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A Meta-analysis of Food Labeling Effects on Consumer Diet Behaviors and Industry Practices

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Abstract

Context: The influence of food and beverage labeling (food labeling) on consumer behaviors, industry responses, and health outcomes is not well established.

Evidence acquisition: PRISMA guidelines were followed. Ten databases were searched in 2014 for studies published after 1990 evaluating food labeling and consumer purchases/orders, intakes, metabolic risk factors, and industry responses. Data extractions were performed

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The dataset was curated from published sources, cited herein. Full statistical code available from the first author at sysgserene@gmail.com.

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independently and in duplicate. Studies were pooled using inverse-variance random effects meta-analysis. Heterogeneity was explored with I^2, stratified analyses, and meta-regression; and publication bias was assessed with funnel plots, Begg's tests, and Egger's tests. Analyses were completed in 2017.

Evidence synthesis: From 6,232 articles, a total of 60 studies were identified including 2 million observations across 111 intervention arms in 11 countries. Food labeling decreased consumer intakes of energy by 6.6% (95% CI= −8.8%, −4.4%, *n*=31), total fat by 10.6% (95% CI= −17.7%, −3.5%, *n*=13), and other unhealthy dietary options by 13.0% (95% CI= −25.7%, −0.2%, *n*=16), while increasing vegetable consumption by 13.5% (95% CI=2.4%, 24.6%, *n*=5). Evaluating industry responses, labeling decreased product contents of sodium by 8.9% (95% CI= −17.3%, −0.6%, *n*=4) and artificial trans fat by 64.3% (95% CI= −91.1%, −37.5%, *n*=3). No significant heterogeneity was identified by label placement or type, duration, labeled product, region, population, voluntary or legislative approaches, combined intervention components, study design, or quality. Evidence for publication bias was not identified.

Conclusions: From reviewing 60 intervention studies, food labeling reduces consumer dietary intake of selected nutrients and influences industry practices to reduce product contents of sodium and artificial trans fat.

CONTEXT

Poor diet, as a risk factor of obesity and noncommunicable disease, is a leading cause of poor health in the U.S. and globally.[1,2] Effective strategies are needed to improve both consumer choices and industry formulations. Food and beverage labeling (food labeling) is increasingly being implemented. Examples include the Nutrition Facts panel,[3] menu calorie labels,[4–6] "traffic light" labels,[7,8] logos such as "Green Keyhole,"[9] "Choice,"[10] and "Heart-Check,"[11] and nutrition or health-related claims.

Although food labeling is widely used and undergoing expansion, early research mostly focused on its influence on consumer attention or awareness, without documenting its effects on actual purchases or intakes.[12–21] Currently a growing number of studies have investigated the effects of food labeling on consumer behaviors.[22] Yet, the results of the individual studies have been inconsistent, and effectiveness of food labeling remains unclear.[23,24] Several reviews provided important insights into labeling,[25−28] yet few quantitative meta-analyses have been performed to pool findings across studies, typically focusing on a subset of the evidence, a specific type of label, or a specific dietary target.[29–31] From prior scoping reviews,[22,23] key gaps were identified in literature including quantitative evidence synthesis of diverse labeling approaches that allows the assessment of overall effects and a comparison of effects of different labeling types.

In addition to effects on consumers, food labeling policies are of interest for effects on industry responses.[32,33] For example, experience in the U.S. suggested that mandatory addition of trans fat content to the Nutrition Facts label led to food reformulation.[34] Conventional wisdom holds that food labeling could influence industry responses and reformulations, yet such responses have not been systematically reviewed.

This study aims to characterize using a systematic review and meta-analysis the quantitative effects of labeling across multiple approaches, to provide effects estimates, uncertainties, and heterogeneities including stratified analyses, and to assess responses of both consumers and industry. This investigation was performed as part of the Food-PRICE (Policy Review and Intervention Cost-Effectiveness) Project (www.food-price.org).

EVIDENCE ACQUISITION

The authors followed the PRISMA guidelines during all stages of design, implementation, and reporting.[35] The study objective, search strategy, and selection criteria were specified in the study protocol (Appendix). This study was not registered in the International Prospective Register of Systematic reviews (PROSPERO) database.

Primary Intervention and Outcomes

Food labeling was evaluated as the primary intervention, characterized as (1) package labeling: all types of standardized provision of nutrition content or healthfulness information on packages, such as nutrient content, nutrition and health-related claims, icons, symbols and logos implemented by government, industry groups or associations, or other non-governmental organizations (i.e., excluding marketing labels developed by individual manufacturers or sellers of the product itself); and (2) menu or other point-of-purchase labeling: standardized provision of nutrition content or healthfulness information at the point-of-purchase including restaurant menus, supermarket or grocery stores, cafeterias, food retail/self-service establishments, and vending machines. Both voluntary and mandatory approaches were included. This study did not include labels only providing ingredient information (e.g., percentage juice), preparation directions, allergen or safety warnings, non-nutritional information (e.g., alcohol content), or ad hoc labeling defined and implemented by individual manufacturers, which were more consistent with nonstandardized marketing. For large-sized printing materials placed adjacent to food/beverage products, careful case-by-case differentiation was made: those denoting the nutrition or healthfulness information of a specific product were included, whereas general dietary health-promoting educational posters and non-nutritional sales-promoting commercial advertisements were excluded.

The outcomes of interests were (1) consumer behaviors, including dietary consumption of labeled foods/beverages and sales/purchases data as proxy measures for consumption; (2) industry responses (i.e., changes in formulations or availabilities of products); and (3) diet-related health measures, including adiposity (e.g., weight, BMI), metabolic risk factors (e.g., blood pressure, serum lipids), and clinical endpoints (e.g., coronary heart disease, diabetes mellitus). This meta-analysis included laboratory studies if foods were ordered and consumed; the meta-analysis excluded cognitive outcomes, such as knowledge, attitudes, or awareness, as well as intended dietary intakes/purchases. Studies had to provide outcome results data that were detailed enough for effective size calculation as specified in the Appendix. Examples of excluding reasons: not reporting sample size of the interested group or arm,[36,37] not reporting mean value or its uncertainty of the interested group or arm,[38] or both.[39–44]

Search Strategy

Ten online English databases were systematically searched through February 28, 2014: PubMed, Embase, CABI, Web of Science, CINAHL, EconLit, PAIS, Cochrane Library, U.S. Department of Agriculture Economic Research Service (USDA-ERS), and Faculty of 1000. Search queries included categories on setting (e.g., school, supermarket, restaurant), intervention (e.g., nutrition logo, Nutrition Facts, traffic light), and outcome (e.g., calories, adiposity, coronary heart disease, reformulation). Search terms, dates, and results are provided in the Appendix. Online searches were complemented by hand-searching of reference lists as well as the first 20 "related articles" in PubMed for each included article through May 22, 2015. For all relevant review articles identified through database searches, their reference lists were manually searched. Gray literature was not searched. One investigator screened titles and abstracts. For any potentially relevant articles, full texts were assessed for eligibility by two investigators independently and in duplicate. Discrepancies were resolved by consensus.

Study Selection

This study searched for all intervention studies including natural experiments that assessed the relationship between food labeling and the outcomes and provided an estimate and a measure of uncertainty or sufficient data to calculate these. Articles were excluded if single time point cross-sectional studies, commentaries, reviews, duplicate publications from the same study that did not provide new data, or publications prior to January 1, 1990. Nonrandomized intervention studies having either a pre-/post- or external comparison were included, as each study design has differing strengths and limitations. This included natural experiments with the outcomes assessed over time by cross-sectional sampling.[45] This meta-analysis sought to include, as much as possible, investigations that aimed to assess the independent effect of labeling without other major legislative or regulatory interventions, as independently adjudicated by two investigators. Multicomponent interventions were evaluated as a potential source of heterogeneity.

Data Extraction

Two investigators extracted data independently and in duplicate using a standardized electronic format, including: (1) general information (i.e., first author, publication year, study region, design, funding source, site, population setting, consumers demographics), (2) intervention characteristics (i.e., legislation, labeled product, label placement, label type, dietary target, other intervention measures if multicomponent, intervention duration, intervention coverage), and (3) outcome data (i.e., outcome definition, inclusion of compensatory dietary intake outside labeling intervention timeframe, ascertainment method, unit, variable type, sample size, central tendency, uncertainty, and adjusted covariates). Multiple scoring systems are available to assess study quality and risk of bias, without any single accepted standard. This investigation elected to use a previously published scoring system that allows grading across different study designs.[46–48] Two investigators independently assessed study quality based on five criteria: study design, assessment of exposure, assessment of outcome, control for confounding, and evidence of selection bias (Appendix Table 1). For each criterion, each study received a score of 0 or 1 (1 being better).

A total quality score was calculated by summing individual scores, with 3–5 considered high quality. Discrepancies in data extraction and quality assessment between investigators were resolved by consensus.

Statistical Analysis

The primary outcomes were pooled across labeling interventions. Stratified results were also evaluated based on study design, label types, and placements. The primary outcomes were differences in consumer dietary behaviors and diet-related health outcomes, as well as industry responses in product formulations/availabilities. Continuous outcomes were standardized as percentage differences from either baseline or control groups, based on the study design (Appendix). For categorical outcomes (e.g., percentage of people selecting a specific food item), effect sizes were calculated as the absolute difference of percentages. For outcomes with at least three study estimates reported, study-specific effect sizes were pooled using inverse-variance weighted random effect meta-analysis (*metan* command in Stata). Uncommon outcomes (two or fewer estimates reported) were pooled together as other healthy options or other unhealthy options based on whether they were recommended to be consumed or avoided by the label (detailed lists of items found in the footnotes for Tables 2, 3, and Appendix Table 12). Heterogeneity was assessed by the I^2 statistic. Potential sources of heterogeneity were assessed using meta-regression (*metareg* command in Stata), including region, design, site, consumers demographics, legislation, label placement and type, labeled product, dietary target, single or multicomponent intervention, duration, intervention coverage, compensatory dietary intake, and quality score. To maximize statistical power and minimize the number of comparisons, meta-regression was only performed for outcomes with ten or more estimates. Publication bias was assessed by visual inspection of funnel plots and Egger's and Begg's tests. Analyses were conducted using Stata, version 13.0 with two-tailed α value of 0.05.

EVIDENCE SYNTHESIS

Study Characteristics

From 5,378 identified abstracts, 668 USDA-ERS websites, and 186 full-text articles identified from hand searching of reference lists and related articles in PubMed, 60 studies from 59 articles met inclusion criteria, comprising 2,078,043 unique observations (consumers, receipts, purchases) across 111 intervention arms (Figure 1). These included 16 randomized[49–64] and 44 nonrandomized[45,65–106] intervention studies conducted in 11 countries across four continents (Table 1, Appendix Tables 3–11). The majority included both sexes, and most evaluated adults. Populations of a range of SES were evaluated. A total of 60.0% of studies had high quality scores of ≥3.

Most studies evaluated intakes of specific products or meals as outcomes, rather than long-term (habitual) intakes. About half were performed in general community,[45,52,53,55–58,61,71–81,84,85,90–93,97,98,101,103–106] and half in universities/schools[49,54,59,60,62–64,70,83,88,89,99,100,102] or hospitals/other worksites[50,51,65–69,86,87,94–96] (Table 1). Overall across these population settings, sites of interventions were relatively evenly divided between cafeterias,[49–51,65–70,86–90] restaurants,[45,52,71–77,90–97] supermarkets/

shops/vending machines,[53,54,78–82,96–103] and laboratories (mostly in RCTs).[55–63,83,84] Label placements included packages (21.7%),[55,58,60,63,66,80,87,97,98,103–106] menus (38.3%),[45,49,52,56,57,61,66–68,71–77,87,90–92,94,95,101] and other point-of-purchase (on shelf, vending machines, posters; 30.0%).[53,54,62,66,69,70,78,79,81,82,84,87,88,96,99–102] The various label approaches were categorized into five types: content quantity, nutrition or health-related claims, logos, grading systems, and physical activity equivalents (Appendix Table 2). Most labels targeted total energy or specific nutrients.

Across all studies, the average intervention duration was 69.8 weeks (range, 3 days to 9 years), except for laboratory studies, which were typically conducted over one to three sessions. In 14 studies, food labeling was combined with other components such as education, mass media campaigns, economic incentives, or direct regulation (restrictions, bans, requirements of the contents or availabilities of certain nutrients or food/beverage items).[50,53,54,59,68,69,71,78,79,81,85,86,96,102] Most studies were funded by nonprofit sources including government, academic institutions, or other organizations; two studies received financial support from both government and industry sources.[60,65]

Consumer Behaviors

In pooled analyses (Table 2), food labeling reduced intakes of energy by 6.6% (95% CI= −8.8%, −4.4%. *n*=31 estimates; Appendix Figures 1 and 2), total fat by 10.6% (95% CI= −17.7%, −3.5%, *n*=13; Appendix Figures 3 and 4), and other unhealthy options by 13.0% (95% CI= −25.7%, −0.2%, *n*=16). Food labeling increased vegetable consumption by 13.5% (95% CI=2.4%, 24.6%, *n*=5; Appendix Figures 13 and 14). A borderline, nonstatistically significant reduction was seen for sodium (−15.3%, 95% CI= −31.3%, 0.7%, *n*=5; Appendix Figures 11 and 12). Labeling did not significantly alter intakes of other dietary targets including total carbohydrate (Appendix Figures 5 and 6), protein (Appendix Figures 7 and 8), saturated fat (Appendix Figures 9 and 10), fruits (Appendix Figure 15 and 16), whole grains (Appendix Figures 17 and 18), or other healthy options.

Several studies reported both objective sales/purchase data and self-reported intake data for total energy (*n*=5),[49,56,57,61,70] total fat (*n*=3),[49,57,70] total carbohydrate (*n*=2),[49,57] total protein (*n*=2),[49,57] and saturated fat (*n*=1).[57] Pooled results prioritizing either sales/purchase or intake data from these studies did not materially alter the results (Table 2 versus Appendix Table 12).

In studies evaluating traffic light systems that included three tiers (Table 3), labeling increased the selections of healthier green (+1.9%, 95% CI=1.8%, 2.0%) and mid-level (+0.4%, 95% 0=0.3%, 0.5%) options, and reduced selection of less healthy red options (−2.3%, 95% CI= −2.4%, −2.2%; Appendix Figure 19). Evaluated in two tiers, food labeling significantly altered the percentage of healthier options selected (+6.1%, 95% 0=2.6%, 9.5%, *n*=16 estimates), but not unhealthy options (−0.9%, 95% CI= −4.6%, 2.8%, *n*=22).

Adiposity, Metabolic Risk Factors, and Clinical Endpoints

Very few studies evaluated adiposity (*n*=2)[50,85] or metabolic risk factors (*n*=4).[50,85,103,104] Because of heterogeneity across the outcomes in these studies, quantitative meta-analysis could not be performed. No identified studies evaluated disease endpoints.

Industry Responses

Reformulation outcomes were evaluated by six studies (Appendix Table 13, Appendix Figures 20–24). Food labeling significantly reduced the contents of trans fat (−64.3%, 95% CI= −91.1%, −37.5%, n=3) and sodium (−8.9%, 95% CI= −17.3%, −0.6%, n=4). Significant effects were not identified on product contents of total energy, saturated fat, dietary fiber, or other healthy (protein and unsaturated fat) or unhealthy (total fat, sugar, and dietary cholesterol) dietary components. Few studies evaluated changes in product availability (n=3),[74,89,96] with heterogeneity in these studies precluding pooling.

Exploration of Heterogeneity

Statistical heterogeneity was seen in many of the pooled analyses. In univariate meta-regression, the authors explored whether the effectiveness of labeling varied depending on underlying population and labeling characteristics (Appendix Table 14). Given multiple comparisons, the focus was on potential interactions with $p_{\text{interaction}}<0.01$. Findings were similar when stratified by interventional designs (randomized, nonrandomized), label placements (menu, package, other point-of-purchase), or label types (Appendix Tables 15, 16). Interventions of longer duration observed larger effects of labeling on consumer intake of total fat ($p_{\text{interaction}}<0.01$), but not on total energy intake. No significant heterogeneity was identified by world region, study design, population, age, sex, race, SES, type of intervention site, labeled products, voluntary or mandatory labeling, presence of other intervention components, inclusion of compensatory intake, or study quality score ($p_{\text{interaction}}>0.01$ each).

Publication Bias

Visual inspection of funnel plots suggested potential publication bias for lower intake of total energy and total fat, but not for other outcomes (Appendix Figures 25–27). Neither Begg's test nor Eggers test identified significant evidence for publication bias (p>0.05 each).

DISCUSSION

In this systematic review and meta-analysis of 60 studies including 111 intervention arms and more than 2 million observations across 11 countries, food labeling reduced consumer consumption of total energy and total fat, while increasing consumption of vegetables. Food labeling did not significantly alter consumer intakes of other dietary targets including sodium, total carbohydrate, protein, saturated fat, fruits, or whole grains. This meta-analysis also found that food labeling altered industry formulations for sodium and trans fat, but did not significantly affect product formulations for total energy, saturated fat, dietary fiber, or other healthy/unhealthy dietary components. To the authors' knowledge, this is the first systematic assessment of the quantitative effects of diverse types of food labeling strategies on both consumers' dietary intakes and health outcomes, and industry responses.

In the past two decades, various types of food labeling have been developed, with the initial efforts mostly focusing on packaged foods. In the U.S., the 1990 Nutrition Labeling and Education Act mandated the placement of the Nutrition Facts panel on packaged foods and the use of the Food and Drug Administration-authorized nutrient-content and health claims.

[107] Later that decade, the Dietary Supplement Health and Education Act and Food and Drug Administration Modernization Act established requirements and procedures for other claims, including structure/function, general well-being and nutrient deficiency claims, as well as claims based on "authoritative statements" from scientific bodies.[107,108] In 1989, Sweden created The Keyhole logo, which later became a common Nordic label by expanding to Denmark and Norway in 2009 and Iceland in 2013.[109–111] However, many manufacturers of eligible products choose not to add this voluntary label, and the Swedish National Food Agency is planning an investigation into the causes of the low uptake.[112] The Netherlands Choice logo was launched in 2006 on products containing higher fiber and lower sodium, added sugar, saturated fat, trans fat, and total energy[110,113,114] and has been implemented in Belgium, Poland, the Czech Republic, Argentina, and Nigeria.[115] With mounting criticism especially that consumers found the Choice logo confusing,[116] the Dutch government in 2016 ordered it to be replaced with a cellphone app.[117] In 2006, the United Kingdom Food Standards Agency recommended a voluntary front-of-pack traffic-light labeling system to highlight contents of total fat, saturated fat, sugar, and sodium in selected food categories.[7,118] In 2015, Chile launched a comprehensive black warning logo program, informing consumers of foods higher in sugar, saturated fat, salt, or energy.[119] Other new front-of-pack labels include the Heart Symbol in Finland[120]; the Health Star Ratings[121] and the Pick the Tick logo[122,123] in Australia and New Zealand; and Nuval,[124] Guiding Stars,[125] Smart Choices,[126] and Heart-Check[127] in the U.S. More recently, the labeling in restaurants and cafeterias has been increasingly considered,[5,128] especially after the 2010 Patient Protection and Affordable Care Act required restaurant chains with 20 or more locations to list calorie counts of standard menu items.[4]

Although the aim of these extensive labeling efforts is to help consumers make informed and healthier choices, and potentially influence manufacturer and restaurant offerings, evidence on these effects had been relatively sparse. Previous systematic reviews and meta-analyses primarily concentrated on a specific type of labels or a specific dietary target, with inconsistent results. Several meta-analyses on effectiveness of menu labeling on total energy intake reported inconsistent findings.[29,30,129,130] In one analysis, health-related claims were found to increase consumption and purchases of the labeled products.[31] A pooled analysis of nine trials found that labeling systems increased selection of healthier products, but did not alter energy intake.[131] In a meta-analysis of 14 studies, menu labeling did not significantly alter intakes of carbohydrate, total fat, saturated fat, sodium, or energy consumed among U.S. adults.[132] Most recently, an analysis of 28 studies concluded that evidence was inconclusive for effectiveness of various types of labeling.[133] The present investigation builds upon and extends the prior evidence by including more studies, more comprehensive types of labeling, and both consumer and industry responses. This allowed new confirmation of significant effects of labeling on consumer intakes and orders of total energy, total fat, and vegetables, and industry formulations of sodium and trans fat.

This meta-analysis identified no significant effects of labeling on several other consumer and industry targets. Because many of these analyses included fewer studies and the nonsignificant results were often in expected directions, these findings demonstrate a need for additional investigation of these and other specific dietary targets. It is also possible that those dietary outcomes are not the primary targets of the labels, for example most of the labels investigated targeted energy calories and it is questionable if such labels would shift whole grain intake. Alternatively, for certain choices labeling alone may be ineffective. Many barriers exist to consumers responses to labeling, such as limited awareness,[12] attention,[134] understanding,[135] attitude,[136] acceptance,[137] usage,[138] or other challenges such as price, taste, and culture.[32,139,140] Other complementary approaches may be crucial, such as choice architecture, economic incentives, novel technologies, mass media campaigns, quality standards, neighborhood environment, and organizational innovations in schools, worksites, and communities.[22,23,47,48,141] This meta-analysis also calls for future investigations about the effectiveness of food labeling for improving health outcomes and disease risk factors, because there has been evidence that selecting label-recommended products is associated with lower cardiometabolic syndrome risk.[142]

It has been proposed that an ideal label should use a simple, interpretative, and standardized symbol, with consistent format and location.[32] Other proposals have favored rating systems, such as the traffic light or Health Star Ratings.[33, 137, 143] This study did not identify consistent differential effects according to label type, placement, intervention duration, or mandatory versus voluntary labeling. This suggests that varieties of labeling may be less quantitatively relevant than the general presence or absence of information to consumers. Other potential sources of heterogeneity were also not significant, although the numbers of studies may limit the statistical power of such assessments.

Food labeling is a dynamic and evolving policy issue, with industry regularly reformulating or eliminating products to meet mandatory or voluntary guidelines. Among the seven dietary factors evaluated, significant industry responses to labeling were seen only for sodium and trans fat. Of note, industrial additives constitute the predominant dietary sources of these two components,[144–146] which can be added to or removed from otherwise similar foods or meals. This suggests that industry responses to labeling may be greatest for additives, compared with intrinsic components of foods, such as macronutrients or energy. With recent efforts in many countries on labeling of added sugars, it will be important to evaluate whether such labeling influences the industry use of this additive. These findings highlight the relative paucity of data in this area.

This meta-analysis did not identify a consistent gradient in responses by SES, age, or sex. This is contrasted to prior reports based on smaller samples, suggesting that these factors may modify the labeling efficacy.[22,32] Yet, although this meta-analysis represents the most comprehensive assessment of these questions to date, only 35 studies (58%) reported socioeconomic information which were defined based on various factors (education, income, etc.). Clearly, the determinants of potentially varying effects of labeling require further studies, and conventional wisdom on modifying effects of population demographics should not be considered a tautology.

This meta-analysis has several strengths. The searches were conducted in multiple databases and citation lists and related articles were manually reviewed, reducing the likelihood of missing multiple or large studies. Inclusion decisions and data extractions were performed independently and in duplicate, reducing potential for errors and bias. A wide range of labels and outcomes were evaluated, increasing its generalizability and making heterogeneity assessment possible. Hypothetical outcomes like purchase intention were excluded, resulting in findings more reflective of real-world behaviors. By including both purchase/sales and consumption results as well as analyzing them separately and altogether, this meta-analysis demonstrated consistent findings across these methods while also increasing the numbers of included studies. Several potential sources of heterogeneity were explored with greater statistical power than previously possible. Finally, responses of both consumers and industry were evaluated, providing complementary information on relevance of labeling efforts.

Limitations

Limitations should be considered. The interventions and settings were extremely heterogeneous, and although the authors carefully documented and explored potential sources of variation, there are likely remaining differences modifying effectiveness. All studies were interventional, yet many were not randomized; conversely, many of the nonrandomized interventions were natural experiments, increasing generalizability.[147] Nearly one quarter of the interventions combined other components, although no evidence was found that these studies had larger effect sizes. Some studies could not be included because of the absence of reported uncertainty or sample size. Searches were performed through 2015, and several newer studies have been published. Given the number of studies already included in the meta-analysis, it is unclear whether the addition of a few new studies would greatly alter many of the conclusions, which can be tested in future updates to this work. In addition, although some recent studies not included here assessed front-of-pack grading systems, such as Health Star Ratings in Australia/New Zealand and NutriScore in France, findings of these studies have been inconsistent[148–150] and often evaluated knowledge or attitudes rather than actual purchasing or consumption.[151]

CONCLUSIONS

From the results of 60 intervention studies, food labeling effectively reduces consumer intakes of total energy and total fat while increasing intake of vegetables. Food labeling also influences industry responses related to product contents of sodium and artificial trans fat. More studies are needed to assess the effects of labeling on other dietary targets, disease risk factors, and clinical endpoints.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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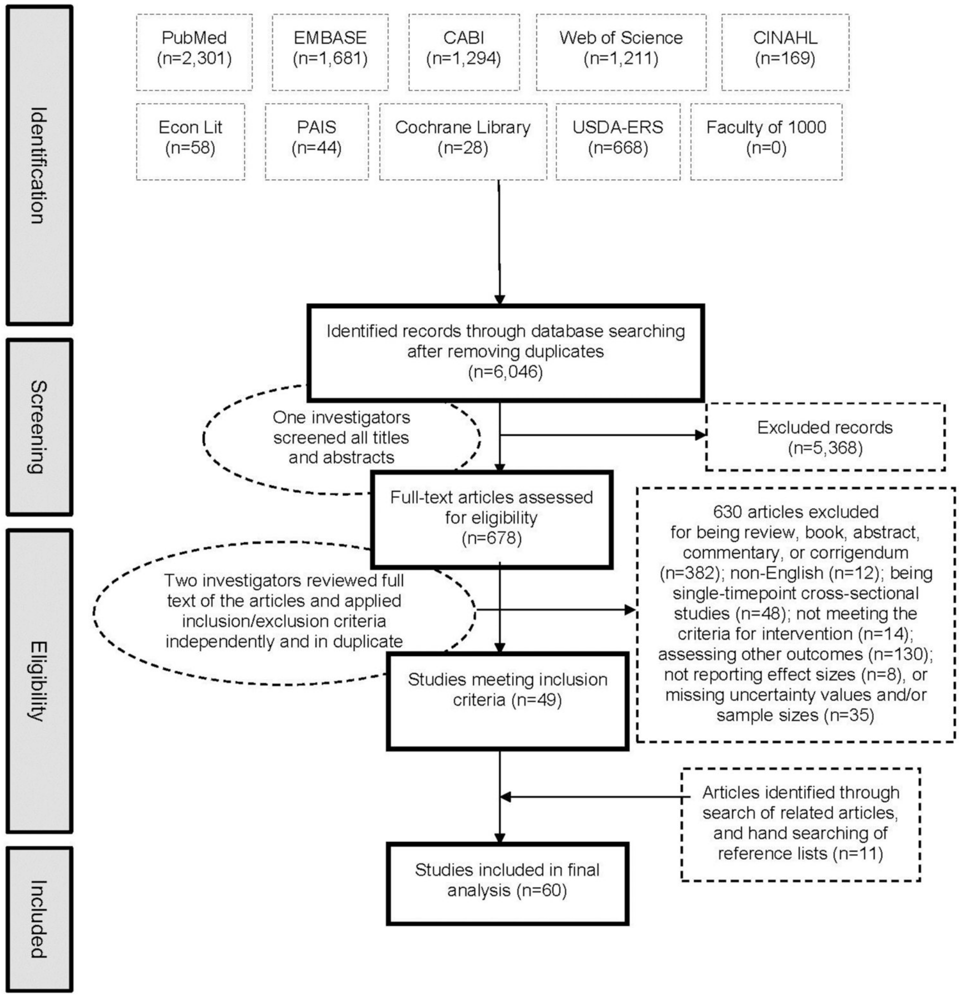

Figure 1.

Screening and selection process for intervention studies evaluating food labeling effects on consumer diet behaviors and industry practices.

Table 1.

Summary of 60 Interventional Trials Evaluating the Effectiveness of Food and Menu Labeling on Consumer and Industry Behavior[a]

Study characteristics	RCTs (n=16)	Interventions with external controls (n=23)	Interventions with pre/post comparisons (n=21)	All studies (n=60)
Region				
U.S./Canada	12 (75.0)	17 (73.9)	14 (66.7)	44 (73.3)
Europe/Australia	4 (25.0)	5 (21.7)	5 (23.8)	14 (23.3)
Asia	0 (0.0)	1 (4.3)	1 (4.8)	2 (3.3)
Site[b,c]				
Cafeterias	3 (18.8)	6 (26.1)	5 (23.8)	14 (23.3)
Restaurants	1 (6.3)	8 (34.8)	8 (38.1)	17 (28.3)
Supermarkets/Shops/Vending	2 (12.5)	6 (26.1)	7 (33.3)	15 (25.0)
Labs	10 (62.5)	3 (13.0)	0 (0.0)	13 (21.7)
Multiple food establishments	0 (0.0)	0 (0.0)	1 (4.76)	1 (1.7)
Not reported	0 (0.0)	0 (0.0)	3 (14.3)	3 (5.0)
Population setting				
University/School	7 (43.8)	3 (13.0)	5 (23.8)	15 (25.0)
Hospital/Worksite	2 (12.5)	5 (21.7)	5 (23.8)	12 (20.0)
Community/Recreational[d]	7 (43.8)	15 (65.2)	11 (52.4)	33 (55.0)
Mean age, years[e]	29.7 (21.8, 44.2)	30.1 (19.7, 50.1)	21 (21.0, 21.0)	29.5 (19.7, 50.1)
Sex, % men[e]	40.2 (0.0, 62.0)	42.3 (0.0, 100.0)	41.8 (0.0, 70.0)	41.2 (0.0, 100.0)
Race[f]				
Mostly white	7 (43.8)	2 (8.7)	2 (9.5)	11 (18.3)
Black or mostly black	0 (0.0)	4 (17.4)	2 (9.5)	6 (10.0)
Mostly Asian or Hispanic	0 (0.0)	2 (8.7)	0 (0.0)	2 (3.3)
Mixed	1 (6.3)	0 (0.0)	1 (4.8)	2 (3.3)
Not reported or not applicable	8 (50.0)	15 (65.2)	16 (76.2)	39 (65.0)
SES[f]				
High or mostly high	6 (37.5)	0 (0.0)	0 (0.0)	6 (10.0)
Mixed	8 (50.0)	5 (21.7)	4 (19.0)	17 (28.3)
Low or mostly low	1 (6.3)	7 (30.4)	4 (19.0)	12 (20.0)
Other or not reported	1 (6.3)	11 (47.8)	13 (61.9)	25 (41.7)
Label placement[c]				
Menu	5 (31.3)	11 (47.8)	7 (33.3)	23 (38.3)
Package	4 (25.0)	2 (8.7)	7 (33.3)	13 (21.7)
Other point-of-purchase	3 (18.8)	8 (34.8)	7 (33.3)	18 (30.0)
Not reported	4 (25.0)	4 (17.4)	3 (14.3)	11 (18.3)
Labeled information[c]				

Study characteristics	RCTs (n=16)	Interventions with external controls (n=23)	Interventions with pre/post comparisons (n=21)	All studies (n=60)
Content quantity	10 (62.5)	14 (60.9)	14 (66.7)	38 (63.3)
Content claim or health claim	9 (56.3)	4 (17.4)	3 (14.3)	16 (26.7)
Logo	4 (25.0)	7 (30.4)	2 (9.5)	13 (21.7)
Grading system	2 (12.5)	3 (13.0)	4 (19.0)	9 (15.0)
Physical activity equivalent	1 (6.3)	0 (0.0)	2 (9.5)	3 (5.0)
Labeled product				
Meals	7 (43.8)	15 (65.2)	10 (47.6)	32 (53.3)
Single foods/beverages	6 (37.5)	3 (13.0)	3 (14.3)	12 (20.0)
Multiple	3 (18.8)	5 (21.7)	8 (38.1)	16 (26.7)
Dietary target[c]				
Calories	9 (56.3)	17 (73.9)	12 (57.1)	38 (63.3)
Nutrients	11 (68.8)	15 (65.2)	14 (66.7)	40 (66.7)
Food or beverage items	2 (12.5)	4 (17.4)	2 (9.5)	8 (13.3)
Not reported	0 (0.0)	0 (0.0)	2 (9.5)	2 (3.3)
Intervention duration, weeks[g]	3.4 (0.1, 26.0)	53.2 (0.1, 364.0)	93.6 (1.0, 468.0)	69.8 (0.1, 468.0)
Label mandated by law	0 (0.0)	6 (26.1)	8 (38.1)	14 (23.3)
Nationwide implementation	0 (0.0)	1 (4.3)	5 (23.8)	6 (10.0)
Additional intervention components[c]				
None (single component)	12 (75.0)	16 (69.6)	18 (85.7)	46 (76.7)
Education	2 (12.5)	1 (4.3)	0 (0.0)	3 (5.0)
Mass media campaign	1 (6.3)	4 (17.4)	1 (4.8)	6 (10.0)
Economic incentives	2 (12.5)	2 (8.7)	0 (0.0)	4 (6.7)
Direct regulation	1 (6.3)	4 (17.4)	3 (14.3)	8 (13.3)
Outcomes evaluated[c]				
Calories	7 (43.8)	12 (52.2)	7 (33.3)	26 (43.3)
Nutrients	7 (43.8)	6 (26.1)	6 (28.6)	19 (31.7)
Food or beverage items	9 (56.3)	11 (47.8)	13 (61.9)	33 (55.0)
Cardiovascular risk factors	2 (12.5)	3 (13.0)	0 (0.0)	5 (8.3)
Other	0 (0.0)	1 (4.3)	2 (9.5)	3 (5.0)
Outcome type[c]				
Sales	2 (12.5)	5 (21.7)	4 (19.0)	11 (18.3)
Purchases (or orders[h])	9 (56.3)	7 (30.4)	8 (38.1)	24 (40.0)
Consumption	11 (68.8)	10 (43.5)	3 (14.3)	24 (40.0)
Availability	0 (0.0)	1 (4.3)	2 (9.5)	3 (5.0)
Reformulation content	0 (0.0)	2 (8.7)	4 (19.0)	6 (10.0)
Adiposity	1 (6.3)	1 (4.3)	0 (0.0)	2 (3.3)
Cardiovascular biomarker	1 (6.3)	1 (4.3)	2 (9.5)	4 (6.7)
Funding[c]				
Academic	7 (43.8)	7 (30.4)	2 (9.5)	16 (26.7)

Study characteristics	RCTs (n=16)	Interventions with external controls (n=23)	Interventions with pre/post comparisons (n=21)	All studies (n=60)
Government	3 (18.8)	14 (60.9)	4 (19)	21 (35.0)
Other non-profit	2 (12.5)	4 (17.4)	9 (42.9)	15 (25.0)
Industry	1 (6.3)	1 (4.3)	0 (0.0)	2 (3.3)
Not reported	4 (25.0)	7 (30.4)	9 (42.9)	20 (33.3)
Quality score, range 0-5[i]	4.5 (3.0, 5.0)	2.2 (0.0, 4.0)	2.4 (0.0, 4.0)	2.9 (0.0, 5.0)

[a]Values are number of studies (percent) for categorical variables and mean (range) for continuous variables. Values may not sum to 100% due to rounding. Details on each of the 60 individual studies are provided in Appendix Tables 3–11.

[b]Study site: Cafeterias=canteen, dining hall, mess hall, kitchen; restaurants=fast food restaurants, carry-out restaurants, full-service restaurants, food outlets; labs or laboratories=classrooms, church rooms or other places serving other purposes rather than real food establishments.

[c]Because multiple responses possible for each study, proportions may sum to greater than 100%.

[d]Setting: Recreation facility=cinema, gym, swimming pool.

[e]Missing values: RCTs: 5 did not report mean age, 3 did not report % males; interventional trials with external controls: 10 did not report mean age, 7 did not report % males; interventional trials with per/post comparisons: 20 did not report mean age, 8 did not report % males.

[f]Population characteristics of the studied sample: not applicable (N/A) to reformulation or availability outcomes. Primary race is defined as ≥50% of the population; SES defined as primarily high: >50% of post-grad education, or high income; primarily low:>50% of blue collar, low income or did not finish college. Otherwise for articles directly reporting the SES status, this study cited the authors' SES category.

[g]Intervention duration: time from the implementation of food labeling to the time of outcome assessment in weeks. Studies conducted in single sessions were assigned value 0.1. One interventional trial with external control did not report duration.

[h]Orders were evaluated largely in laboratory settings, where meals were selected but not paid for. This study only included interventional studies in laboratory settings which evaluated the actual provision or serving of foods/beverages ordered, not theoretical orders.

[i]Calculated based on 5 criteria (Appendix Table 1), each coded as either 0 or 1 and with values summed. The total score could range from 0 to 5, with 3-5 considered as higher quality.

Table 2.

Meta-Analyses of Effects of Food Labeling Interventions on Consumer Dietary Behaviors (Continuous Outcomes)[a]

Dietary factor	Number of study estimates (individual studies)	Number of consumers or purchases	Percent difference with labeling (95% CI)[b]
Calories	31 (23)	43,707	−6.6 (−8.8. −4.4)
Total fat	13 (12)	4,409	−10.6 (−17.7.−3.5)
Total carbohydrate	8 (7)	1,928	2.2 (−5.1, 9.5)
Total protein	6 (5)	1,110	0.6 (−2.8, 4.0)
Saturated fat	5 (5)	2,227	−8.4 (−23.7, 6.8)
Sodium	5 (5)	2,016	−15.3 (−31.3, 0.7)
Vegetables	5 (5)	1,497	13.5 (2.4.24.6)
Fruits	3 (3)	1,103	10.9 (−16.0, 37.7)
Whole grains	3 (2)	760	14.4 (−11.8, 40.6)
Other healthy options[c]	30 (11)	2,685	−0.5 (−2.8, 1.7)
Other unhealthy options[d]	16 (7)	5,548	−13.0 (−25.7.−0.2)

[a]Food labeling (i.e., standardized provision of nutrition or health information) included product package, menu, or other point-of-purchase labeling. Dietary behaviors were evaluated by direct observation (e.g., weighed plate waste) or self-report from single sessions, 24-hour diet recalls, food diaries, or food frequency questionnaires; or as consumer purchases, food outlet sales, or choices/orders as a proxy for consumers' self-reported dietary intakes. When the same study evaluated both sales/purchase data and consumer intake data, the authors utilized sales/purchase data given its objectivity. Pooled findings prioritizing consumer intake data for these studies were not appreciably different (Appendix Table 12). Appendix Figures 1–18 show individual forest plots and more details on each meta-analysis. Results stratified by consumer intake vs purchases/sales are also available but not shown.

[b]Based on the units reported in the study (e.g., most commonly kcal for calories, gram or percent energy for dietary fats, servings or g/d for foods, etc).

[c]Items recommended by labels to consume, such as salads, soups, low-fat dairy, lean meat, low-fat desserts, fish and seafood, water, diet soda, and foods higher in dietary fiber, vitamin C, and calcium.

[d]Items recommended by labels to avoid, such as sugar-sweetened beverages, alcoholic beverages, non-alcoholic caloric beverages, French fries, potatoes, white bread, and foods higher in saturated fat, trans fat, added sugars or sodium.

Table 3.

Meta-Analyses of Effects of Food Labeling Interventions on Consumer Dietary Behaviors (Categorical Outcomes)[a]

Dietary factor	Number of study estimates (individual studies)	Number of consumers or purchases	Percent change with labeling (95% CI)[b]
Green options (traffic light system)	3 (3)	1,970,452	1,9 (1.8, 2.0)
Amber options (traffic light system)	3 (3)	1,970,452	0.4 (0.3, 0.5)
Red options (traffic light system)	3 (3)	1,970,452	−2.3 (−2.4. −2.2)
Other healthy options[c]	16 (11)	42,126	6.1 (2.6, 9.5)
Other unhealthy options[d]	22 (10)	33,990	−0.9 (−4.6, 2.8)

[a]Food labeling (i.e., standardized provision of nutrition or health information) includes product package, menu, or other point-of-purchase labeling. Dietary behaviors in these studies were evaluated as consumer purchases, food outlet sales, or choices/orders. Appendix Figure 19 shows individual forest plots and more details on each meta-analysis.

[b]The absolute difference in percentages of consumers or purchases making a certain selection.

[c]Items recommended by labels to consume, such as green salad, “healthy items” not otherwise specified, low-fat items, low-sodium items, moderately nutrient-dense snacks, and high nutrient-dense snacks.

[d]Items recommended by labels to avoid, such as sugar-sweetened beverages, large portion size sugar-sweetened beverages, caloric beverages, desserts, French fries, added cheese to hamburgers/sandwiches, full-fat meals or foods, high calorie meals, high saturated fat meals, high sodium meals, low vegetable content meals, and low nutrient-dense snacks.