted foods/beverages: Purchases of fruits and vegetables were incentivized in nearly all of the studies (28 of 29). The majority of studies (19) focused exclusively on fruits and or vegetables: 10 included all forms of fruits and vegetables (fresh and processed, although often excluding those with high amounts of added sugars and/or sodium or otherwise deemed unhealthy), 7 included fresh fruits and vegetables only, 1 included fresh fruit only, and 1 included fresh vegetables only. Another 10 studies added additional foods meeting healthy food criteria such as meats, dairy, soups, legumes, whole-grain products, and beverages in stores or healthy entrees and beverages in cafeterias.

Incentive amount and frequency: The size of the incentive varied widely. For those offering a fixed dollar incentive (10 studies), the amount offered per week ranged from $1.30 to $10.00 (median $6.08), and the incentives were provided once (at beginning or end of study) or more often (monthly or every two months). Most studies provided the same incentive amount regardless of household size although three adjusted the amount proportionate to size. Nineteen

studies based incentive size on the proportion of total purchases of eligible items. The proportion ranged from 10% to 100% (median 30%) and was most often provided with each transaction but also weekly, semi-monthly, monthly or at the end of intervention. Incentives were capped in 16 of the studies, with the cap ranging from $5-120 per month per household ($5.20 - $3,480 [median $120] for the entire intervention) or in two studies at $10 per shopping trip or per day.

Type of incentive: The forms of incentives varied. We developed a scheme to classify the incentives into four mutually exclusive categories:

- *Discount* is an incentive that offers consumers a reduced price on specific items when they are purchased. The reduced price is often in the form of a certain percentage of the regular price. Frequently a discount is provided electronically at the point of sale, but it could also be provided via a coupon that is received by the consumer prior to the purchase (13 studies).
- *Match* is an incentive that matches all or a portion of the amount a consumer spends on eligible foods to provide additional buying power and thereby increases the amount a consumer can purchase. The incentive amount is directly tied to the dollar amount a consumer spends (e.g. $1 for every $1 spent, or for every $2 spent). It is often provided in the form of vouchers or tokens received during the shopping trip or prior (2 studies).
- *Rebate* is an incentive that provides cash back to a consumer after the purchase. The value of the rebate is often a certain percentage of the price of the item (e.g. a 30% rebate on $1 worth of apples would reimburse the consumer $0.30). The rebate is earned on eligible foods but can be used for any type of future purchase and can be considered a reimbursement (7 studies).
- *Subsidy* is an incentive that provides a cash value amount to a consumer to purchase specific foods. It is not linked to how much a consumer spends. A subsidy is often provided ahead of time in the form of a voucher, token or coupon but could be added electronically to a debit card (7 studies).

How incentive provided: Incentives were delivered electronically or physically. Electronic delivery was used in 15 studies through an automatic price deduction at the point of sale or an automatic credit back to a debit or gift card. Nearly all the discounts and rebates were transmitted electronically while matches and subsides did not use this mechanism. Incentives in a physical format, such as paper coupons, were used in 14 studies, primarily for subsidies and matches but also in a few cases for rebates and discounts.

Studies varied the time at which the consumer could use the incentives - immediately or in the future. The incentive was provided at the time of a purchase for immediate use in 14 studies, generally as a discount on the price taken at the register of a food store or cafeteria. The incentive was redeemable for future in 15 studies, either as a coupon provided in advance of a store or farmers market visit (9 studies) or as a rebate that the consumer could use at a later date (6 store-based studies).

Source: Program participants received their incentives at various sites - in food stores (6 studies); electronically as a rebate added to a debit, gift or SNAP EBT card (5 studies); at the register in a cafeteria/restaurant (4 studies); at a WIC office (3 studies); at a farmers market (3 studies); at a health center (2); by mail (3 studies); at multiple settings (1 study); or not reported (2 studies).

Where used: The majority of incentives were for use in food stores (13 studies – mostly supermarkets). They were also redeemable in cafeterias/restaurants (6 studies), farmers markets (5 studies), both stores and farmers markets (2 studies), or at multiple locations (3 studies).

Duration: Interventions varied widely in duration. Six were very short, lasting 3-5 weeks. Another 13 occurred over 8 weeks to 4 months, while 10 were longer with durations from 24 weeks to 29 months. Median duration was 3 months.

Co-interventions: Of the 29 studies, 7 looked solely at pricing incentives. The other 22 studies described interventions that included a combination of pricing incentives as well as one or more additional co-intervention strategies (e.g. nutrition education, on-site promotion and placement, or purchasing restrictions). Of these, 9 of assessed the additional co-intervention independent of the pricing intervention.

Country: Most studies took place in the US (19 studies), with 2 in Australia, 2 in France, and 1 each in Denmark, Netherlands, New Zealand, Peru, South Africa and the UK.

Populations: More than half of studies (16) enrolled exclusively low-income participants, 5 included a wider range of income groups, 7 did not report income and one enrolled high-income participants. Eleven had predominantly non-white participants, 9 had predominantly white participants and 9 did not report race/ethnicity.

Study characteristics: All but 2 studies measured outcomes before and after the pricing intervention, while 2 reported post-only data. Most (17) included a comparison group, although 2 reported only pre/post within-group changes for the intervention effect on the outcome of interest for this review. Fourteen used random assignment to groups. About half of the studies (15) used rigorous data collection methods, defined as 24-hour dietary recalls, supermarket scanner data, or cash register sales data. The remaining studies used receipts turned in by participants (compromised by substantial missing data) or less reliable self-reported dietary assessments (e.g. food screeners).

Effectiveness of pricing incentives

Overall effectiveness: Twenty-three of 29 studies reported a statistically significant effect of incentives on at least one outcome measure, after taking into account multiple outcome comparisons. The variety of reported outcome measures precludes a simple summary of effect size across studies. For fruit and/or vegetable consumption, difference in differences (DID) effect sizes ranged from 0.28 - 0.38 times/day, 0.8-1.8 servings/day, or 0.11 - 0.24 cups/day. DID as percentage of mean baseline value for the total study population ranged from 18-82%. For fruit and/or vegetable sales or purchases, the DID ranged from 31-278 grams per day (DID as percentage of the mean baseline value for the total study population was 8%-59%) and $0.34 – $8.16 per week (DID as percentage of baseline mean was 23-194%).

Effects on fruits vs. vegetables: Incentives appeared to be more likely to impact vegetable outcomes compared to fruit outcomes. Of the 11 studies that assessed both fruit and vegetable outcomes separately, 8 reported significant effects on vegetables versus 3 on fruits.

Study and incentive features associated with significant findings

Study design. Higher quality study design features, including use of a comparison group, randomized controlled design, quality of outcome measurement, participant retention, and analysis of missing data, appeared to be associated with finding a significant outcome (Table 1).

- RCT vs. non-RCT: Of the 13 RCTs, 11 of 13 reported one or more significant outcomes, compared to 1 of 2 non-randomized controlled trials and 9 of 14 studies without comparison groups. RCTs were more common among significant studies (11/23) compared to non-significant ones (2/6).
- Outcome measure: Among the studies using more robust outcome measures (defined as 24 hour dietary recalls, electronic scanner data, and cash register sales measures), 14 of 15 reported a significant finding compared to 9 of 14 with lower quality measures. Use of more robust outcome measures was more likely in significant studies (14/23) compared to non-significant ones (1/6).
- Participant retention rate and missing data: Eighteen of the studies had participant retention rates of at least 80%, less than 10% missing data, described adequate methods for analyzing missing data or had complete data by virtue of study design (e.g. used retail transaction data). Among these studies, 14 of 15 had a significant finding and among studies less adequate retentions rates or missing data analysis, 10 of 13 had a significant result. Among significant studies, 14 of 23 had adequate retention or data completeness and 3 of 6 non-significant studies did.

Of note, non-significant studies documented adequate statistical power (>80%) less often than significant ones (1 of 6 vs. 8 of 23).

Intervention characteristics. Some incentive characteristics appeared to be associated with finding at least one significant effect: provision of the incentive electronically (rather than physically), on more than on occasion (rather than once), and for longer periods of time (more than 24 weeks rather than less; including a broader selection of healthy foods (i.e. all fruit and vegetable types rather than fresh only or additional types of healthy foods); and redemption in stores (rather than farmers markets). Greater details follow and are also included in Table 1.

- Incentive amount: Larger incentives did not appear to be associated with significant outcomes. Among studies with a large incentive, 11 of 13 reported a significant outcome while 2 of 4 with medium incentives and 10 of 12 with low incentives did so. A large incentive was slightly more common among significant studies (11 of 23 significant studies had a large incentive compared to 2 of 6 non-significant ones).
- Cap: The presence of a cap on the amount of the incentive did not appear to be associated with a significant outcome nor were significant studies more or less likely to have caps. Among the 16 programs with a cap, 12 had a significant outcome compared with 11 of 13 without a cap. Among the 23 significant studies, 12 had a cap versus 4 of the 6 non-significant studies.
- Type of incentive: In general, the frequency of significant studies did not seem to vary with incentive type: 5 of 7 rebate programs, 11 of 13 discount programs, 6 of 7 subsidy programs, and 1 of the 2 matching programs had significant findings. The proportions of incentive

types among significant studies did not seem notably different from those among non-significant studies, although small numbers of each type of incentive limited this analysis.

- Mechanism for providing the incentive: Studies with electronic provision of incentives seemed to have significant findings (13 of 15) more often than did those with physical incentives (10 of 14). Electronic provision of incentives was used more commonly in significant studies (13 of 23) whereas physical forms of incentives were more frequent in non-significant ones (4 of 6).
- Frequency of awarding incentive: Significant outcomes seemed more likely in programs that delivered incentives more than once (22 of 25) while 1 of 4 that gave the incentive once had a significant finding. While 3 of 6 non-significant studies provided the incentive only once, only 1 of 23 significant studies did so.
- Type of healthy foods included: Studies that included a broader selection of healthy foods (i.e. all fruit and vegetable types rather than fresh only or additional types of healthy foods) were more likely to report significant findings. Among those that allowed redemption for all types of fruits and vegetable products, 9 of 10 were significant. Among those that included additional types of healthy foods beyond fruits and vegetables, 9 of 10 were significant, while 5 of 9 limited to fresh produce were significant. Among significant studies, 5 of 23 were limited to fresh produce while 4 of 6 non-significant ones were.
- Site at which incentive received: There was no apparent relationship between the site at which the incentive was received and significant findings. Small numbers of studies in each type of site category limited the detection of any pattern.
- Site at which incentive used: Programs in which participants used their incentives at stores were substantially more likely to report significant findings (11 of 13 in which stores were the sole redemption site and 4 of 5 using multiple sites including stores) while 3 of 5 programs using exclusively farmers markets had significant findings. Among the 23 significant studies, 11 used stores as the redemption site while redemption at other sites was less common.
- Duration of intervention: Longer duration programs (24 weeks or longer) were much more likely to have significant findings (10 of 10 were positive versus 9 of 13 of medium and 4 of 6 of short term duration). They were substantially more common in significant studies (10 of 21) than among non-significant ones (0 of 8).
- Co-intervention: An association between the presence of a co-intervention (combining pricing with another strategy) and study significance was not apparent. Co-interventions included nutrition education, skill-building, exposure to healthy foods (e.g. food tastings and cooking demonstrations), feedback on healthfulness of purchases, media and promotional campaigns, health messaging, product placement, and purchasing restrictions. Among programs with co-interventions, 18 of 22 were significant compared to 5 of 7 without. Joint co-interventions were present in 18 of 23 significant studies and 4 of 6 non-significant ones. Eight studies analyzed the effects of co-interventions independently from pricing. None found a significant difference in effect size on fruit and/or vegetable outcomes between the combined intervention versus the pricing intervention alone. Three observed a non-significantly greater effect with the combination (one observed an enhanced effect on vegetable sales and on amount purchased,[28] one on amount of fruits and vegetables purchased[51] and one on the Healthy Eating Index but not fruit or vegetable consumption).[33]

- Income and race of participants: We were unable to assess whether effects of pricing incentives varied by the race/ethnicity or socioeconomic status of participants due to limitations in the data available. While race/ethnicity was reported in 20 studies and income in 22, few studies reported outcomes stratified by race/ethnicity or socioeconomic status. The measures and categories used to describe these demographic characteristics varied substantially across studies.

Conclusions

Pricing incentives are effective in increasing healthy food, and particularly fruit and vegetable, consumption, purchasing and expenditures, as documented in multiple evidence reviews.[6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18] Our review, which includes newer studies published after completion of these earlier reviews, supports this conclusion. Twenty-one of the 29 included studies in this review showed a significant impact on at least one outcome measure. The measures used to assess effect size varied across studies. For fruit and/or vegetable consumption, difference in difference effect sizes ranged from 0.28 - 0.38 times/day, 0.8-1.8 servings/day or 0.11 - 0.24 cups/day. For fruit and/or vegetable sales or purchases, the DID ranged from 31-287 grams per day or $0.34 – 8.16 per week. Incentives seemed more effective in increasing vegetable outcomes compared to fruit outcomes. Higher quality studies were more likely to report significant outcomes.

It is less certain what features of incentives are most likely to produce these positive outcomes. The incentive programs in this review varied widely with respect to key design features, such as incentive size, frequency and type, method of incentive delivery, sites where incentives could be used, and program duration. Incentive features associated with finding at least one significant effect were provision of the incentive electronically (rather than physically), providing the incentive more than once, and for longer periods of time (more than 24 weeks rather than less), inclusion of a broader selection of healthy foods (e.g. all fruit and vegetable types rather than fresh only or additional types of healthy foods, and redemption in stores (rather than farmers markets). The relatively small number of studies included in this review, which resulted in small numbers of studies with a given incentive feature, precluded statistical testing of the association of feature and outcome significance. Therefore, it is prudent to interpret these findings as tentative qualitative conclusions.

Of note, we did not observe significant associations between the of size of the incentive or presence of co-interventions (such as education) with any outcomes. This finding is consistent the results of a meta-analysis by Afshin and colleagues.[6] Prior reviews have also concluded that there is insufficient evidence to draw clear conclusions on the impact of store-based nutrition education in particular.[16, 17, 18]

The quality of the included studies varied. Most included a comparison group while slightly less than half were randomized trials. Robust data collection methods were used in about half of the studies. Participant retention was adequate in most studies. The evidence supporting the overall effectiveness of pricing incentives is thus based on generally well-designed studies.

Studies took place almost exclusively in high income countries, and most were in the US. Thus, it remains unknown how well pricing incentives work in middle and low income countries.[57]

Nearly all studies in this review included low socioeconomic status populations and many enrolled ethnically/racially diverse participants. We were unable to assess whether incentive impact varied with respect to these demographic characteristics given limitations in the available data. A few of the included studies examined whether an interaction between the intervention and *income* was present. Ball et al did not detect effect modification by income in a supermarket discount study, although they used an ecologic area-level measure of socioeconomic status.[25] Blakely et al, using an individual measure of socioeconomic status in another supermarket discount study, also did not find effect modification.[52] In a hospital cafeteria study post-hoc subgroup analysis, Thorndike et al observed that their cafeteria rebate intervention did not have significant effects on customers who were more likely to be from less educated groups.[48] Buscail et al noted that their supermarket and farmers market subsidy intervention yielded smaller (and non-significant) effects among households with precarious economic circumstances.[29] Polacsek noted that the effect size on fruit and vegetable purchases was greater among SNAP participants than for non-participants in their supermarket discount study.[44] Only two studies assessed for an interaction between *race/ethnicity* and study group assignment. One found no interaction[46] and the second observed a significant interaction by ethnicity with no effect seen in one (indigenous) minority group.[52] Additional information on variation of effectiveness by socioeconomic status and race/ethnicity is needed to clarify the effect of pricing incentives on health equity.

Well-designed studies are now needed to systematically compare incentive characteristics to learn which contribute most to effectiveness, to understand more about the factors that influence feasibility and sustainability of implementation, and to explore how incentives might be tailored to specific populations to maximize impact. Our ability to reach more definitive conclusions about program features associated with effectiveness was limited by the broad range of study designs, outcome measures and analytic methods employed. It would be helpful if future studies used common outcome measures to allow comparisons across studies and pooling of data. These measures should include effects of incentives on overall diet quality – few of the included studies did so. No studies directly compared different approaches to provision of incentives; future research should include this as a priority.

Our findings are consistent with previously published reviews and includes studies identified in a search current through January 2019 (the most recent prior review completed its search in June 2017[8]). We add new information about the features of incentive programs that may be associated with significant outcomes. Three recent reviews of pricing studies [6, 7, 8] confirmed that pricing incentives for healthy foods increase consumption or purchases, as have older reviews. [9, 10, 11, 12, 13, 14, 15, 16, 17, 18] Gittelsohn and colleagues reviewed 30 pricing intervention studies and found 23 reported increases in purchases or consumption of healthy produce or decreases in unhealthy ones.[7] Most focused on fresh produce. Afshin and colleagues included 23 intervention and 7 prospective cohort studies in a review quantifying the effect of changes in food prices on diet.[6] They confirmed that decreases in prices of healthy foods overall and of fruits and vegetables in particular increased consumption. Meta-regression suggested that study design, setting, duration, age of participants, presence of additional intervention components (e.g. education, food promotion) did not influence the impact of incentives. Hartmann-Boyce and colleagues conducted a review of several real-world grocery store interventions and found that price decreases were more effective for changing purchase of healthy foods compared to store environment changes and education

interventions.[8] These reviews noted limitations similar to the ones we observed, such as short duration of intervention, and lack of assessment of substitution effects and impact on diet overall.

This review is subject to several limitations. Studies used a variety of outcome measures, making it difficult to compare outcomes and conduct a quantitative analysis. It was not possible to compute a common outcome (e.g. quantity of fruits and vegetables consumed or purchased per day per person) across studies. The relatively small number of studies and diversity of approaches to incentive implementation limited our ability to compare some aspects of program features because of small numbers of studies with a given feature. Some studies combined incentives with additional co-interventions, making it challenging to isolate the effect of the incentive component. Race of participants was not reported in 9 studies, limiting our ability to assess differential effects by race. The extent of implementation of program elements was not consistently reported, making an assessment of effectiveness more difficult. Our search was limited to articles published after 2000 and to those included in PubMed. Studies conducted more than 18 years ago may be less relevant to current conditions. We defined a positive study as one that found a statistically significant increase in healthy food consumption or purchases either in comparison to a control group (difference in differences) or in a pre/post analysis of a single intervention group. While we would have preferred to include only the former, the limited number of available studies led us to use this more liberal definition. We recognize the limitation of using statistical significance as the criterion for a positive study. We did not use an effect size threshold to define a positive study because of lack of a common outcome metric. In addition, several studies with medium to large effect sizes either did not test for statistical significance or did not find a significant result.

Our study has several strengths. This is the first systematic review to specifically focus on the characteristics of pricing incentive programs in relation to effectiveness. We followed review guidelines from the Cochrane Collaborative[19] and the National Academy of Medicine.[20] We included studies with a broad range of designs, used inclusive search criteria, included a medical librarian on our team, and arranged for peer review of our search strategy. Two reviewers independently reviewed studies for selection, extracted data, and rated study quality. We shared preliminary findings with more than a dozen experts for feedback on methods and findings.

Increasing access to healthy foods by making them more affordable is one pricing strategy for improving diet quality. Another important approach is raising prices of unhealthy foods. Taxes on sugary drinks may reduce sales and consumption of these products, although effect sizes have varied and more evidence is needed.[58, 59, 60, 61, 62] The combination of pricing incentives for purchase of fruits and vegetables with restrictions on the purchase of unhealthy foods may improve diet quality to a greater extent than either intervention alone.[33]

In conclusion, moderate to good quality evidence supports the use of pricing incentives to increase consumption or purchases of fruits and vegetables. More information on how best to design pricing incentive programs is needed. Our review suggests that providing the incentive electronically on more than one occasion for 24 weeks or longer, including a broader selection of healthy foods (e.g. all fruit and vegetable types rather than fresh only or additional types of healthy foods) and allowing redemption in stores may be features associated with successful programs.

Figure 1: PRISMA flow diagram

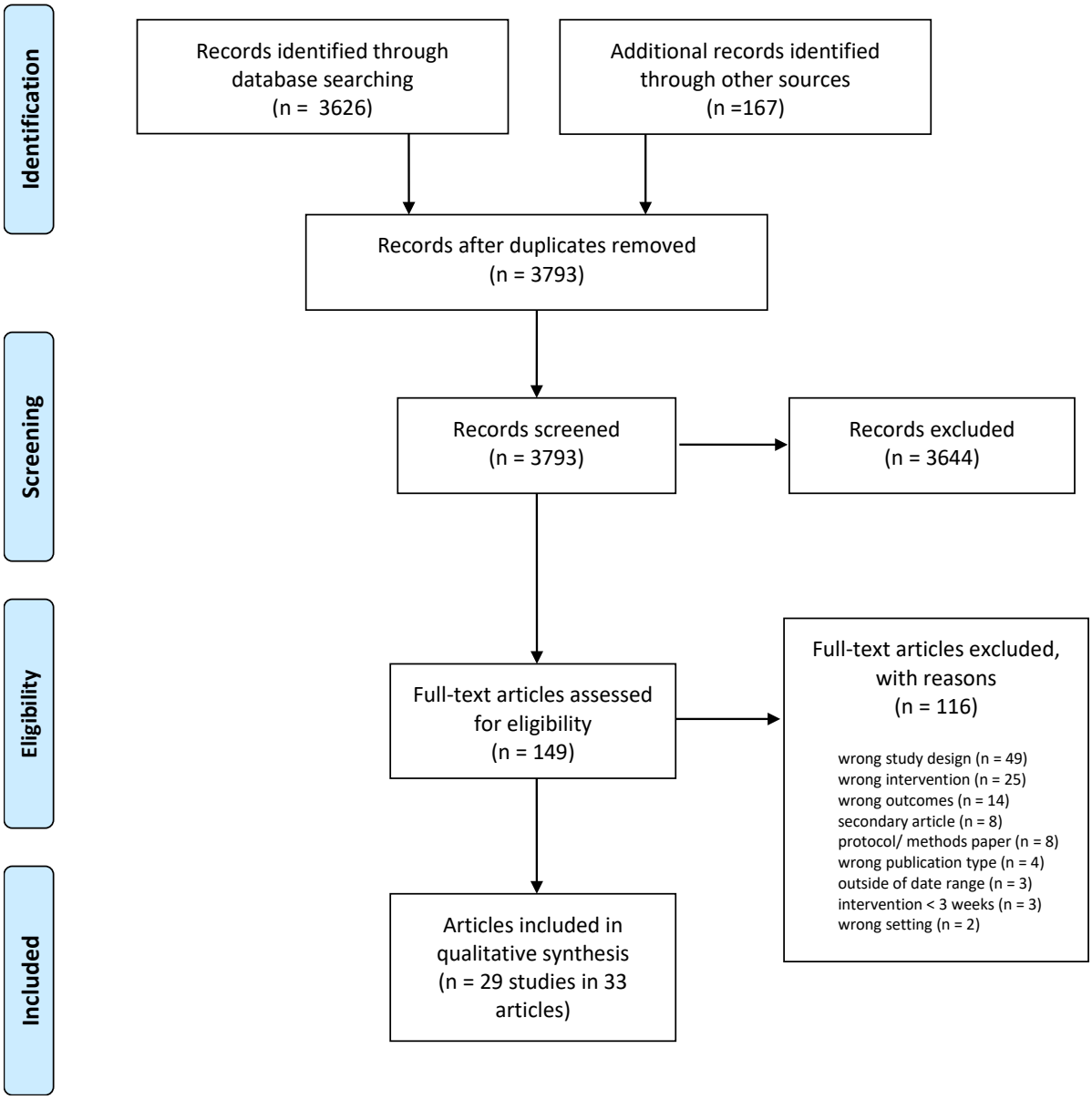

Table 1: Association of study significance with incentive characteristics

Characteristic	Value	Signif		Non-signif	
		N	Row %	N	Row %
Number of studies total (29)		**23**	79%	**6**	21%
amount of incentive	**high**	**11**	85%	**2**	15%
	col %	48%		33%	
	med	**2**	50%	**2**	50%
	col %	9%		33%	
	low	**10**	83%	**2**	17%
	col %	43%		33%	
cap on incentive	**yes**	**12**	75%	**4**	25%
	col %	52%		67%	
	no	**11**	85%	**2**	15%
	col %	48%		33%	
type of incentive	**rebate**	**5**	71%	**2**	29%
	col %	22%		33%	
	discount	**11**	85%	**2**	15%
	col %	48%		33%	
	subsidy	**6**	86%	**1**	14%
	col %	26%		17%	
	match	**1**	50%	**1**	50%
	col %	4%		17%	
mechanism by which incentive provided	**electronic**	**13**	87%	**2**	13%
	col %	57%		33%	
	physical	**10**	71%	**4**	29%
	col %	43%		67%	
frequency with which incentive provided	**each trans**	**12**	86%	**2**	14%
	col %	52%		33%	
	weekly/2x month	**2**	67%	**1**	33%
	col %	9%		17%	
	monthly/bimonthly	**8**	100%	**0**	0%
	col %	35%		0%	
	once	**1**	25%	**3**	75%
	col %	4%		50%	
immediate vs. future use of incentive	**immediate**	**12**	86%	**2**	14%
	col %	52%		33%	
	future	**11**	73%	**4**	27%
	col %	48%		67%	
site where incentive provided	**cafeteria/consumption**	**3**	75%	**1**	25%
	col %	13%		17%	
	electronically	**4**	80%	**1**	20%
	col %	17%		17%	
	store/FM/purchasing site	**8**	89%	**1**	11%
	col %	35%		17%	
	mail	**3**	100%	**0**	0%
	col %	13%		0%	
	multiple (store+cafeteria)	**1**	100%	**0**	0%
	col %	4%		0%	
	clinic/WIC	**3**	60%	**2**	40%
	col %	13%		33%	
	Not reported	**1**	50%	**1**	50%
	col %	4%		17%	

Characteristic	Value	Signif		Non-signif	
		N	Row %	N	Row %
Number of studies total (29)		**23**	79%	**6**	21%
site where incentive used	**cafeteria**	**5**	83%	**1**	17%
	col %	22%		17%	
	farmers market	**3**	60%	**2**	40%
	col %	13%		33%	
	store	**11**	85%	**2**	15%
	col %	48%		33%	
	multiple sites	**4**	80%	**1**	20%
	col %	17%		17%	
duration of provision of incentive (weeks)	**3-7.9**	**4**	67%	**2**	33%
	col %	17%		33%	
	8-23.9	**9**	69%	**4**	31%
	col %	39%		67%	
	24+	**10**	100%	**0**	0%
	col %	43%		0%	
co-intervention added to incentive	**absent**	**5**	71%	**2**	29%
	col %	22%		33%	
	present	**18**	82%	**4**	18%
	col %	78%		67%	
type of healthy food	**alt healthy foods**	**9**	90%	**1**	10%
	col %	39%		17%	
	all FV	**9**	90%	**1**	10%
	col %	39%		17%	
	fresh FV	**5**	56%	**4**	44%
	col %	22%		67%	
participant income (of 22 studies reporting)	**mixed/high**	**6**	100%	**0**	0%
	col %	35%		0%	
	low	**11**	69%	**5**	31%
	col %	65%		100%	
participant race (of 20 studies reporting)	**non-white**	**8**	73%	**3**	27%
	col %	50%		75%	
	white	**8**	89%	**1**	11%
	col %	50%		25%	
study design: comparison group	**yes**	**14**	82%	**3**	18%
	col %	61%		50%	
	no	**9**	75%	**3**	25%
	col %	39%		50%	
study design: randomized and controlled	**RCT**	**11**	85%	**2**	15%
	col %	48%		33%	
	non RCT controlled	**2**	67%	**1**	33%
	col %	9%		17%	
	non RCT - uncontrolled	**10**	77%	**3**	23%
	col %	43%		50%	
study design: outcome quality	**higher**	**14**	93%	**1**	7%
	col %	61%		17%	
	lower	**9**	64%	**5**	36%
	col %	39%		83%	
study design: retention and missing data quality	**higher**	**13**	81%	**3**	19%
	col %	57%		50%	
	lower	**10**	77%	**3**	23%
	col %	43%		50%	

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