Chapter 6

Effectiveness of Dietary Policies to Reduce Noncommunicable Diseases

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INTRODUCTION

In nearly every region, suboptimal diet is the leading risk factor for poor health; hunger and malnutrition result in substantial burdens and contribute to the incidence and prevalence of noncommunicable diseases (NCDs) (Forouzanfar and others 2015; Lim and others 2012). Improving individual and population dietary habits needs to become a health system and public health priority (IFPRI 2015). In recent years, interventions have been evaluated to improve dietary habits, including individual-level interventions in the health system (for example, nutrition counseling); population-level interventions; and novel, technology-based interventions (for example, Internet- and mobile-based programs). A detailed discussion of these interventions is beyond the scope of this chapter. Here, we focus on dietary priorities and policies for global NCDs, including key dietary targets, current distributions of consumption, and ensuing health burdens. We summarize the evidence for effective population-level interventions to improve diet quality, and we discuss data gaps and needs for assessing cost-effectiveness.

The global effects of hunger and nutrient deficiencies have been recognized for more than a century, but the emergence of poor diet as a major cause of NCDs has been documented only in recent decades (Forouzanfar and others 2015; Lim and others 2012). Optimal responses to this global challenge have been slowed by several factors, including the relatively recent attention given to the science of diet and NCDs; a historical focus on isolated nutrients rather than foods and diet patterns; and an emphasis on diet-induced obesity (WHO 2012). These factors have led to the neglect of the far larger burdens of NCDs owing to nonobesity-related pathways. Modern nutritional science, originating in the early 20th century, focused on nutrient deficiency diseases, such scurvy, pellagra, and rickets. The initial recognition in the late twentieth century of the additional major effect of diet on NCDs led to nutrient deficiency paradigms being extended to the study of chronic diseases (Mozaffarian and Ludwig 2010). Nutrient deficiency diseases, however, are explicitly caused and can be prevented or treated by single nutrients. In contrast, NCDs arise from complex perturbations of food intakes and overall dietary patterns, including insufficiencies of specific healthful foods and excesses of unhealthful foods (Afshin and others 2014; Chen and others 2013; de Munter and others 2007; Imamura and others 2015; Kaluza, Wolk, and Larsson 2012; Micha, Wallace, and Mozaffarian 2010; Mozaffarian and Rimm 2006; Mozaffarian and others 2006).

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The global obesity epidemic has appropriately focused attention on diet. However, adiposity is only one pathway of effect of diet on NCDs. Diet quality has an enormous effect on NCDs, in particular, cardiovascular diseases, independent of body weight or obesity. Although *undernutrition* is an appropriate term for caloric and nutrient deficiency, *overnutrition* is an incorrect corollary for NCDs and even obesity. The term fails to capture the complexity of poor food habits that cause NCDs: (1) inadequate ingestion of healthful foods; and (2) ingestion of foods created by suboptimal processing (for example, those rich in refined grains, starches, and sugars), foods prepared by modern methods (for example, high temperature commercial cooking), and foods containing additives such as trans fats and sodium. Accordingly, the appropriate term for the global epidemic of diet-induced NCDs is not *overnutrition*, but *malnutrition*: poor dietary quality or composition.

DIETARY RISK FACTORS FOR NONCOMMUNICABLE DISEASES

Understanding the key dietary factors that have the strongest evidence of effect on NCDs, and the effective and cost-effective policies to address these factors, is essential to help guide public health planning and interventions. The Global Burden of Disease Study (GBD) of 2010 and 2013 systematically evaluated the evidence for effects of key foods, beverages, and nutrients on NCDs, including causal effects, optimal consumption levels for lowering risk, and current distributions of intakes worldwide (Forouzanfar and others 2015; Lim and others 2012; Micha and others 2012; Micha and others 2014; Micha and others 2015; Powles and others 2013; Singh, Micha, Khatibzadeh, Lim, and others 2015; Singh, Micha, Khatibzadeh, Shi, and others 2015).

Overall, consumption levels were suboptimal for each evaluated dietary risk factor on a global scale, but substantial diversity in consumption existed across regions and even neighboring countries (Micha and others 2104; Micha and others 2015; Mozaffarian and others 2014; Singh, Micha, Khatibzadeh, Lim, and others 2015; Singh, Micha, Khatibzadeh, Shi, and others 2015). For most dietary factors, the proportion of nations with average consumption levels meeting optimal intakes was low, typically representing less than 20 percent of the global adult population. Based on the 2010 GBD analysis, the five leading dietary contributors to death were as follows:

- Low fruits (4.9 million attributable deaths per year)
- High sodium (3.1 million)
- Low nuts and seeds (2.5 million)
- Low vegetables (1.8 million)
- Low whole grains (1.7 million).

In comparison, high sugar-sweetened beverage (SSB), low milk, and high red meat intakes had lower estimated mortality burdens at 184,000; 101,000; and 38,000 attributable deaths per year, respectively. These findings highlight the particular relevance of malnutrition rather than overnutrition. This evidence contrasts with conventional dietary priorities to reduce NCDs, which have traditionally focused on unhealthful factors such as saturated fat, sodium, red meats, SSBs, and added sugars. Reductions in these factors are important. However, such reductions would have a relatively small effect on overall NCD burdens compared with a coordinated strategy that increases intakes of healthful foods.

The 2010 and 2013 GBD studies focused not only on foods, beverages, and nutrients with probable or convincing evidence of effect on NCDs, but also on available global evidence on their consumption levels (table 6.1). Because of a lack of available global data, certain dietary factors such as refined carbohydrates and dairy foods beyond milk could not be included. Refined carbohydrates include white rice, bread, most breakfast cereals, added sugars, and starches such as white potatoes. Refined carbohydrates are clearly relevant for NCDs, with clear links to greater weight gain (Mozaffarian and others 2011; Te Morenga, Mallard, and Mann 2013), diabetes, and coronary heart disease (CHD) (Mozaffarian 2014). Recent global policy efforts focus on added sugars, especially SSBs. SSBs are clearly adverse for weight gain and cardiometabolic health (Mozaffarian and others 2011; Pan and Hu 2011) and are particularly heavily consumed by youth and younger adults. A general focus on reducing all refined carbohydrates—not only added sugars—is warranted because of their adverse health effects (Dietary Guidelines Advisory Committee 2015).

Dairy foods are a major component of many diets; they are particularly relevant for sufficient protein, nutrients, and calories among the poorest populations. Their cardiometabolic effects, relevant bioactive characteristics (for example, fatty acids, probiotics, and fermentation), and potential effects by subtype (for example, milk, cheese, and yogurt) remain understudied. Current evidence supports guidelines for modest dairy consumption of two to three servings a day, in particular, yogurt and cheese (Aune and others 2013; Chen and others 2014). Conventional recommendations to select fat-reduced, rather than whole-fat, dairy are not strongly evidence based; according to current data, both appear to be reasonable choices (Mozaffarian 2014).

Table 6.1 Global Consumption and Optimal Levels, Deaths, and Disability-Adjusted Life Years Attributable to Dietary Habits with Largest Public Health Effect, 2010

Dietary factor[a]	Global consumption, 2010 (mean, 95% UIs)[b]	Optimal consumption[c]	Global adult population meeting optimal levels (%)	Related NCD outcomes at increased intakes	Global deaths, 2010 (mean, 95% UIs)[d]	Global DALYs, 2010 (mean, 95% UIs)[d]
Foods						
Fruits	81.3 g/d (78.9–83.7)	300 ± 30 g/d	0.4	↓ CHD; ↓ stroke; ↓ mouth, pharynx, larynx, esophagus, lung cancers	4,902,242 (3,818,356–5,881,561)	104,095 (81,833–124,169)
Vegetables	208.8 g/d (203.4–214.3)	400 ± 40 g/d	7.8	↓ CHD; ↓ stroke; ↓ mouth, pharynx, larynx, esophagus cancers	1,797,254 (1,205,059–2,394,366)	38,559 (26,006–51,658)
Nuts and seeds	8.9 g/d (8.3–9.5)	4 (28.35 g = 1 oz) ± 0.4 servings/wk	9.6	↓ CHD	2,471,823 (1,559,603–3,226,994)	51,289 (33,482–65,959)
Whole grains	38.4 g/d (35.5–41.7)	2.5 (50 g) ± 0.25 servings/d	7.6	↓ CHD; ↓ stroke; ↓ DM	1,725,812 (1,342,896–2,067,224)	40,762 (32,112–48,486)
Red meats	41.8 g/d (40.8–42.8)	1 (100 g) ± 0.1 serving/wk	20.3	↑ DM; ↑ colorectal cancer	38,092 (10,749–65,727)	1,853 (870–2,946)
Processed meats	13.7 g/d (13.2–14.3)	0	0	↑ CHD; ↑ DM; ↑ colorectal cancer	840,857 (188,952–1,460,279)	20,939 (6,982–33,468)
Milk	81.7 g/d (79.7–83.9)	2 (226.8 g = 8 oz) ± 0.2 servings/d	0	↓ Colorectal cancer	100,951 (29,728–171,340)	2,101 (619–3,544)
SSBs	101.4 g/d (94.9–109.1)	0	0	↑ BMI-mediated effects[e]; ↑ DM	210,780 (136,271–299,863)	5,250 (3,052–7,402)

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Table 6.1 Global Consumption and Optimal Levels, Deaths, and Disability-Adjusted Life Years Attributable to Dietary Habits with Largest Public Health Effect, 2010 (continued)

Dietary factor[a]	Global consumption, 2010 (mean, 95% UIs)[b]	Optimal consumption[c]	Global adult population meeting optimal levels (%)	Related NCD outcomes at increased intakes	Global deaths, 2010 (mean, 95% UIs)[d]	Global DALYs, 2010 (mean, 95% UIs)[d]
Nutrients						
PUFA in place of SFA	n-6 PUFA: 5.9 %E (5.7–6.1); SFA: 9.4 %E (9.2–9.5)	12 ± 1.2 %E[f]	n-6 PUFA: 0.1; SFA: 61.8[f]	↓ CHD	533,603 (245,096–820,854)	11,680 (5,360–17,798)
Seafood omega-3 fats	163 mg/d (154–172)	250 ± 25 mg/d	18.9	↓ CHD	1,389,896 (1,010,300–1,781,401)	28,199 (20,624–35,974)
Trans fats	1.4 %E (1.36–1.44)	0.5 ± 0.05 %E	0.6	↑ CHD	515,260 (371,081–649,451)	11,592 (8,395–14,623)
Sodium	3,953.6 mg/d (3,885.4–4,014.0)	1,000 ± 100 mg/d	0	↑ SBP-mediated effects[g]; ↑ stomach cancer	3,104,308 (2,016,734–4,105,019)	61,231 (40,124–80,342)

Source: Lim and others 2012.

Note: BMI = body mass index; CHD = coronary heart disease; d = day; DALYs = disability-adjusted life years; DM = diabetes mellitus; %E = percent energy; g = gram; mg = milligram; NCD = noncommunicable disease; oz = ounce; PUFA = polyunsaturated fatty acid; SBP = systolic blood pressure; SFA = saturated fatty acid; SSBs = sugar-sweetened beverages; UIs = uncertainty intervals; wk = week.

a. These are dietary risk factors for which we identified probable or convincing evidence of etiologic effects on chronic diseases, including CHD, stroke, type 2 DM, BMI, SBP, or cancers. Using available evidence, we identified etiologic effects on CHD, stroke, or DM by fruits, vegetables, nuts and seeds, whole grains, red meats, processed meats, SSBs, PUFAs as a replacement for SFAs, seafood omega-3 fats, trans fats, and dietary sodium. For cancers, we based our assessments on World Cancer Research Fund and American Institute for Cancer Research (2007) and subsequent updates (World Cancer Research Fund International 2016).

b. Optimal metrics for each dietary factor were defined to be consistent with definitions used in epidemiological studies that provided evidence of etiologic effects on chronic diseases, and optimal units were applied to match those of studies used to evaluate relationships with disease risk as well as major dietary guidelines (Micha and others 2012). Dietary factors were evaluated as percent energy, or %E (PUFA, SFA, trans fats), or were standardized using the residual method (Willett 1998) to 2,000 kilocalories per day (fruits, vegetables, nuts and seeds, whole grains, red meats, processed meats, milk, SSBs, seafood omega-3 fats, dietary sodium). We performed systematic searches for individual-level dietary surveys in all countries (187 worldwide). The results of our search strategy by dietary factor, time, and region have been reported (Khatibzadeh and others 2012). We identified a total of 266 surveys of adults representing 113 of 187 countries and 82 percent of the global population. Measurement comparability and consistency across surveys was maximized by (1) using a standardized data analysis approach, which accounted for sampling strategies within the survey by including sampling weights; the average of all days of dietary assessment to quantify mean dietary intakes; a corrected population standard deviation (SD) to account for within- versus between-person variation; and standardized dietary metrics and units of measure across surveys and (2) adjusting for total energy to reduce measurement error and also account for differences in body size, metabolic efficiency, and physical activity (Willett 1998). To address missing data, imperfect estimates, incomparability, and related effects on uncertainty of dietary estimates, we developed an age-integrating Bayesian hierarchical imputation model, which has been described in detail (Lim and others 2012). Using simulation (Monte Carlo) analyses, we drew 1,000 times from the posterior distribution of each exposure for each age-sex-country-year stratum; computed the mean exposure from the 1,000 draws; and used the 95 percent UIs as the 2.5th and 97.5th percentiles of the 1,000 draws.

c. For each dietary factor, the optimal consumption level was identified on the basis of both the observed levels at which lowest disease risk occurs and the observed mean consumption levels in at least two to three countries. We considered whether such identified levels were consistent with major dietary guidelines (FAO 2010; U.S. Department of Health and Human Services and U.S. Department of Agriculture 2010). Because not all individuals within a population can have precisely the same exposure level, the plausible SD of optimal consumption was calculated from the average SD for all metabolic risk factors in the Global Burden of Disease Study 2010 (10 percent of the mean).

d. We estimated the burden (mortality and morbidity) attributable to dietary risk factors by comparing the present distribution of exposure to the optimal exposure distribution. Attributable mortality was estimated using the diet-disease population-attributable fraction (PAF) (Lim and others 2012). The number of deaths attributable to each dietary factor was calculated by multiplying the estimated PAF by the observed number of disease-specific deaths. The proportion of total DALYs was similarly estimated. Mean deaths and DALYs were computed from the 1,000 draws of probabilistic simulation analyses, and the 95 percent UIs were used as the 2.5th and 97.5th percentiles of the 1,000 draws, further incorporating uncertainty in dietary exposure data and etiologic relative risks by age and sex. These comparative risk assessment analyses do not account for joint effects of multiple risk factors (multi-causality). Given potential for joint distributions and interactions, the effects of multiple dietary factors should not simply be summed to determine total effects (Lim and others 2012).

e. The effects of high intake of SSBs on CHD, stroke, other cardiovascular diseases, DM, and other related diseases; other NCDs; and cancers were estimated through their measured effects on BMI (Renehan and others 2008; Singh and others 2013). Direct effects on BMI and (independent of this) additional direct effects on DM were included.

f. Optimal consumption was based on increasing PUFA to 12%E as a replacement for SFA, in accordance with evidence that this specific nutrient replacement reduces risk (Jakobsen and others 2009; Mozaffarian, Micha, and Wallace 2010). To estimate the percentage of global adult population meeting optimal levels for SFA only, we based recommended intake levels of less than 10%E for a 2,000 kilocalorie per day diet on the U.S. Department of Agriculture and United Nations Food and Agriculture Organization guidelines (U.S. Department of Health and Human Services and U.S. Department of Agriculture 2010).

g. The effects of high intake of dietary sodium on CHD, stroke, and other cardiovascular diseases were estimated through their measured effects on SBP (Singh and others 2013).

GBD 2010 and 2013 also did not systematically assess the cardiometabolic effects of flavonoid-rich foods, including cocoa, berries, apples, and tea. Although these appear potentially beneficial, the heterogeneity of specific phenolics, the variability of dietary sources, and fewer studies that evaluate clinical endpoints limit strong conclusions (Hooper and others 2012; Shrime and others 2011) but provide a strong basis for further investigation.

EFFECTIVENESS OF POPULATION INTERVENTIONS TO IMPROVE DIET

Because of current and projected disease burdens, identifying and implementing effective interventions to improve diet quality needs to be a health system priority and public health priority for all regions. Behavior change interventions that target individuals with individualized nutrition counseling within the health system can be effective. However, these often have limited coverage, can be more costly, and may have limited sustainability (Artinian and others 2010; Rose 1985). In comparison, population-based interventions can have broader effect, lower cost, and greater sustainability, as well as the potential to reduce disparities (McGill and others 2015; Mozaffarian and others 2012). Such interventions include those implemented at health system, organizational (for example, schools and workplaces), community, state, and national levels. The evidence of effectiveness of such interventions has been systematically reviewed, including for education and mass media campaigns, food labeling and consumer information, food pricing and economic incentives, school and worksite interventions, and direct restrictions and mandates (Afshin, Penalvo, and others 2015; Mozaffarian and others 2012). Several effective policy strategies are listed in table 6.2.

Mass Media Campaigns

Mass media campaigns, alone or as a part of multicomponent interventions, can improve diet when focused on specific dietary targets. Supportive evidence includes quasi-experimental studies of the "5 A Day For Better Health!" and "Fruits & Veggies—More Matters" campaigns in the United States and multicomponent strategies in Finland (Pekka, Pirjo, and Ulla 2002; Puska and Stahl 2010), Singapore (Bhalla and others 2006), and

Table 6.2 Evidence-Based Population Interventions to Improve Diet[a]

Population area	Intervention
Media and education	• Sustained, focused media and education campaigns (using multiple modes) for increasing consumption of specific healthful foods or reducing consumption of specific less healthful foods or beverages, either alone (class IIa B) or as part of multicomponent strategies (class I B)[b,c,d] • On-site supermarket and grocery store educational programs to support the purchase of healthier foods (class IIa B)[b]
Labeling and information	• Mandated nutrition facts panels or front-of-pack labels or icons as a means to influence industry behavior and product formulations (class IIa B)[b,e]
Economic incentives	• Subsidy strategies to lower prices of more healthful foods and beverages (class I A)[b] • Tax strategies to increase prices of less healthful foods and beverages (class IIa B)[b] • Changes in both agricultural subsidies and other related policies to create infrastructure that facilitates production, transportation, and marketing of healthier foods, sustained over several decades (class IIa B)[b]
Schools	• Multicomponent interventions focused on improving both diet and physical activity, including specialized educational curricula, trained teachers, supportive school policies, formal physical education programs, serving of healthier food and beverage options, and parental or family component (class I A)[b] • School garden programs, including nutrition and gardening education and hands-on gardening experiences (class IIa A)[b] • Fresh fruit and vegetable programs that provide free fruits and vegetables to students during the school day (class IIa A)[b]
Workplaces	• Comprehensive worksite wellness programs with nutrition, physical activity, and tobacco cessation or prevention components (class IIa A)[b] • Increased availability of healthier food and beverage options and strong nutrition standards for foods and beverages served, in combination with vending machine prompts, labels, or icons to select healthier choices (class IIa B)[b]
Local environment	• Increased availability of supermarkets near homes (class IIa B)[b,c,f]

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Table 6.2 Evidence-Based Population Interventions to Improve Diet[a] (continued)

Population area	Intervention
Restrictions and mandates	• Restrictions on television advertisements for less healthful foods or beverages advertised to children (class I B)[b] • Restrictions on advertising and marketing of less healthful foods or beverages near schools and public places frequented by youths (class IIa B)[b] • General nutrition standards for foods and beverages marketed and advertised to children in any fashion, including on-package promotion (class IIa B)[b] • Regulatory policies to reduce specific nutrients in foods (for example, trans fats, salt, certain fats) (class I B)[b,d]
Agricultural	• Fiscal, trade, and regulatory instruments where feasible and proven effective to improve production, storage, and distribution of healthful foods (for example, fruits and vegetables) • Development of mutual metrics that can be used to measure and evaluate the contributions of each relevant sector to improving diet

Source: Adapted from Mozaffarian and others 2012.

a. The specific population interventions listed here are those that achieved either a class I or a class IIa recommendation, together with an evidence grade of either A or B. The American Heart Association evidence grading system is as follows:

- Class I: Evidence or general agreement exists that the intervention is beneficial, useful, and effective; the intervention should be performed.
- Class II: There is conflicting evidence or a divergence of opinion about the usefulness or efficacy of the intervention.
- Class IIa: Weight of evidence or opinion is in favor of usefulness or efficacy; performing the intervention is reasonable.
- Class IIb: Usefulness or efficacy is less well established by evidence or opinion; the intervention may be considered.
- Class III: There is evidence or general agreement that the intervention is not useful or effective and in some cases may be harmful.

The weight of evidence in support of the recommendation is classified as follows:

- Level of Evidence A: Data are derived from multiple randomized clinical trials or, given the nature of population interventions, from well-designed quasi-experimental studies combined with supportive evidence from several other types of studies.
- Level of Evidence B: Data are derived from a single randomized trial or nonrandomized studies.
- Level of Evidence C: Evidence consists of only consensus opinion of experts, case studies, or standard-of-care. For brevity, we have not cited all of the more than 500 individual studies reviewed in that American Heart Association Scientific Statement.

b. At least some evidence is found in studies conducted in high-income western regions and countries, for example, North America, Europe, Australia, and New Zealand.

c. At least some evidence is found in studies conducted in high-income nonwestern regions and economies, for example, Hong Kong SAR, China; Japan; the Republic of Korea; and Singapore.

d. At least some evidence is found in studies conducted in low- and middle-income regions and countries, for example, Africa, China, India, and Pakistan.

e. Such labeling strategies alone have limited effect if not complemented with environmental changes.

f. Based on cross-sectional studies only; only two longitudinal studies have been performed, with no significant relations seen.

Mauritius (Dowse and others 1995) that included mass media. The effect size of mass media campaigns appears to vary depending on the population (for example, generally more effectiveness in more educated and higher-income groups) and the features of the campaign (for example, coverage, duration, modes of delivery and communication, and presence or absence of additional intervention components). The cost-effectiveness of such strategies, which can require relatively high resources, has not been formally evaluated.

We recently systematically reviewed and synthesized the evidence of effectiveness of mass media campaigns to improve diet (Afshin and others 2013; Afshin, Penalvo, and others 2015). We identified eight studies of a mass media campaign in isolation and six of a mass media campaign as part of multicomponent national programs. The campaigns were implemented nationally (four studies), regionally (two studies), and locally (eight studies). They used a variety of mediums: audiocassette tapes (Connell, Goldberg, and Folta 2001); television, radio, and print advertising (Pollard and others 2008; Stables and others 2002); logos and branding (Ashfield-Watt 2006; Stables and others 2002); newspapers (Nishtar and others 2004); and booklets and brochures (Marcus and others 2001). The duration of campaigns varied from one month to 30 years. The number of participants in these studies totaled approximately 60,000 adults and children (n = 700 to 32,500 in individual studies). Women constituted the majority of study participants in each study (range, 52–94 percent). The populations covered a wide range of income and socioeconomic levels, and most were Caucasian. Pooling the results of five studies evaluating mass media campaigns in isolation, we identified a 0.2-serving-per-day increase in fruit and vegetable consumption. Among national multicomponent interventions that included a prominent mass media campaign (n = 3), we found lower prevalence of hypertension (15 percent less, 95 percent confidence interval 10–21) and hypercholesterolemia (61 percent less, 95 percent confidence interval 40–75).

In contrast with focused media campaigns, passive provision of consumer information appears to have little effect on behavior (Afshin, Penalvo, and others 2015). Evidence from both observational and quasi-experimental studies demonstrates that providing nutrition information on food packages, on restaurant menus, or at the point of purchase is generally ineffective for altering consumer behavior (Shangguan and others 2015). Anecdotal evidence suggests that mandating such information might in some cases influence food industry reformulations, but further investigation of this approach is required.

In sum, these findings support effectiveness of mass media campaigns for improving diet. However, more studies are needed to confirm and expand these findings.

Fiscal Policies

Fiscal measures, including taxation and subsidies, are among the most promising dietary policies. These measures are recommended in the American Heart Association Scientific Statement on population interventions; by the United Nations Political Declaration on NCDs; and by the World Health Organization's (WHO) Global Strategy on Diet, Physical Activity and Health (Mozaffarian and others 2012; UN 2011; WHO 2004). Cross-sectional price-elasticity analyses of demand (Andreyeva, Long, and Brownell 2009; Green and others 2013), evidence from prospective studies (Thow, Downs, and Jan 2014), and evidence from intervention studies (An 2013) demonstrate consistent efficacy of changes in food pricing, including subsidies to increase healthful foods and taxes to decrease unhealthful foods and drinks. The magnitude of the effect is proportional to the price change; larger changes of 10–50 percent have greater effect. Although small taxes are not expected to have a major effect on population consumption levels, such taxes are more politically feasible and can generate large amounts of revenue for other prevention programs. Fiscal approaches also have larger effects in low-income countries and on lower socioeconomic groups, the populations who are at highest risk and have the most to gain from improved diets (Green and others 2013).

Evidence from cross-sectional analyses of price elasticity of demand suggests that each 10 percent change in the price of foods and beverages is associated with a 4 percent to 8 percent change in consumption (table 6.3). Several factors may influence the magnitude of this effect, including the specific dietary target and national and individual socioeconomic status.

We systematically evaluated and quantified the prospective effect of price changes on dietary consumption in 23 interventional and seven observational studies (Afshin, Del Gobbo, and others 2015). The interventional studies were conducted in five countries (France, the Netherlands, New Zealand, South Africa, and the United States), and the observational studies were conducted in the United States. Pooling all studies, we found that each 10 percent price decrease was associated with a 14 percent (95 percent confidence interval 11–17) increase in consumption of fruits and vegetables and a 16 percent (95 percent confidence interval 10–23) increase in consumption of other healthful foods. A 10 percent price increase was associated with 7 percent (95 percent confidence interval 3–10) lower consumption of SSBs and 3 percent (95 percent confidence interval 1–5) lower consumption of fast foods. The study also found that lower prices of fruits and vegetables were associated with lower body mass index (0.04 kilogram per square meter [kg/m^2] per 10 percent price decrease [95 percent confidence interval 0.00–0.08 kg/m^2]). Thus, price changes clearly influence consumption significantly. The effect on health can be modified by other factors, such as alternative choices (for example, a consumer's selection of substitutes in response to reducing purchases of a taxed food or increasing purchases of a subsidized food) and food industry responses (for example, use of internal pricing strategies to reduce the effect of taxation).

Table 6.3 Change in Demand for Major Food Groups per 10 Percent Change in Price of the Food Groups in Low-, Middle-, and High-Income Countries, 1990–2011

percent

	Countries		
Food group	**Low income**	**Middle income**	**High income**
Fruits and vegetables	7.2 (6.6–7.7)	6.5 (5.9–7.1)	5.3 (4.8–5.9)
Meat	7.8 (7.3–8.3)	7.2 (6.6–7.8)	6.0 (5.4–6.6)
Fish	8.0 (7.4–8.5)	7.3 (6.7–7.9)	6.1 (5.5–6.7)
Dairy	7.8 (7.3–8.4)	7.2 (6.6–7.8)	6.0 (5.4–6.6)
Eggs	5.4 (4.2–6.7)	4.8 (3.5–6.1)	3.6 (2.3–4.9)
Cereals	6.1 (5.6–6.6)	5.5 (4.9–6.1)	4.3 (3.6–4.8)
Fats and oils	6.0 (5.4–6.5)	5.4 (4.7–6.0)	4.2 (3.5–4.8)
Sweets, confectioneries, and SSBs	7.4 (6.5–8.2)	6.8 (5.9–7.7)	5.6 (4.8–6.5)
All food groups combined	7.4 (6.9–7.9)	6.8 (6.2–7.3)	5.6 (5.0–6.1)

Source: Based on Green and others 2013.
Note: SSBs = sugar-sweetened beverages.

Organizational Settings

In accordance with randomized controlled trials and quasi-experimental studies, both schools and workplaces represent effective settings for improving diet and diet-related risk factors (Afshin, Penalvo, and others 2015;

Micha and others 2016). Isolated interventions have limited effects, but more comprehensive, multicomponent programs are effective. Interventions are most effective if they include formal educational curricula; supportive school or worksite policies; environmental changes, such as healthier vending machine and cafeteria options; and family and parental or peer-support components.

Local Food Environment

Differences in neighborhood food environments, such as supermarkets, grocery stores, fast food outlets, and other restaurants, have come under investigation as determinants of diet (Mozaffarian and others 2012). The low availability of supermarkets, termed *food deserts*, has been considered a potential risk factor for poor diet (Cummins and Macintyre 2002). Yet, the evidence for the effect of neighborhood food environments on consumption has generally been mixed and inconclusive. Across numerous studies, differences in proximity and density of grocery stores, convenience stores, fast food outlets, and other restaurants each inconsistently relate to either dietary intakes or diet-related risk factors, such as adiposity (Afshin, Penalvo, and others 2015). Positive associations of the availability of supermarkets with healthier diets (in particular, intakes of fruits and vegetables) and lower adiposity have been the most consistent. However, nearly all the investigations of neighborhood food environments have been cross-sectional, greatly limiting inference on either temporality or causality. Insufficient evidence exists to draw strong conclusions on the dietary effects of altering the availability or density of different types of food establishments.

Examples of Successful National Policies to Improve Diet

Trans Fats Restrictions

Denmark was the first country to pass legislation to limit the trans fat content of foods (Leth and others 2006). Danish Order No. 160 of March 11, 2003, stipulated a maximum of 2 percent of industrially produced trans fats in oils and fats (2 grams per 100 grams of fat). Evidence from a series of assessments of the trans fat content in a broad range of foods sold in Denmark conducted from the end of 2002 to early 2003 (253 samples preregulation) and again at the end of 2004 to early 2005 (148 samples postregulation) indicated this policy was highly effective in reducing the trans fat content of foods to the targeted levels. The legislation represented a final key step after a decade of intermittent, industry-specific voluntary attempts to reduce the consumption of trans fat in the country (Bech-Larsen and Aschemann-Witzel 2012; Leth and others 2006). Subsequently, several other European countries, including Austria, Hungary, Iceland, Norway, Sweden, and Switzerland, also banned trans fat at the national level (WHO 2015). The United States recently indicated that partially hydrogenated oils (the major source of industrial trans fat) would no longer be generally recognized as safe, effectively eliminating their use in the food supply (Downs, Thow, and Leeder 2013; U.S. Food and Drug Administration 2015). Among low- and middle-income countries (LMICs), Argentina is the first to restrict industrial trans fat content of vegetable oils and margarines to 2 percent of total fat (Rubinstein and others 2015).

Taxation of Unhealthy Beverages or Foods

Several countries have introduced specific taxes on unhealthy foods and beverages (Mytton, Clarke, and Rayner 2012). Evidence from legislative documents and political debates, as well as the size of the implemented taxes, suggests that, in addition to the aim of improving diets, revenue generation has been a major driving force behind most of the implemented taxes (Bodker and others 2015; Vallgarda, Holm, and Jensen 2015).

In 2011, Hungary introduced a tax on specific packaged foods and beverages with a high content of sugar, salt, or caffeine, such as SSBs, energy drinks, confectionery products, salted snacks, condiments, flavored alcohol, and fruit jams. This tax now generates more than US$75 million per year, but its size and target food categories have changed since implementation. In 2012, France introduced a tax on nonalcoholic beverages with added sugars and artificial sweeteners (US$0.03 per can), which has generated nearly US$300 million per year. In 2014, Mexico implemented a tax of 10 percent per liter of soda. A preliminary analysis in Mexico demonstrates significant reductions in SSB consumption at one year, with an average national decline of 6 percent, and partial replacement with noncaloric beverages (Colchero and others 2016). SSB reductions were largest in lower-income groups (average decline of 9 percent), strongly suggesting a causal effect of the tax rather than population trends as a result of public awareness or education. Mexico's tax also targeted many processed snack foods, generating substantial national revenue that was intended to help increase access to water in public schools.

In October 2011, Denmark implemented a national "fat tax" that was based on the saturated fat content of foods (Bodker and others 2015; Vallgarda, Holm, and Jensen 2015). The tax (US$2.30 per kg of saturated fat) was introduced on all foods containing more than 2.3 percent saturated fat, including meats, dairy, and many cooking oils). The result was price increases ranging from 7 percent for one liter of olive oil to 30 percent for a package of butter. This tax was anticipated to generate more than US$200 million per year and reduce saturated fat consumption by 4–10 percent. However, after only 15 months, the tax was repealed mainly because of sustained industry opposition and lobbying alleging economic harms that include administrative costs, job losses, and consumer reactions (Bodker and others 2015; Vallgarda, Holm, and Jensen 2015). The weak evidence for prioritizing fat or even saturated fat alone as a metric (Mozaffarian 2015; Mozaffarian and Ludwig 2015) may also have contributed to the failure of this proposal.

Based on these experiences, national taxes can be effective to both generate revenue and improve dietary habits when they are focused on strong evidence-based priorities that also resonate with the public, such as reduction of SSBs. Optimally, revenue from such taxes should be used to improve population diet further, for example, by means of policies that reduce the prices of more healthful food choices.

Multicomponent Interventions

In 1987, Mauritius instituted a five-year national, multicomponent intervention to reduce NCD risk factors (Uusitalo and others 1996). Approaches included a mass media campaign; fiscal and legislative changes; education; and a regulatory policy that mandated replacement of palm oil—the most common cooking oil—with 100 percent soybean oil, which is high in n-6 and n-3 polyunsaturated fats. National cross-sectional surveys in 1987 and 1992 demonstrated reductions in saturated fat intake (by 3.5 percent energy) and increases in intake of polyunsaturated fat intake (by approximately 5.5 percent energy) over that period. In addition, mean population total blood cholesterol levels fell significantly, with absolute reductions of 0.80 millimoles per liter. In accordance with established effects of dietary fats on blood cholesterol, the changes in cooking oil were estimated to account for about 50 percent of this improvement. The prevalence of hypercholesterolemia decreased by 80 percent.

Other targeted lifestyle factors also improved, including decreased smoking (from 58 percent to 47 percent in men and 7 percent to 4 percent in women), increased moderate leisure activity (from 17 percent to 22 percent in men and 1 percent to 3 percent in women), and decreased frequent alcohol intake (from 18 percent to 14 percent in men). The prevalence of all hypertension and borderline hypertension tended to decrease (Dowse and others 1995). In contrast, during this same period, the prevalence of overweight and obesity increased (in men, from 23 percent to 30 percent and from 3 percent to 5 percent, respectively; in women, from 28 percent to 33 percent and from 10 percent to 15 percent, respectively). However, the prevalence of diabetes and impaired glucose tolerance remained stable. Because overweight and obesity increased in all nations globally during this period, whether these increases in Mauritius might have been even worse without the national interventions is unclear.

Overall, these findings, together with similar experiences in Finland, indicate that multicomponent national dietary policies, including mandates to increase healthier foods, can have major positive effects on NCD risk factors.

COST-EFFECTIVENESS OF POPULATION INTERVENTIONS TO IMPROVE DIET

Cost is a key potential barrier to implementation and sustainability of any evidence-based intervention. Although based on the first principles that many population-level dietary interventions may be highly cost-effective or even cost saving, formal cost-effectiveness analyses in this area are limited (Cobiac, Veerman, and Vos 2013). Historically, this paucity of data results from lack of reliable data on dietary habits in many populations, insufficient systematically determined effect sizes of population-level interventions to improve diet, controversy over causal effects of dietary changes, and little systematically collected data on costs of such interventions. In recent years, efforts have been made to address these gaps. The 2010 and 2013 GBDs assess global consumption levels of a range of dietary factors by age and gender in 187 countries and the best evidence for their etiologic effects on NCDs. The WHO NCD Costing Tool provides data on health care costs in many countries, as well as resource ingredient needs and corresponding costs of selected policy interventions such as mass media campaigns and alcohol taxation (Evans and others 2005; Murray and others 2000; WHO 2003). For most policies, acquiring the data needed to estimate the cost of the intervention remains a challenge. Chapter 20 in this volume (Watkins, Nugent, and Verguet 2017) offers a detailed review of cost-effectiveness studies of dietary policies.

The early evidence that has emerged from evaluations of actual policies is mixed. In a short-term evaluation of the first city-level tax on SSBs in the United States, Cawley and Frisvold (2015) found relatively little pass through of the Berkeley, California, SSB tax to consumers; retail prices rose by less than half of the amount of the tax. The direct effect on consumption and obesity is likely to be smaller than expected in much of the literature that found or assumed full shifting or even overshifting of taxes. In light of the uncertainty about the effectiveness of diet-related fiscal policies, the examination of their cost-effectiveness by only a minority of studies is not surprising, particularly in LMICs. Cecchini and others' (2010) article was the only published paper to model obesity prevention policies in LMICs, covering Brazil, China, India, Mexico, and South Africa. Their results indicate that fiscal measures (including increasing the price of unhealthy food content or reducing the cost of healthful foods rich in fiber) were less expensive per person than were regulatory or individual interventions; they were the only measures considered that were cost saving for all LMICs at both 20- and 50-year time horizons. In addition, they were cost saving by a magnitude of twice the other interventions considered. Price interventions and regulation appear to produce the largest health gains in the shortest time frame.

As one of the earlier, fairly wide-ranging applications of the modeling approach based on the WHO Choosing Interventions that are Cost-Effective (WHO-CHOICE), Murray and others (2003) modeled salt reduction, mass media health education, and individual treatment, as well as various combinations of different interventions, in two lower-income regions (South-East Asia, with high rates of adult and child mortality, and Latin America, with low adult and child mortality) and one high-income region (Europe, with very low adult and child mortality). Their findings indicate that the nonpersonal interventions have a lower, more favorable cost-effectiveness ratio than do the personalized health service interventions. Voluntary agreements to reduce salt are less cost-effective than legislative measures; salt reduction legislation is estimated to buy one DALY for as little as US$3.74 in South-East Asia and US$2.60 in Latin America. Combinations of salt legislation and mass media programs on healthy behavior have the potential to lower the cost-effectiveness ratio even further. However, the most cost-effective set of interventions is a mix of population-level interventions, preventive interventions, and personalized treatments.

Two follow-up studies to Murray and others (2003) have attempted to provide global or at least multiregional estimates of the cost-effectiveness of salt regulation (as well as other interventions). Asaria and others (2007) modeled the cost and effects of shifts in the distribution of risk factors associated with salt intake and tobacco use on chronic disease mortality for 23 countries that account for 80 percent of chronic disease burden in LMICs. They showed that, over 10 years (2006–15), 13.8 million deaths could have been averted by implementation of these interventions, at a cost of less than US$0.40 per person per year in low-income countries and lower-middle-income countries and US$0.50–US$1.00 per person per year in upper-middle-income countries, as of 2005. Ortegon and others (2012) provide updated evidence on broadly similar interventions in Africa and South-East Asia. In the salt domain, they model the cost-effectiveness of salt reduction in processed foods via voluntary agreements with industry and salt reduction in processed foods via legislation. Rubinstein and others used a more geographically focused application of the WHO-CHOICE approach in two closely related papers, one focusing on Buenos Aires (Rubinstein and others 2009) and the other on Argentina as a whole (Rubinstein and others 2010). The interventions modeled in both studies are similar, including lowering salt intake in the population through voluntary agreements to reduce the levels of salt in bread and providing mass education programs and individual treatment options (Murray and others 2003). The findings in Argentina indicate that any salt reduction would be cost saving; the Buenos Aires–related study suggests that a salt reduction policy would cost very little and would be more cost-effective than a mass media campaign.

Ferrante and others (2012) also looked at salt reduction in Argentina using a simulation model not based on WHO-CHOICE. They analyzed the costs and expected effects of a slightly different salt-related intervention entailing a salt content reduction by 5–25 percent, not only in bread but also in a wider range of food groups that contribute a significant percentage of the salt consumed in the normal diet (for example, bread products, meat products, canned foods, soups, and dressings). Results suggested that this intervention was cost saving and produced substantial benefits to population-wide, diet-related health outcomes. The expectation that salt reduction may be cost saving, applied on its own or in combination with other interventions, has been supported by evidence from four countries in the eastern Mediterranean region (Mason and others 2014). This study evaluated three policies to reduce dietary salt intake, alone and in combination: a health promotion campaign, labeling of food packaging, and mandatory reformulation of salt content in processed food.

In light of the scarcity of evidence of policy effect in high-income countries as well, cost-effectiveness estimates of trans fat policies are difficult to obtain. A recent exception is a much-discussed contested modeling study by Allen and others (2015) that simulated costs and effects of three options for further restricting trans fat consumption in England: a ban of trans fatty acids in processed foods, improved labeling of trans fatty acids, and a restaurant ban of trans fatty acids. The researchers had a specific interest in examining the distributional effects of the various approaches across different socioeconomic groups. The reported findings suggest that the expected health effects of a total ban, as well as policies to improve labeling or simply remove trans fatty acids from restaurants and fast food stores, would lead to a considerable reduction in coronary heart disease mortality. Moreover, these benefits would be larger among lower socioeconomic groups—a rare example of an intervention that may increase average population health and health equity. In addition, the study predicts large cost savings from these policies. However, through inclusion of informal care costs and productivity costs, the cost categories in the analysis of cost-effectiveness reach far beyond the types of costs commonly included in health economic evaluations. Nevertheless, the study is critical of the health and economic effects of a continued reliance on industry to voluntarily reformulate products.

CONCLUSIONS

Suboptimal diet is the single-largest risk factor for poor health globally. Specific population interventions, including taxation and subsidies, food regulations, mass media campaigns, and school and workplace interventions, appear effective in improving diet. Many such interventions may be highly cost-effective (efficient health gained per dollar spent) or even cost saving (health gains with reduced overall spending). These interventions are highly attractive and complement the preventive health system strategies promoted in high-, middle-, and low-income countries. Selected policy interventions may also reduce health disparities.

Specific knowledge gaps remain in quantitative effectiveness and cost-effectiveness of several dietary policies in different settings and within different population subgroups. These gaps highlight the urgent need for governments, foundations, advocacy groups, and private industry to prioritize relevant implementation and evaluation of these approaches.

NOTE

World Bank Income Classifications as of July 2014 are as follows, based on estimates of gross national income (GNI) per capita for 2013:

- Low-income countries (LICs) = US$1,045 or less
- Middle-income countries (MICs) are subdivided:
  (a) lower-middle-income = US$1,046 to US$4,125
  (b) upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

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