Annual Review of Nutrition

The Influence of Front-of-Package Nutrition Labeling on Consumer Behavior and Product Reformulation

Christina A. Roberto,[1] Shu Wen Ng,[2] Montserrat Ganderats-Fuentes,[1] David Hammond,[3] Simon Barquera,[4] Alejandra Jauregui,[5] and Lindsey Smith Taillie[2]

[1]Department of Medical Ethics and Health Policy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA; email: croberto@pennmedicine.upenn.edu, mgandera@wharton.upenn.edu

[2]Department of Nutrition, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, North Carolina 27516, USA; email: shuwen@unc.edu, taillie@unc.edu

[3]School of Public Health and Health Systems, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada; email: david.hammond@uwaterloo.ca

[4]Department of Nutrition Policy Research, National Institute of Public Health, 62100 Cuernavaca, Mexico; email: sbarquera@insp.mx

[5]Department of Physical Activity and Healthy Lifestyles, National Institute of Public Health, 62100 Cuernavaca, Mexico; email: alejandra.jauregui@insp.mx

Annu. Rev. Nutr. 2021. 41:529–50

First published as a Review in Advance on August 2, 2021

The *Annual Review of Nutrition* is online at nutr.annualreviews.org

https://doi.org/10.1146/annurev-nutr-111120-094932

Keywords

front-of-package, food labeling, nutrition labeling, reformulation, dietary choices, natural experiments

Abstract

Countries worldwide have implemented mandatory or voluntary front-of-package nutrition labeling systems. We provide a narrative review of (*a*) real-world evaluations of front-of-package nutrition labels that analyze objective sales data and (*b*) studies that objectively assess product reformulation in response to a front-of-package nutrition label implementation. We argue that there is sufficient scientific evidence to recommend that governments implement mandatory front-of-package nutrition labeling systems to improve

population health. We also present a conceptual framework to describe front-of-package label influence and provide recommendations for the optimal label design, emphasizing that labeling systems should be highly visible and salient, be simple and easy to understand, leverage automatic associations, and integrate informational and emotional messaging. The existing research suggests that Guideline Daily Amount labels should be avoided and that the Health Star Rating and Nutri-Score systems are promising but that systems with warning labels like the one in Chile are likely to produce the largest public health benefits.

Contents

INTRODUCTION

Food labeling serves an important role in supporting public health. Detailed nutrition facts labels have been displayed on food products across the globe for a long time, though they vary across countries on the information that is required versus recommended (89). Although these labels provide important information, the information is dense and can be difficult to quickly understand and manipulate, often requiring numeric calculations. This is particularly worrisome for groups with lower education levels who may struggle with numeracy (54, 62). These concerns spurred a movement starting in the early 2000s to put key nutrition information on the front of packaged foods so that it is easily accessible to consumers at the point of purchase. Mandatory and voluntary nutrition labeling systems placed on the front of packages or on store shelves have been implemented in a number of countries and are recommended by the World Health

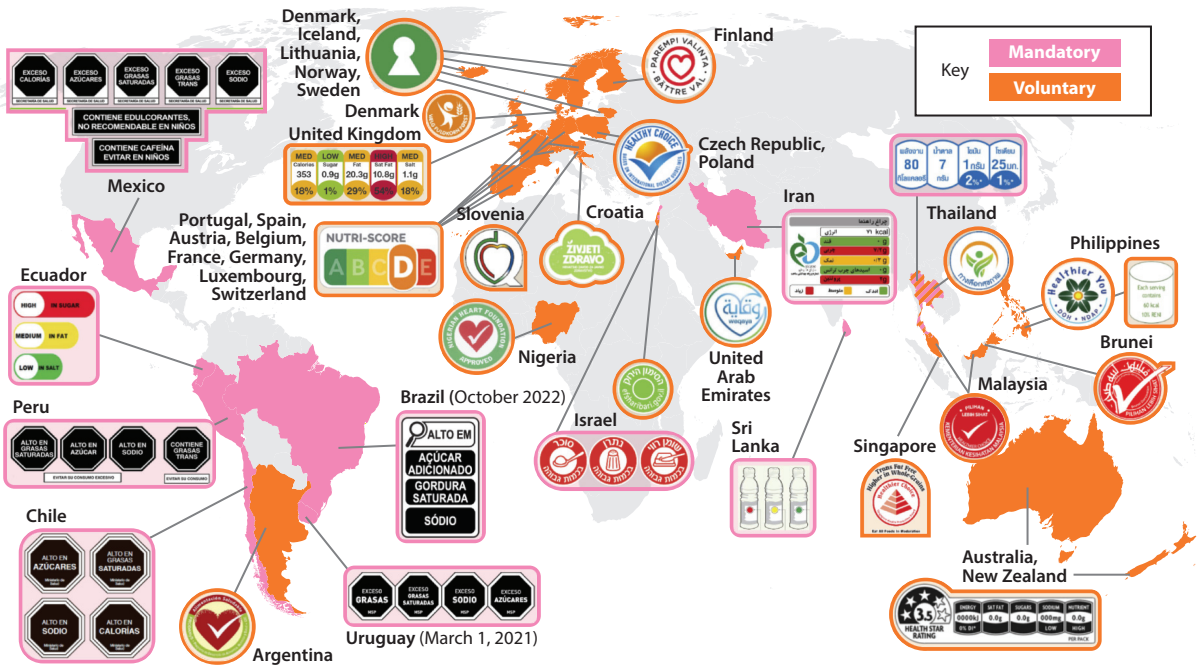


Figure 1

Countries with mandatory or voluntary interpretive front-of-package labels on packaged foods and drinks. Figure adapted with permission from the Global Food Research Program at the University of North Carolina at Chapel Hill.

Organization as a strategy to address noncommunicable diseases (see **Figure 1**) (90). Across countries, front-of-package label policies have widespread public support (3, 13, 39, 45, 60). Most labeling systems opt to either only highlight products with unhealthy amounts of certain nutrients or only highlight healthy products. Israel, however, is an example of a country that has chosen to combine mandatory warning labels for products that exceed certain thresholds for nutrients of concern with voluntary positive green logos for healthy products (24).

Simple, easy-to-understand, front-of-package labels inform consumers about the nutrition content of their food and help them focus on key health-related information rather than other package marketing. Although informing consumers is the primary goal of food labeling systems, there is real-world evidence that well-designed front-of-package nutrition information can help encourage healthier choices (11, 36, 40, 59, 80, 92). Nutrition label use is consistently shown to be associated with healthier diets (10), but as with any intervention, the degree of influence depends on purchasing contexts and customer characteristics (5) as well as the label design. Nutrition labels can also prompt the food industry to reformulate foods to have healthier nutrition profiles (16, 27, 43, 50, 59, 87, 91). Finally, labeling the food supply can undergird other policies designed to incentivize healthy choices. If an entire food supply is labeled to indicate more and less healthy options, government procurement policies can use the labeling system to require that a certain percentage

of healthy foods be purchased and offered, and food assistance programs can implement incentives to encourage the purchase of foods labeled as healthy. For example, some countries, such as Chile and Mexico, are using their front-of-package labeling systems to determine what can be marketed to children (81). For all these reasons, many countries are considering or are implementing standardized front-of-package nutrition labeling systems to address the high global prevalence of chronic diseases (47).

In this article, we provide a narrative (not systematic) review of (*a*) real-world evaluations of front-of-package food and beverage labels that use objective sales data to evaluate the influence on consumer purchasing behavior and (*b*) studies that objectively assess product reformulation in response to a real-world front-of-package label implementation. On the basis of this research, we argue that there is sufficient scientific evidence to recommend that governments implement mandatory front-of-package nutrition labeling systems to improve population health. Multiple natural experiments using objective sales data indicate that well-designed front-of-package labels are associated with decreases in purchases of less healthy products and increases in purchases of healthier ones. Further, a small but growing body of evidence suggests that such labels prompt the food and beverage industry to reformulate products so that they have a healthier nutritional profile. Although requiring a standardized food labeling system places some burden on industry to print labels on products, front-of-package food labels hold promise as a cost-effective way to promote healthier food choices (35). But label effects are likely to be limited if the label is not well designed.

In addition to our narrative review, we present a conceptual model of how front-of-package nutrition labels influence consumers, integrating theories from psychology, behavioral economics, communication, and marketing. We then describe different dimensions of existing label designs and use theory and empirical data to answer questions about the optimal label design (e.g., should a label include numbers or images?). On the basis of these discussions, we recommend that front-of-package nutrition labels be highly visible and salient as well as simple and easy to understand. Ideally, a labeling system should leverage automatic associations through symbols and colors to help consumers interpret nutrition information quickly and accurately and should integrate informational and emotional messaging. Although it is critical that any front-of-package labeling system be based on rigorous, evidence-based nutrition criteria, it is beyond the scope of this review to interrogate the different criteria being used.

Although we believe countries should implement well-designed, mandatory front-of-package nutrition labels, it is important to recognize that such labels are generally shifting people toward healthier versions of ultraprocessed foods and beverages and not necessarily toward more whole foods. Some simulation evidence suggests that well-designed front-of-package labels are likely to improve population health (2, 30, 35, 66), but we lack real-world evidence. To date, there is research reporting an association between mandatory restaurant calorie labeling and reductions in body mass index in one area of the United States (prior to the national implementation of the US requirement for all chain restaurants to post calorie labels) compared with jurisdictions that do not require labeling, suggesting front-of-package labels might have similar effects (58). As more countries implement front-of-package labeling systems, it will be important to evaluate changes in population health over time through these natural experiments.

CONCEPTUAL FRAMEWORK FOR HOW LABELS INFLUENCE CONSUMERS AND MANUFACTURERS

There are several pathways through which well-designed front-of-package nutrition labels influence consumers (**Figure 2**). First, the label needs to capture the consumer's attention (4, 88).

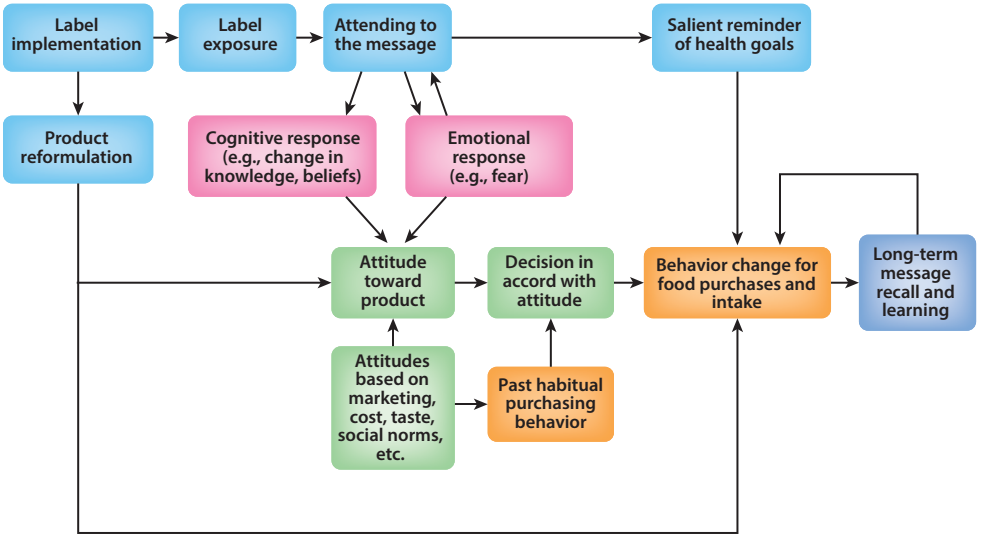


Figure 2

Conceptual model of front-of-package nutrition label influence.

Once seen by the consumer, the label can work through different influence channels. The first influence mechanism is through cognitive effects, such as imparting knowledge and changing product perceptions. Seeing a traffic-light label on a food, for example, might educate a consumer that a product they thought was healthy—such as a high-sugar fruit drink touting vitamin C—is not. Labels that contain novel health information that challenges existing beliefs and attitudes are likely to have the greatest impact. Expectancy disconfirmation theory posits that consumers' attitudes toward a product will shift when new, unexpected information is provided (49). For example, Burton and colleagues (8) experimentally demonstrated that calorie labels on restaurant menus tended to influence consumers to choose fewer calories for items that had unexpectedly high calorie amounts (e.g., a salad) as opposed to desserts, which are expected to be high in calories. Labels can also influence behavior by simply serving as a salient reminder of one's long-term health goals. A person might already know that soda has a lot of sugar and that overconsuming it is not good for one's health, but the label can remind them that they are trying to make healthy choices and thus should avoid it. Labels can also exert effects by inducing emotional reactions (32, 41). Seeing a red traffic-light or warning label, for example, might engender feelings of anxiety about one's health. Food labels might also prompt discussion between friends and family, exerting further influence on decision making (82), which can also lead to broader changes in social norms (32, 79). These cognitive, emotional, and social influences can in turn affect attitudes toward foods or directly influence behavior. Once a decision is made to buy a product, labels can continue to exert influence on consumption. Someone staring at their breakfast cereal box while eating might notice the information and eat less in the moment or learn from that information and change their behavior later on. There is evidence that providing calorie information on restaurant menus, for example, led to learning over time that influenced decisions in the absence of such information later (6). Food labels can also indirectly influence consumer purchases by motivating the food industry to reformulate products so that they have better nutritional profiles. Manufacturers might work, for example, to lower the sodium in a product so that it no longer must display a warning label. Taken together, this evidence shows that food labels are one of many environmental factors (e.g., taste, cost,

marketing, social norms) that shape purchasing and consumption behaviors, and they interact in different ways with individual-level attributes of the consumer (e.g., numeracy, education level) (55, 79).

TYPES OF FRONT-OF-PACKAGE NUTRITION LABELS

Existing front-of-package nutrition labeling systems vary across several dimensions that we briefly discuss (see **Table 1**). One key dimension is a summary indicator versus a nutrient-specific label. Summary indicator labels provide an overall rating of a product, while nutrient-specific labels provide information about specific nutrients in a product. Another dimension is interpretive versus noninterpretive or neutral information provision. Interpretive labels assist consumers in judging the healthfulness of a product with indicators such as "high in" statements that refer to the amounts of nutrients or warnings that flag health concerns associated with overconsuming a product, such as a statement indicating that the product is high in sugar. Neutral information provision systems only display facts about the nutrient content with no additional guidance on how to interpret those facts (83). A third dimension of a front-of-package labeling system is whether or not a label is displayed only on products considered to meet the threshold for a healthier choice. These systems only highlight products that are healthy enough to display a label and do not include a symbol on products that do not meet a nutritional quality threshold. A final dimension to consider is the symbol used for the label, including the shape, color, and number of indicator levels if it is an interpretive system (e.g., 3 stars, 5 stars). Commons symbols include stop signs, graded star systems, color scales or letter grades, and traffic lights. In the second half of this review, we discuss the strengths and weaknesses of the different design approaches.

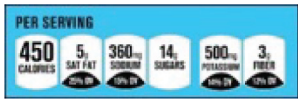
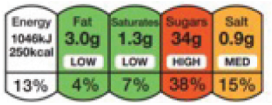
WHAT DOES REAL-WORLD EVIDENCE TELL US ABOUT THE INFLUENCE OF FRONT-OF-PACKAGE NUTRITION LABELS ON CONSUMER BEHAVIOR?

We focus this section on real-world studies that use a natural experiment design with objective sales data to describe what is known about the influence of front-of-package labels on purchasing behavior. Despite growing global interest in implementing front-of-package labeling systems, there are only a handful of real-world studies. Many more laboratory and online experiments exist, and these are referenced throughout our discussion of the optimal label design. Taken together, the most rigorous studies suggest that well-designed front-of-package nutrition labels lead consumers to buy products with better nutritional profiles. Although the magnitude of change in sales may appear small for some studies, on a population level they can be meaningful.

One of the first real-world evaluations of a labeling system was conducted in the United States in 1985 by Levy et al. (40), who evaluated a voluntary special-diet-alert shelf tag that flagged items as low or reduced in sodium, calories, fat, or cholesterol. The labeling system was implemented in 90 stores in Washington, DC, on 400 products across 20 food categories. Using sales data from 14 food categories across 2 years, they compared 10 intervention stores that had the labels with 10 matched control stores in Baltimore, Maryland. They reported that the labeled products grew in sales 4–8% compared with the nonlabeled products, depending on product category, in Washington, DC, versus Baltimore.

Later, Cawley and colleagues (11) examined the influence of the voluntary Guiding Stars program in 168 northeastern US supermarkets between January 2005 and December 2007. The program labels foods with 0 to 3 stars, with more stars indicating a more nutritious product. The researchers reported a statistically significant 8% decline in sales for foods with 0 stars and

Table 1 Dimensions of front-of-package nutrition labels and common labeling systems

Dimension	Guideline Daily Amount	Traffic light (United Kingdom)	Nutri-Score (France)	Health Star Rating (Australia)	High in (Chile)
Symbol	No symbol 	Traffic lights 	Letters/colors 	Star system 	Stop sign displaying "high in" statement(s) 
Summary indicator versus nutrient-specific	Nutrient-specific	Nutrient-specific	Summary	Summary	Nutrient-specific
Interpretive versus non-interpretive information provision	Noninterpretive	Interpretive	Interpretive	Interpretive	Interpretive
Nutrient threshold(s) for label display	No threshold	No threshold	No threshold	No threshold	Threshold

Note: Front-of-package labeling systems, such as the traffic-light label and the Health Star Rating, are displayed along with additional information on nutrient amounts.

a nonsignificant 6% increase in sales of starred foods based on weekly unit sales data across 102 food categories. These results expanded initial, similar findings from Sutherland et al. (80), who evaluated the Guiding Stars program from the same supermarket chain between 2006 and 2008 during the prelabeling period and 2 years later. They reported a small but significant increase in purchased items that had at least 1 star, from 24.5% at baseline to 24.98% and then 25.89% 1 and 2 years later, respectively.

Another more recent examination of Guiding Stars was conducted by Hobin et al. (36). They examined sales data across three supermarket chains in Ontario, Canada, which implemented Guiding Stars in 2012, comparing stores that used labels with control stores that did not. Consistent with other research on Guiding Stars, they found small, statistically significant increases in sales of foods with better nutritional profiles, though the direction and magnitude of changes differed by food category. They also reported increases in total revenue associated with the labeling system.

Another study used a difference-in-differences approach to evaluate the voluntary NuVal shelf label, which scores products from 1 (least healthful) to 100 (most healthful) (92). The researchers analyzed yogurt sales transaction data from a US store that implemented the labels and five control stores that did not. They estimated that NuVal labels increased the demand for labeled products by 14.13 units, or approximately 39%. During the same time, at the control stores, the average weekly quantity sold for each labeled universal product code decreased from 24.65 units to 19.34 units, with the average weekly unit price decreasing by about $0.03. The difference in differences in the means suggests that posting NuVal labels increased demand for the labeled yogurts by 14.13 units, or 14%, with larger increases for healthier yogurts (a 25.89 unit increase for higher-scoring yogurts compared with a 2.88 increase for lower-scoring yogurts).

One study evaluated the United Kingdom's voluntary labeling initiative, which recommended that retailers adopt multiple-traffic-light nutrition labels on store-brand products within seven food categories. The researchers compared sales of products at retailers that introduced the labels with those of control retailers that did not. They found the program was associated with monthly reductions of 588 kcal, 14 g of saturated fats, 7 g of sugar, and 0.8 mg of sodium from labeled, store-brand foods (21). In contrast, two older, smaller-scale studies of the multiple-traffic-light labeling system reported no association between the labels and product sales. Sacks et al. (64) examined changes in sales data from a major UK retailer and found no influence of the labels on two product categories (ready meals and sandwiches) 4 weeks before and after traffic-light labels were introduced. Another study examined the influence of traffic-light labels displayed on an Australian online grocer website during a 10-week trial (65). The traffic-light labels consisted of four color indicators representing levels of fat, saturated fat, sugar, and sodium content for 53 retailer-owned brands across five food categories (milk, bread, breakfast cereals, biscuits, and frozen meals). The researchers reported no influence of the labels on sales for any of the categories, both within stores and when comparing the intervention with control stores. One possible explanation for these mixed findings for the traffic-light labeling system is that it presents consumers with information that can be conflicting. Some products, for example, might display a green label for sugar while simultaneously displaying a red light for sodium (25). This suggests some advantage to providing consumers with a single message about the overall healthfulness of a food or beverage, with the trade-off that consumers who care about limiting a certain nutrient (e.g., sodium) over other nutrients may have less detailed information to make such a decision.

Boztuğ et al. (7) used data from a major UK retailer in 2006 to examine the association between sales and the retailer's implementation of the monochrome Guideline Daily Amount (GDA) label that provided information on energy, fat, saturated fat, sugar, and salt in a serving of food. Although they reported slight reductions in sales of less healthy foods following the GDA

implementation, there was no systematic change in behavior. This result is consistent with other experimental research showing that consumers have difficulty understanding GDA labeling systems and underscores that not all front-of-package label designs will produce behavior change (15, 78).

Chile has been a leader in front-of-package food labeling and now requires products to display octagonal (stop-sign-shaped) black labels indicating when foods meet a threshold for being "high in" calories, saturated fat, sodium, or sugar. Products can thus have up to four warning logos. Additionally, products with at least one warning logo are not allowed to be marketed to children in any media (including digital media). Separate nutrient thresholds were set for solids versus liquids, and these thresholds became stricter over time, with the first phase being implemented in June 2016, the second phase in 2018, and the final phase in 2019. A recent evaluation of Chile's law on food labeling and advertising estimated that household purchases of sugary drinks (i.e., beverages that received the high-in-sugar label) decreased by 11.9 cal/capita/day, or 27.5% relative to the counterfactual (76). This was slightly offset by an increase in non-high-sugar beverages (+5.7 cal/capita/day, or a 10.8% increase relative to the counterfactual) but led to an overall reduction in calories from beverages purchased (−7.4 cal/capita/day, or a 7.5% decrease relative to the counterfactual). One limitation of this analysis is that Chile also implemented restrictions on food marketing and sales of products high in calories, saturated fat, sodium, and sugar in schools, making it difficult to tease apart the impact of the labels versus the other policies. In fact, some initial evidence suggests that these policies may interact in important ways. For example, one set of focus groups showed that the school policy enhanced the impact of labels in families: Children learned about the labels in schools and then educated their mothers and requested that they purchase unlabeled products (14). This highlights the benefits of labeling the food supply in a standardized way, as Chile was able to create marketing regulations stipulating that labeled foods cannot be advertised to children.

In summary, the most rigorous real-world studies using sales data as a behavioral outcome find that well-designed front-of-package nutrition labels prompt customers to purchase foods and beverages with better nutritional profiles, though these effects can vary by type of product category. Also, although label effects may be small, such changes on a large scale can lead to healthier eating habits at the population level. However, not all front-of-package label designs produce behavior change (e.g., the GDA label), underscoring the importance of implementing consumer-friendly labels that are informed by scientific principles of behavior change.

WHAT DOES REAL-WORLD EVIDENCE TELL US ABOUT THE INFLUENCE OF FRONT-OF-PACKAGE LABELS ON FOOD INDUSTRY REFORMULATION OF PRODUCTS?

Real-world evidence indicates that front-of-package labels not only motivate behavior change among consumers but also prompt the food industry to improve the nutritional quality of the food supply. The majority of evidence on product reformulation following implementation of front-of-package systems comes from voluntary labeling systems and a handful of evaluations (72). Overall, these results suggest that front-of-package labeling systems consistently led to improvements in the nutritional profile of foods and drinks, though effects can be limited for some voluntary systems.

Product reformulation can play a critical role in improving population-level dietary intake. In 2005, for example, the UK government rolled out a sodium-reduction information campaign and engaged in efforts to encourage food manufacturers to voluntarily reduce sodium in their products. It was estimated that product reformulation was responsible for three-fourths of the

sodium reduction seen in the food supply (27). Another example is the large-scale removal of trans fat from the US food supply following a requirement that companies disclose the amount of trans fat on the packaging (50). This was likely so successful because there were easy, affordable trans fat substitutes.

One evaluation of New Zealand's voluntary Health Star Rating system (which displays 1 to 5 stars, with more stars indicating a better nutritional profile) found that the vast majority (83%) of products displaying the star rating in 2016 had been reformulated (defined as at least a 5% change in a key nutrient) since the system's implementation in 2014 (43). In addition, the amount of reformulation was greater in labeled products than in nonlabeled products (though nonlabeled products were healthier at baseline). The majority of products that displayed the Health Star Rating also had ratings in the top half of the range (i.e., 3.0–5.0 stars) (43). One evaluation conducted 2 years after adoption of the Health Star Rating system reported very low uptake of it, with only 5.3% of products displaying the label, representing 7.2% of purchases. A more recent analysis examining uptake over time between 2014 and 2019 reported that the Health Star Rating system appeared on 41% of eligible products, though this was skewed toward products considered to be healthier with higher ratings (products with the logo had a mean star rating of 3.4 versus 2.6 for products without the logo) (70). A government authority recommended the system be mandatory if in 5 more years uptake was lower than 70% (70). An evaluation of children's products from Australian supermarkets that adopted the Health Star Rating system in 2014 found similar results, with the majority (81.5%) of labeled products having at least 3.0 stars. Labeled products were also significantly more likely to be classified as healthy than those without the rating (46). An audit of products offered in vending machines after Australia's implementation of the labeling system reported an increase from 7% to 14% in the proportion of healthy snacks offered (74). In these studies, however, it is unclear whether companies actually improved the nutritional profile of foods or simply selectively placed the logo primarily on healthier items. In addition, even though a product does not have to meet nutritional thresholds to carry the Health Star Rating, because it is voluntary, companies can simply choose not to put voluntary labels on unhealthy products, reducing their incentive to reformulate them to achieve a better rating. Despite these limitations, a cost-effectiveness analysis of the reformulation driven by the labeling system estimated that it would lead to small changes in population energy intake that would likely translate to reductions in body weight (−0.01 kg if voluntary and −0.11 kg if mandatory) (35).

There have also been reformulation studies of food labeling systems that only highlight healthy options. The Pick the Tick program implemented in New Zealand in 1991 by the National Heart Foundation licensed certain food products to use their symbol on the fronts of packages as a marker of healthfulness (91). To earn the logo, products needed to be chemically analyzed by the foundation and meet their nutrient criteria. An evaluation of the program carried out in 1999 found that 55 food companies and 390 products participated in the program. Manufacturers reported that their product reformulations reducing sodium content were due exclusively to their desire to display the Pick the Tick logo, and there was not a previous trend of sodium reduction. The study found that over 12 months, breakfast cereals showed the largest decrease in sodium, with a 61% reduction, followed by bread, with a 26% reduction, and margarine, with an 11% drop. These reductions, however, only accounted for 23 products, making it unlikely that they had meaningful effects on population health (91). Another study interviewed food manufacturers about New Zealand's Pick The Tick program to understand what influenced their decision to reformulate. The researchers reported that the food manufacturers viewed the label as a credible health endorsement that they could market to consumers (84) but also considered other drivers such as consumer demand, sales trends, and current technology when deciding whether to reformulate.

Evaluations of the Netherlands' voluntary Choices program, which places a logo only on foods meeting a certain healthfulness threshold, found similar results. On the basis of self-reported data from 47 food manufacturers that participated in Choices, about half of products carrying the Choices logo were existing products that already met the nutritional criteria for Choices, while 20% of products were reformulated and 29% of products were newly developed. Of the reformulated products, sodium was the most common nutrient to be reduced, with reductions in saturated fat, added sugar, and calories and increases in dietary fiber occurring in fewer food groups. Of the newly introduced products, the greatest changes were seen for fiber, which was increased compared with referent products (87).

Finally, a study of Canada's Health Check label reported that 40% of sampled products ($n = 371$) had reduced sodium levels to meet the Health Check label criteria following implementation (16).

The data from voluntary labeling systems is encouraging, but these programs likely had limited impact because of their voluntary nature. Companies do not have to display the labels and can choose to omit the labels rather than reformulate products. In Australia and New Zealand, for example, the labels appeared on fewer than half the products, and food manufacturers were more likely to display the Health Star Rating on products with better nutritional profiles (46, 70). Voluntary industry labels and claims are also more likely to promote the presence of positive nutrients or reductions in negative nutrients on packaged foods and rarely highlight high levels of negative nutrients (12). Research also suggests that consumers are more likely to believe a front-of-package label if it has a government attribution (1), and labeling systems will be viewed as more credible when endorsed by a national or international health organization, underscoring the importance of a mandatory, government-sponsored label (20).

Larger effects in product reformulation have been observed in Chile, which, as mentioned above, requires octagonal-shaped "high in" warning labels on products high in various nutrients. After the first phase of Chile's Food Labeling and Advertising law, the percentage of products qualifying for a high-in-sugar label went from 80% to 60%, while the proportion qualifying for a high-in-sodium label went from 74% to 27%. There was, however, very little change in the proportion of products containing a label for saturated fat or calories. In addition, following label implementation, the distribution of nutrients of concern for most food groups moved just below the nutrient cutoffs, and this change suggests that the companies are reformulating just enough to avoid the label (59). It is likely that a mandatory label that requires companies to disclose the unhealthy attributes of their products will lead to more extensive reformulation, but that reformulation may only occur for products that are close to the threshold.

Although it seems likely that mandatory food labeling such as trans fat labeling in the United States and warning labels in Chile are the reasons that larger reformulation effects have been observed, it is not possible to determine what role the label design played in producing larger versus smaller effects (e.g., a warning that appears on all products versus a positive logo only appearing on some). The Israeli model of implementing a combined method of a mandatory red warning label and a voluntary green, positive logo (24) could promote more extensive reformulation, but no data are available yet.

More research is needed to understand the ways in which mandatory front-of-package labeling systems influence industry reformulation and product offerings. A recent (2019) review on sodium reduction interventions, for example, found that while 31 countries have front-of-package schemes to reduce sodium in foods, only four studies in the review evaluated sodium changes (68). In addition, the majority of studies conducted have been in high-resourced countries, and it is unclear what the extent or speed of reformulation will be in lower-resourced countries. Finally, as more labeling laws or regulations are passed, it will be important to monitor how reformulation spreads

RECOMMENDATIONS FOR FRONT-OF-PACKAGE NUTRITION LABEL DESIGN

Front-of-package nutrition labels should

- be highly visible and salient;
- convey a simple and easy-to-understand message(s);
- limit or avoid numeric information;
- use symbols and colors that leverage automatic associations to help consumers interpret nutrition information quickly and accurately (e.g., stop signs, letter grades, traffic lights);
- integrate informational and emotional messaging;
- be displayed on less healthy foods as well as healthier ones (not just on healthier foods); and
- warn or caution consumers (e.g., with words/phrases such as excess, high in, avoid, or warning).

across countries and regions, both due to the import of products from countries carrying labels and because companies have developed the technology to reformulate products. For example, several data sets of the packaged food supply in South America, including Peru, Colombia, and Brazil, have found inclusion of Chilean products with warning labels, as well as products that had already been reformulated, prior to the implementation of a front-of-package law in those countries.

In summary, the research on reformulation indicates that front-of-package labeling systems are associated with improvements in the nutritional profile of the food supply, though voluntary systems have more limited effects than mandatory systems and it is unclear whether certain label designs are more or less likely to prompt reformulation.

HOW SHOULD A FRONT-OF-PACKAGE NUTRITION LABEL BE DESIGNED?

There is clear evidence that front-of-package labels can alter food purchases, but it is very difficult to compare different features of labeling systems to each other within a single real-world study using objective outcomes. Therefore, in this section, we draw from theories in psychology, behavioral economics, marketing, and communication to help us predict which types of front-of-package labels are likely to be most effective, and we integrate empirical data where available (see the sidebar titled Recommendations for Front-of-Package Nutrition Label Design). The first overarching psychological theory to bear in mind is the idea that there are two systems we use to process information: system 1 and system 2 (37, 38). System 1 is engaged when we are making faster, more impulsive, reflexive, and emotional decisions. In contrast, system 2 is engaged when we are using more deliberative, controlled, analytic reasoning processes. When our cognitive resources are limited (if we are hungry, stressed, or distracted), then system 1 tends to be activated (37, 38). When it comes to food shopping, we are often making decisions with system 1. Yet, processing the typical nutrition facts label requires more deliberate, reasoned action, often requiring manipulation of numeric information and a need to compare across products. Part of the reason humans rely so heavily on system 1 is because we have a limited ability to attend to, process, and remember information (37, 38). This broad theory emphasizes that front-of-package labels are likely to be most influential when they (*a*) are highly visible and salient, (*b*) are simple and easy to understand, (*c*) leverage automatic associations, and (*d*) integrate informational and emotional messaging.

Research has found that those with higher education and income are more likely to use and understand nutrition facts labels (10, 75), a finding that underscores the need for front-of-package

labels that communicate nutrition messages in an easy-to-understand manner that does not rely heavily on numbers or text, particularly in countries where large segments of the population do not speak the primary language. With this in mind, in the next section, we attempt to answer several questions about the optimal front-of-package label design.

SHOULD A FRONT-OF-PACKAGE NUTRITION LABEL INCLUDE NUMBERS AND IMAGES?

Given low levels of numeracy and health and nutrition literacy throughout the world, labeling systems should not rely exclusively on numbers (10, 51, 53, 54) and are likely to be more influential if they avoid or limit numeric information. Evidence from tobacco research indicates that using pictures and symbols on warning labels compared with only having text helps reach youth and those with lower education levels (23, 33, 48, 52) and makes such labels a more promising approach to reduce health disparities (48, 71). It also makes the labels interpretable to those who do not read the language used on the label.

One of the most common numeric-based front-of-package labeling systems is the GDA, which reflects the percentage of a recommended daily amount of a specific nutrient in the product. This labeling system began in 1998 as a collaborative approach between the UK government, the food industry, and consumer organizations, overseen by the Institute of Grocery Distribution. The GDA was initially intended to be included in back-of-package information for consumers, and it eventually expanded through Europe, Australia, and New Zealand over time. In 2006, the International Food and Beverage Alliance of packaged food companies in Australia and the United Kingdom launched voluntary labeling systems based on GDAs. These systems continued to spread and by the mid-2010s were widely used by international food companies and found on packaged products globally. Similarly, in the United States there is no mandated front-of-package labeling system, but the food industry has voluntarily implemented Facts Up Front, which provides consumers with numeric information, including percent daily value for calories, saturated fat, sodium, and sugars. The industry can also display up to two nutrients to encourage. Psychological and communication theories would predict that these number-heavy labeling systems would be difficult for consumers to quickly understand and use, and this difficulty is borne out in the empirical research. One study of the Facts Up Front label revealed that consumers had difficulty using it to accurately judge which of two products was healthier (77). Qualitative research from Mexico, a middle-income country with low levels of nutrition literacy and numeracy, highlights the difficulty that people have interpreting the GDAs (15), and other data showed that even nutrition students in Mexico had difficulty interpreting the GDAs (78). Experimental data from Brazil revealed that the monochrome GDA label, compared with the multiple-traffic-light or warning label in a black octagon, led parents to rate products as healthier when they had the GDA label compared with a warning label; there was no difference for the multiple-traffic-light label. Among children, those aged 6 to 12 in public schools did not differ in their healthfulness ratings, but 9- to 12-year-olds in private schools gave products with GDAs higher healthfulness ratings (42). Taken together, these results are consistent with real-world behavioral data showing limited effects of the GDA (7) and provide evidence that numeric-based systems such as the GDA should be avoided.

WHAT TYPE OF NUTRITION INFORMATION/NUTRIENTS SHOULD BE FEATURED IN FRONT-OF-PACKAGE LABELING SYSTEMS?

Psychology theory and existing evidence suggest that a front-of-package label is likely to be most influential if it communicates a single, simple message and not only provides consumers with

information about healthier options but also highlights less healthy foods. A large body of human and animal studies support negativity dominance theory (63), which argues that people tend to give greater weight to negative entities (e.g., events, objects, personal traits) compared with positive ones. This suggests that a front-of-package label is likely to be more influential if it explicitly provides a dissuasive message about certain unhealthy foods rather than simply highlighting healthier choices. This is consistent with evidence on tobacco warnings: Warnings that elicit negative emotional arousal are associated with greater message acceptance, perceived health risk, and downstream behavioral outcomes (32, 41). This suggests that Choices, the voluntary front-of-package and shelf-tag system introduced in the Netherlands in 2006, is likely to be less influential because its labels only appear on foods that meet the criteria for the logo. Because the Choices system does not explicitly convey negative information about the healthfulness of products, it is appealing to the food industry and it is used in more than 20 countries with varying label names such as Green Keyhole, heart logo, and Healthier Choice Symbol (61). The logo is assigned to products that contain lower levels of sodium, sugar, saturated fats, total fat, and caloric content and increased levels of dietary fiber compared with similar products within the same product category.

In contrast, a traffic-light labeling system that uses green lights for healthy foods and red lights for less healthy foods is able to leverage automatic associations (green means go, red means stop) and simply convey information about foods to encourage healthier choices and discourage less healthy ones. Evidence from a study in a US hospital cafeteria showed that a single-traffic-light labeling system increased the purchase of healthy "green" foods and decreased the purchase of less healthy "red foods," with effects sustained over time (85). In practice, however, countries that have adopted front-of-package traffic-light labeling systems use a more complex version than a single traffic light. In 2014, Ecuador's Health Regulation for Processed Food Labeling required a traffic-light labeling system that called out high/medium/low levels of fat, sugar, and salt (without GDA values) (17). Iran also implemented a mandatory multiple-traffic-light system similar to that of Ecuador, but with the addition of trans fat in 2015. Although these traffic-light labeling systems are a step in the right direction (22), and an improvement over strategies such as the GDA, one worry is that they do not present a simple, clear message. Instead, they provide various colors for different nutrient levels. This means a product might score green on one nutrient but yellow or red on others, leading to some consumer confusion (25). Imagine driving up to a traffic light that simultaneously displayed green and red. What would you do? So although this approach does a good job of presenting the negative aspects of food products, it violates the principle of simplicity by providing a lot of information that at times might be conflicting. Though it can be helpful to have multiple traffic lights for those who are trying to watch certain nutrients, displaying a single traffic light that captures the overall nutritional value of a food product will likely be more user friendly for the majority of consumers.

Single score–based front-of-package systems have been implemented in some countries. One example is the voluntary Health Star Rating system created by the food standards agency of Australia and New Zealand, which provides products with a range from a half star to 5 stars. Real-world evaluations of the Guiding Stars labeling system, which is similar to the Health Star Rating, found that consumers purchased labeled products with higher nutritional quality (11, 36, 80). The Health Star Rating corrects one design limitation of the Guiding Stars system, which scores products from 0 to 3 stars, by including a half star as the lowest rating. This addresses the problem of consumers not understanding what a score of 0 stars means (26, 36).

Another well-designed single summary label is the French government's voluntary Nutri-Score (57) label (also called the 5-Color Nutrition Label), implemented in 2017, which leverages automatic associations with colors and grades (dark green/A to dark red/E) that alert consumers to healthy and less healthy products. In a 12-country study comparing people's abilities to use the

labels to rank the healthfulness of products in three food categories, the Nutri-Score performed best, followed by a multiple-traffic-light label, a Health Star Rating, a warning symbol, and reference intakes (19). In an online experiment with Swiss consumers, the Nutri-Score label led to the highest accuracy, compared with a multiple-traffic-light label, a nutrition facts label, and no label, in helping consumers identify the healthier of two products (31). In a French cohort, Nutri-Score led to the highest consumer scores in classifying products in terms of healthfulness, followed by a simplified nutrition labeling system, a multiple-traffic-light label, and modified reference intakes (18). Although the Nutri-Score and Health Star Rating systems are promising approaches, more real-world evaluation data are needed, and both systems likely would be bolstered by messaging that more explicitly warns consumers.

SHOULD A FRONT-OF-PACKAGE NUTRITION LABEL EXPLICITLY WARN CONSUMERS?

It is likely that front-of-package labeling systems that warn consumers (like those in Chile) with words or phrases such as excess, high in, avoid, or warning will be more influential than systems such as the Health Star Rating or Nutri-Score, which do not give an explicit warning message. Many countries have now pursued front-of-package warnings. Since Chile's implementation, Peru followed suit in June 2019 (using red octagonal/stop-sign symbols that also highlight trans fat and include the message to avoid consumption). Uruguay passed a regulation in August 2018, and Israel has required red pictorial warning logos on products with excess sugar, sodium, and saturated fat content since January 2020. Mexico has also implemented its regulation using stop signs to warn about excess nutrients on products since October 2020, while Brazil's health regulatory board has passed a similar system that includes a magnifying glass with text indicating the product is high in sugar, sodium, and saturated fat.

In the United States, several states and cities have introduced bills to require warning labels on sugar-sweetened beverages. These proposals differ from approaches in many other countries because they warn about the potential health harms of overconsuming the product rather than warning about the excess nutrients of concern in the product. An example statement would be, "Warning: drinking beverages with added sugar contributes to obesity, diabetes, and tooth decay." A meta-analysis of experimental studies of sugar-sweetened-beverage warning labels concluded that such warnings lowered healthfulness perceptions for sweetened beverages and increased disease risk perceptions (28). They also led to reductions in hypothetical purchases of sugary drinks as well as reductions in actual purchases and consumption. One limitation is that most of these studies did not compare warning labels with other types of front-of-package labeling systems. In an online experiment, Grummon and colleagues (29) found that warnings were perceived to be more effective when they included language about the health effects of overconsuming sugary drinks versus no information or nutrition information such as high in sugar and that using the word warning specifically was more influential than phrases such as high in. Although the word warning may be more influential than messages with words or phrases such as excess or high in, each country must operate within its own legal regulations and definitions to decide what types of label messages are appropriate and feasible.

WHAT COLORS AND SHAPES SHOULD BE USED FOR FRONT-OF-PACKAGE NUTRITION LABELS?

Psychological theory suggests that people are likely to process a front-of-package label more efficiently if it uses colors and shapes that already have automatic associations (and ideally colors should be combined with shapes to help those with color blindness) (38). This is the reason many

countries use traffic symbols such as stop signs or lights. In an experimental study with a convenience sample of 1,360 adults, Grummon and colleagues (29) found that an octagonal (stop-sign) shape was more influential than a rectangle shape for a sugary drink warning. Each country, however, must consider the specific associations of certain shapes and colors in that culture. There is evidence from the United States, for example, that people associate green labels with health. In one randomized experiment by Schuldt (69), participants shown the US Facts Up Front label on a candy bar rated the candy bar as healthier when the nutrition information appeared in green compared with red. This highlights the need for color and message congruency and the need to avoid the display of information about unhealthy foods in colors that have positive associations. It is also important to consider that any labeling system should keep packaging colors in mind. For this reason, if a color-based labeling system is pursued, it will be important to make sure it is on a black or white background that will stand out from the packaging. This is the reason that some countries have used a black-and-white symbol, which are also colors that companies already use on packaging and thus can keep costs down. In addition, a study among adults from Uruguay evaluated the perceived healthfulness associated with colors of circles and found that perceived healthfulness was lower for gray and black circles and higher for circles in other colors (i.e., yellow, blue, green, and white) (9).

POTENTIAL UNINTENDED NEGATIVE CONSEQUENCES OF FRONT-OF-PACKAGE FOOD LABELS

Mandatory food labeling has not always led to improvements in the food supply. For example, a study by Moorman et al. (44) found that implementation of the US nutrition facts label was associated with a decrease in the nutritional quality (defined as a combination of fat, cholesterol, sodium, and fiber) of most labeled products, though there was evidence that labeling promoted healthier reformulation among particularly unhealthy items (e.g., French fries, hot dogs, and pancake syrup). Companies were also more likely to improve nutritional quality when introducing a new brand compared with changing an existing brand (44). The existing evidence on reformulation associated with front-of-package labels is encouraging, but research is needed to carefully monitor potential unintended consequences.

A growing concern in the public health community is the observation that products high in sugar are being reformulated by increasing noncaloric sweetener content. A Chilean study, for example, analyzed 1,489 food products from categories including dairy, cereal, processed fruits, nonalcoholic beverages, and sweets and other desserts and found that 56% of them had at least one noncaloric sweetener after the regulation (56). Further, 67% of dairy products in Chile contain noncaloric sweeteners compared with 14% in Brazil and 21% in the United States (67). This research is unable to causally attribute these differences to the Chilean warning labels, and other work suggests a previous trend of high non-nutritive caloric sweetener consumption in children in Chile (86), but it will be important to track use of noncaloric sweetener in the food supply in association with the implementation of policies such as front-of-package food labels and taxes given the uncertainty about their relationship with health outcomes (73). Currently, some labeling systems address this concern by including warnings or disclosures about noncaloric sweeteners. For example, Mexico's labeling system includes a rectangle that states "Contains (noncaloric) sweetener, not recommended for children."

Another concern when designing a front-of-package labeling system is to ensure that it does not stigmatize individuals, a concern that has been raised with some proposals for graphic warning labels in the United States (34). Few studies examine feelings of stigmatization as an outcome, which should be addressed in future research.

Finally, although this review is not focused on the nutrition criteria underlying a labeling system, we briefly note a major difference between some of the existing systems. The Health Star Rating and Nutri-Score systems developed food-category-specific thresholds, and therefore the number of stars or grades reflects how a product performs relative to other products within the same food category, which is different than the United Kingdom's Office of Communication scoring system underlying traffic-light labels. Although a food-category-specific system allows comparison between two types of ice cream, it is not necessarily useful for comparing between an ice cream and a candy bar. This may suggest that while it can help improve choices and offerings within categories among products that use these labels, it is unclear if it can help improve overall diets. Relatedly, Nutri-Score allows for beneficial nutrients to offset nutrients of concern. This is problematic because it does not reflect how we metabolize foods: Adding dried fruit to a granola bar, for example, doesn't offset the effects of added sugar or sodium. Without rigorous, evidence-based nutrition criteria underlying it, no labeling system, no matter how well designed, will be able to move the needle on population health.

CONCLUSION

On the basis of the existing evidence, countries should implement well-designed, mandatory, front-of-package food labels to inform consumers. Such labeling systems are widely supported by the public as a way to inform consumers. There is also now sufficient evidence from real-world studies using objective outcomes that a well-designed labeling system can encourage purchases of healthier foods and reduce purchases of less healthy foods. In addition, a small but growing body of evidence shows that front-of-package labels can encourage positive industry reformulation. But having an effective labeling system depends on a design that people can understand and easily use. There is clear evidence that GDA labels are not well understood and therefore are unlikely to influence consumers, with real-world data showing null effects. Although early evidence cast doubt on a multiple-traffic-light approach, a larger, real-world study suggests it can influence consumers. Psychological and communication theories, however, suggest a single-traffic-light summary label is likely to be more effective because multiple traffic lights can lead to consumer confusion. The Nutri-Score and Health Star Rating systems are promising, but more real-world evaluations are needed, and both systems would likely produce stronger effects if they included warning messages. Most promising is the Chilean stop-sign symbol, though more real-world evaluation data are needed, including data on long-term changes in population health.

A critical and often overlooked benefit of mandating a front-of-package labeling system is that it can facilitate the implementation of other policies and regulations. For example, marketing restrictions can prohibit manufacturers from being able to make nutrient content or health claims on the packaging or include child-targeted marketing on foods that are labeled as high in certain nutrients. Chile, Peru, and Mexico all leverage their front-of-package labeling systems in this way to inform marketing regulations for children. Finally, the implementation of any front-of-package labeling system should be accompanied by a widespread consumer education campaign to inform the public about how to understand and use the labels.

FUTURE ISSUES

1. Additional natural experiments examining the influence of new front-of-package mandatory and voluntary labeling systems using objective sales and reformulation data are needed.

2. Studies are needed that examine sales data broken down by key sociodemographic groups (e.g., consumers with low literacy levels, low-income consumers).
3. Natural experiments of existing labeling systems that examine changes in population health outcomes over time associated with label implementation are needed.
4. Longitudinal, randomized-controlled studies are needed to compare behavioral outcomes of different label designs.
5. Further examination of potential unintended consequences associated with existing labeling policies is necessary.
6. Studies are needed that examine synergistic effects between front-of-package nutrition labels and other policies (e.g., marketing restrictions, taxes).
7. Implementation research on mandatory and voluntary front-of-package labeling systems is necessary.
8. Qualitative research with subpopulations of interest is needed to understand potential confusion about label interpretation and barriers to use of labels.
9. Research is needed to inform the design of complementary consumer education campaigns.

DISCLOSURE STATEMENT

S.W.N. has received research grant funding from Bloomberg Philanthropies, Arnold Ventures, and the Robert Wood Johnson Foundation, and consults for the World Bank on food and nutrition policy issues, including labeling, fiscal policy, and regulatory designs. D.H. has served as an expert witness on behalf of public health authorities in response to industry legal challenges to public health litigation, including on behalf of San Francisco in the challenge to an ordinance requiring health warnings on sugar-sweetened beverages.

LITERATURE CITED

1. Acton RB, Vanderlee L, Roberto CA, Hammond D. 2018. Consumer perceptions of specific design characteristics for front-of-package nutrition labels. *Health Educ. Res.* 33(2):167–74
2. Ananthapavan J, Sacks G, Brown V, Moodie M, Nguyen P, et al. 2020. Priority-setting for obesity prevention—The Assessing Cost-Effectiveness of obesity prevention policies in Australia (ACE-Obesity Policy) study. *PLOS ONE* 15(6):e0234804
3. Bhawra J, Reid JL, White CM, Vanderlee L, Raine K, Hammond D. 2018. Are young Canadians supportive of proposed nutrition policies and regulations? An overview of policy support and the impact of socio-demographic factors on public opinion. *Can. J. Public Health* 109:498–505
4. Bialkova S, Grunert KG, Juhl HJ, Wasowicz-Kirylo G, Stysko-Kunkowska M, van Trijp HCM. 2014. Attention mediates the effect of nutrition label information on consumers' choice. Evidence from a choice experiment involving eye-tracking. *Appetite* 76:66–75
5. Bleich SN, Economos CD, Spiker ML, Vercammen KA, VanEpps EM, et al. 2017. A systematic review of calorie labeling and modified calorie labeling interventions: impact on consumer and restaurant behavior. *Obesity* 25(12):2018–44
6. Bollinger B, Leslie P, Sorensen A. 2011. Calorie posting in chain restaurants. *Am. Econ. J. Econ. Policy* 3(1):91–128
7. Boztuğ Y, Juhl HJ, Elshiewy O, Jensen MB. 2015. Consumer response to monochrome Guideline Daily Amount nutrition labels. *Food Policy* 53:1–8

8. Burton S, Creyer EH, Kees J, Huggins K. 2006. Attacking the obesity epidemic: the potential health benefits of providing nutrition information in restaurants. *Am. J. Public Health* 96(9):1669–75
9. Cabrera M, Machín L, Arrúa A, Antúnez L, Curutchet MR, et al. 2017. Nutrition warnings as front-of-pack labels: influence of design features on healthfulness perception and attentional capture. *Public Health Nutr*. 20(18):3360–71
10. Campos S, Doxey J, Hammond D. 2011. Nutrition labels on pre-packaged foods: a systematic review. *Public Health Nutr*. 14(8):1496–506
11. Cawley J, Sweeney MJ, Sobal J, Just DR, Kaiser HM, et al. 2015. The impact of a supermarket nutrition rating system on purchases of nutritious and less nutritious foods. *Public Health Nutr*. 18(1):8–14
12. Christoforou A, Dachner N, Mendelson R, Tarasuk V. 2018. Front-of-package nutrition references are positively associated with food processing. *Public Health Nutr*. 21(1):58–67
13. Comans T, Moretto N, Byrnes J. 2017. Public preferences for the use of taxation and labelling policy measures to combat obesity in young children in Australia. *Int. J. Environ. Res. Public Health* 14(3):324
14. Correa T, Fierro C, Reyes M, Carpentier FRD, Taillie LS, Corvalan C. 2019. Responses to the Chilean law of food labeling and advertising: exploring knowledge, perceptions and behaviors of mothers of young children. *Int. J. Behav. Nutr. Phys. Act.* 16(1):21
15. De la Cruz-Góngora V, Torres P, Contreras-Manzano A, de la Mota AJ, Mundo-Rosas V, et al. 2017. Understanding and acceptability by Hispanic consumers of four front-of-pack food labels. *Int. J. Behav. Nutr. Phys. Act.* 14:28
16. Dummer J. 2012. Sodium reduction in Canadian food products with the health check program. *Can. J. Diet. Pract. Res.* 73(1):e227–32
17. Minist. Salud Pública. 2014. Reglamento sanitario sustiutivo de etiquetado de alimentos procesados para el consumo humano. 318-Segundo Supl. 318. Minist. Salud Pública. Quito, Ecuador
18. Egnell M, Ducrot P, Touvier M, Allès B, Hercberg S, et al. 2018. Objective understanding of Nutri-Score Front-Of-Package nutrition label according to individual characteristics of subjects: comparisons with other format labels. *PLOS ONE* 13(8):e0202095
19. Egnell M, Talati Z, Hercberg S, Pettigrew S, Julia C. 2018. Objective understanding of front-of-package nutrition labels: an international comparative experimental study across 12 countries. *Nutrients* 10(10):1542
20. Feunekes GIJ, Gortemaker IA, Willems AA, Lion R, van den Kommer M. 2008. Front-of-pack nutrition labelling: testing effectiveness of different nutrition labelling formats front-of-pack in four European countries. *Appetite* 50(1):57–70
21. Fichera E, von Hinke S. 2020. The response to nutritional labels: evidence from a quasi-experiment. *J. Health Econ.* 72:102326
22. Freire WB, Waters WF, Rivas-Mariño G, Nguyen T, Rivas P. 2017. A qualitative study of consumer perceptions and use of traffic light food labelling in Ecuador. *Public Health Nutr*. 20(5):805–13
23. Gibson L, Brennan E, Momjian A, Shapiro-Luft D, Seitz H, et al. 2015. Assessing the consequences of implementing graphic warning labels on cigarette packs for tobacco-related health disparities. *Nicotine Tob. Res.* 17(8):898–907
24. Gillon-Keren M, Kaufman-Shriqui V, Goldsmith R, Safra C, Shai I, et al. 2020. Development of criteria for a positive front-of-package food labeling: the Israeli case. *Nutrients* 12(6):1875
25. Gorski Findling MT, Werth PM, Musicus AA, Bragg MA, Graham DJ, et al. 2018. Comparing five front-of-pack nutrition labels' influence on consumers' perceptions and purchase intentions. *Prev. Med.* 106:114–21
26. Graham DJ, Mohr GS. 2014. When zero is greater than one: consumer misinterpretations of nutrition labels. *Health Psychol*. 33(12):1579–87
27. Griffith R, O'Connell M, Smith K. 2017. The importance of product reformulation versus consumer choice in improving diet quality. *Economica* 84(333):34–53
28. Grummon AH, Hall MG. 2020. Sugary drink warnings: a meta-analysis of experimental studies. *PLOS Med*. 17(5):e1003120
29. Grummon AH, Hall MG, Taillie LS, Brewer NT. 2019. How should sugar-sweetened beverage health warnings be designed? A randomized experiment. *Prev. Med.* 121:158–66

30. Grummon AH, Smith NR, Golden SD, Frerichs L, Taillie LS, Brewer NT. 2019. Health warnings on sugar-sweetened beverages: simulation of impacts on diet and obesity among U.S. adults. *Am. J. Prev. Med.* 57(6):765–74
31. Hagmann D, Siegrist M. 2020. Nutri-Score, multiple traffic light and incomplete nutrition labelling on food packages: effects on consumers' accuracy in identifying healthier snack options. *Food Qual. Prefer.* 83:103894
32. Hammond D. 2011. Health warning messages on tobacco products: a review. *Tob. Control* 20(5):327–37
33. Hammond D, Thrasher J, Reid JL, Driezen P, Boudreau C, Santillán EA. 2012. Perceived effectiveness of pictorial health warnings among Mexican youth and adults: a population-level intervention with potential to reduce tobacco-related inequities. *Cancer Causes Control* 23:57–67
34. Hayward LE, Vartanian LR. 2019. Potential unintended consequences of graphic warning labels on sugary drinks: Do they promote obesity stigma? *Obes. Sci. Pract.* 5(4):333–41
35. Herrera AM, Crino M, Erskine H, Sacks G, Ananthapavan J, et al. 2018. Cost-effectiveness of product reformulation in response to the Health Star Rating food labelling system in Australia. *Nutrients* 10(5):614
36. Hobin E, Bollinger B, Sacco J, Liebman E, Vanderlee L, et al. 2017. Consumers' response to an on-shelf nutrition labelling system in supermarkets: evidence to inform policy and practice. *Milbank Q.* 95(3):494–534
37. Kahneman D. 2003. Maps of bounded rationality: psychology for behavioral economics. *Am. Econ. Rev.* 93(5):1449–75
38. Kahneman D. 2013. *Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux. 1st ed.
39. Kim WK, Kim J. 2009. A study on the consumer's perception of front-of-pack nutrition labeling. *Nutr. Res. Pract.* 3(4):300–6
40. Levy AS, Mathews O, Stephenson M, Tenney JE, Schucker RE. 1985. The impact of a nutrition information program on food purchases. *J. Public Policy Mark.* 4(1):1–13
41. Li Y, Yang B, Owusu D, Popova L. 2020. Higher negative emotions in response to cigarette pictorial warning labels predict higher quit intentions among smokers. *Tob. Control* 29(5):496–501
42. Lima M, Ares G, Deliza R. 2018. How do front of pack nutrition labels affect healthfulness perception of foods targeted at children? Insights from Brazilian children and parents. *Food Qual. Prefer.* 64:111–19
43. Mhurchu CN, Eyles H, Choi Y-H. 2017. Effects of a voluntary front-of-pack nutrition labelling system on packaged food reformulation: the Health Star Rating system in New Zealand. *Nutrients* 9(8):918
44. Moorman C, Ferraro R, Huber J. 2012. Unintended nutrition consequences: firm responses to the Nutrition Labeling and Education Act. *Mark. Sci.* 31(5):717–37
45. Morley B, Martin J, Niven P, Wakefield M. 2012. Public opinion on food-related obesity prevention policy initiatives. *Health Promot. J. Austr.* 23(2):86–91
46. Morrison H, Meloncelli N, Pelly FE. 2019. Nutritional quality and reformulation of a selection of children's packaged foods available in Australian supermarkets: Has the Health Star Rating had an impact? *Nutr. Diet.* 76(3):296–304
47. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, et al. 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 384(9945):766–81
48. Noar SM, Hall MG, Francis DB, Ribisl KM, Pepper JK, Brewer NT. 2016. Pictorial cigarette pack warnings: a meta-analysis of experimental studies. *Tob. Control* 25(3):341–54
49. Oliver RL. 1980. A cognitive model of the antecedents and consequences of satisfaction decisions. *J. Mark. Res.* 17(4):460–69
50. Otite FO, Jacobson MF, Dahmubed A, Mozaffarian D. 2013. Trends in trans fatty acids reformulations of US supermarket and brand-name foods from 2007 through 2011. *Prev. Chronic Dis.* 10:120198
51. Paulos JA. 1988. *Innumeracy: Mathematical Illiteracy and Its Consequences*. New York: Macmillan
52. Peebles K, Hall MG, Pepper JK, Byron MJ, Noar SM, Brewer NT. 2016. Adolescents' responses to pictorial warnings on their parents' cigarette packs. *J. Adolesc. Health* 59(6):635–41
53. Pelletier AL, Chang WW, Delzell JE Jr., McCall JW. 2004. Patients' understanding and use of snack food package nutrition labels. *J. Am. Board Fam. Pract.* 17(5):319–23
54. Peters E, Hibbard J, Slovic P, Dieckmann N. 2007. Numeracy skill and the communication, comprehension, and use of risk-benefit information. *Health Aff.* 26(3):741–48

55. Petty RE, Cacioppo JT. 1986. *The Elaboration Likelihood Model of Persuasion*. New York: Springer
56. Quitral V, Arteaga J, Rivera M, Galleguillos J, Valdés I. 2019. Comparison of sugar and non- caloric sweetener content in beverages before and after implementing Chilean law 20.606. *Rev. Chil. Nutr.* 46(3):245–53
57. Repub. Fr. 2017. Arrêté du 31 octobre 2017 fixant la forme de présentation complémentaire à la déclaration nutritionnelle recommandée par l'Etat en application des articles L. 3232-8 et R. 3232-7 du code de la santé publique. *J. Off. Repub. Fr.* 0257:16
58. Restrepo BJ. 2017. Calorie labeling in chain restaurants and body weight: evidence from New York. *Health Econ.* 26(10):1191–209
59. Reyes M, Smith Taillie L, Popkin B, Kanter R, Vandevijvere S, Corvalán C. 2020. Changes in the amount of nutrient of packaged foods and beverages after the initial implementation of the Chilean Law of Food Labelling and Advertising: a nonexperimental prospective study. *PLOS Med.* 17(7):e1003220
60. Roberto CA, Wong D, Musicus A, Hammond D. 2016. The influence of sugar-sweetened beverage health warning labels on parents' choices. *Pediatrics* 137(2):e20153185
61. Roodenburg AJC, Popkin BM, Seidell JC. 2011. Development of international criteria for a front of package food labelling system: the International Choices Programme. *Eur. J. Clin. Nutr.* 65(11):1190–200
62. Rothman RL, Housam R, Weiss H, Davis D, Gregory R, et al. 2006. Patient understanding of food labels: the role of literacy and numeracy. *Am. J. Prev. Med.* 31(5):391–98
63. Rozin P, Royzman EB. 2001. Negativity bias, negativity dominance, and contagion. *Pers. Soc. Psychol. Rev.* 5(4):296–320
64. Sacks G, Rayner M, Swinburn B. 2009. Impact of front-of-pack 'traffic-light' nutrition labelling on consumer food purchases in the UK. *Health Promot. Int.* 24(4):344–52
65. Sacks G, Tikellis K, Millar L, Swinburn B. 2011. Impact of 'traffic-light' nutrition information on online food purchases in Australia. *Aust. N. Z. J. Public Health* 35(2):122–26
66. Sacks G, Veerman JL, Moodie M, Swinburn B. 2011. 'Traffic-light' nutrition labelling and 'junk-food' tax: a modelled comparison of cost-effectiveness for obesity prevention. *Int. J. Obes.* 35:1001–9
67. Sambra V, López-Arana S, Cáceres P, Abrigo K, Collinao J, et al. 2020. Overuse of non-caloric sweeteners in foods and beverages in Chile: a threat to consumers' free choice? *Front Nutr.* 7:68
68. Santos JA, Sparks E, Thout SR, McKenzie B, Trieu K, et al. 2019. The science of salt: a global review on changes in sodium levels in foods. *J. Clin. Hypertens.* 21(8):1043–56
69. Schuldt JP. 2013. Does green mean healthy? Nutrition label color affects perceptions of healthfulness. *Health Commun.* 28(8):814–21
70. Shahid M, Neal B, Jones A. 2020. Uptake of Australia's Health Star Rating system 2014–2019. *Nutrients* 12(6):1791
71. Shang C, Huang J, Cheng K-W, He Y, Chaloupka FJ. 2017. The association between warning label requirements and cigarette smoking prevalence by education—findings from the Global Adult Tobacco Survey (GATS). *Int. J. Environ. Res. Public Health* 14(1):98
72. Shangguan S, Afshin A, Shulkin M, Ma W, Marsden D, et al. 2019. A meta-analysis of food labeling effects on consumer diet behaviors and industry practices. *Am. J. Prev. Med.* 56(2):300–14
73. Shankar P, Ahuja S, Sriram K. 2013. Non-nutritive sweeteners: review and update. *Nutrition* 29(11–12):1293–99
74. Shi Y, Grech AL, Allman-Farinelli M. 2018. Changes in the nutritional quality of products sold in university vending machines since implementation of the health star rating in 2014; an environmental audit. *BMC Public Health* 18(1):1255
75. Sinclair S, Hammond D, Goodman S. 2013. Sociodemographic differences in the comprehension of nutritional labels on food products. *J. Nutr. Educ. Behav.* 45(6):767–72
76. Smith L, Reyes M, Colchero A, Popkin B, Corval C. 2019. Changes in sugar-sweetened beverage purchases one year after Chile's front-of-package warning labels and marketing restrictions: a pre-post analysis. *protocols.io*. **https://dx.doi.org/10.17504/protocols.io.8tchwiw**
77. Soederberg Miller LM, Cassady DL, Beckett LA, Applegate EA, Wilson MD, et al. 2015. Misunderstanding of front-of-package nutrition information on US food products. *PLOS ONE* 10(4):e0125306. Correction. 2015. *PLOS ONE* 10(7):e0134772

78. Stern D, Tolentino L, Barquera S. 2011. *Revisión del etiquetado frontal: análisis de las Guías Diarias de Alimentación (GDA) y su comprensión por estudiantes de nutrición en México*. Inst. Nac. Salud Pública, Cuernavaca, Mex.
79. Strahan EJ, White K, Fong GT, Fabrigar LR, Zanna MP, Cameron R. 2002. Enhancing the effectiveness of tobacco package warning labels: a social psychological perspective. *Tob. Control* 11(3):183–90
80. Sutherland LA, Kaley LA, Fischer L. 2010. Guiding Stars: the effect of a nutrition navigation program on consumer purchases at the supermarket. *Am. J. Clin. Nutr.* 91(4):1090S–94S
81. Taillie LS, Busey E, Mediano Stoltze F, Dillman Carpentier FR. 2019. Governmental policies to reduce unhealthy food marketing to children. *Nutr. Rev.* 77(11):787–816
82. Taillie LS, Hall MG, Popkin BM, Ng SW, Murukutla N. 2020. Experimental studies of front-of-package nutrient warning labels on sugar-sweetened beverages and ultra-processed foods: a scoping review. *Nutrients* 12(2):569
83. Talati Z, Egnell M, Hercberg S, Julia C, Pettigrew S. 2019. Consumers' perceptions of five front-of-package nutrition labels: an experimental study across 12 countries. *Nutrients* 11(8):1934
84. Thomson RK, McLean RM, Ning SX, Mainvil LA. 2016. Tick front-of-pack label has a positive nutritional impact on foods sold in New Zealand. *Public Health Nutr*. 19(16):2949–58
85. Thorndike AN, Sonnenberg L, Riis J, Barraclough S, Levy DE. 2012. A 2-phase labeling and choice architecture intervention to improve healthy food and beverage choices. *Am. J. Public Health* 102(3):527–33
86. Venegas Hargous C, Reyes M, Smith Taillie L, González CG, Corvalán C. 2020. Consumption of non-nutritive sweeteners by pre-schoolers of the food and environment Chilean cohort (FECHIC) before the implementation of the Chilean food labelling and advertising law. *Nutr. J.* 19:69. Correction. 2020. *Nutr. J.* 19:135
87. Vyth EL, Steenhuis IHM, Roodenburg AJC, Brug J, Seidell JC. 2010. Front-of-pack nutrition label stimulates healthier product development: a quantitative analysis. *Int. J. Behav. Nutr. Phys. Act.* 7(1):65
88. Wogalter MS, Conzola VC, Smith-Jackson TL. 2002. Research-based guidelines for warning design and evaluation. *Appl. Ergon.* 33(3):219–30
89. World Cancer Res. Fund Int. 2020. NOURISHING database, World Cancer Res. Fund Int., London, accessed on Nov. 1, 2020. **https://policydatabase.wcrf.org**
90. World Health Organ. 2019. *Guiding principles and framework manual for front-of-pack labelling for promoting healthy diet*. Manual, World Health Organ., Geneva
91. Young L, Swinburn B. 2002. Impact of the Pick the Tick food information programme on the salt content of food in New Zealand. *Health Promot. Int.* 17(1):13–19
92. Zhen C, Zheng X. 2017. The impact of NuVal shelf nutrition labels on food purchase. *Appl. Econ. Perspect. Policy* 42:870–87

Annual Review of Nutrition

Volume 41, 2021

Contents

Errata

An online log of corrections to *Annual Review of Nutrition* articles may be found at http://www.annualreviews.org/errata/nutr