Volume 5. Chapter 7
Weight Management

Vasanti Malik and Frank Hu

Introduction

Once considered a problem only in high-income countries, obesity has become a major contributor to the global disease burden (Finucane 2011; Misra and Khurana 2008). Excess adiposity particularly around the subcutaneous abdominal region is an important risk factor for morbidity and mortality from type 2 diabetes, cardiovascular diseases, and some cancers (Danaei and others 2005; Whitlock and others 2009; WHO 2009). Although some studies have suggested lower mortality among overweight or obese persons than among healthy-weight persons (Carnethon and others 2009), this has not been observed in studies that properly account for the confounding effects of smoking and other biases (Tobias, Pan, and Fu 2014). The costs of obesity and comorbidities are staggering in terms of both health care expenditures and quality of life, underscoring the importance of implementing obesity prevention strategies on a global scale.

The changes needed to reverse global trends in obesity will likely require numerous interventions and policy recommendations that target diet, lifestyle, and environmental risk factors. In this chapter we summarize the global burden of obesity and the impact of a spectrum of obesity risk factors ranging from sociopolitical and economic forces that are largely beyond an individual's control to modifiable lifestyle factors and genetic and epigenetic risks. We also review the effectiveness of population-based interventions and policies for preventing obesity,

some individual-level treatment options across various platforms, and the cost-effectiveness of select interventions.

Global Burden of Obesity

Obesity arises as the result of an energy imbalance between calories consumed and calories expended, creating an energy surplus resulting in excess body weight. In adults, overweight and obesity are typically defined as having a body mass index (BMI), measured as weight in kilograms divided by height in meters squared , equal to or greater than 25 and 30, respectively. These values are based on associations with chronic disease risk (WHO 1995, 2000). However, since Asian populations develop type 2 diabetes and metabolic risk at a younger age and lower BMI than Western populations, the World Health Organization (WHO) has proposed lower BMI "action points" of 23 and 28 for Asian adults (WHO Expert Consultation 2004). South Asian adults, in particular, also have a higher percentage of body fat and are more prone to developing abdominal obesity at a given BMI than Western adults, which may account for their high risk for type 2 diabetes (WHO Expert Consultation 2004). In children, obesity is generally defined as BMI equal to or greater than the 95th percentile age-for-sex BMI (Kuczmarski and others 2000). However, obesity-related comorbidities may develop below this threshold, and ethnic differences may exist in these processes. In a cross-sectional analysis of 662 rural Indian children, Indian boys had a higher percentage of body fat than white boys in the United Kingdom, despite lower BMI (Lakshmi and others 2012).

The WHO formally recognized the global impact of the obesity epidemic during a special obesity consultation in 1997. In the past 15 years, a large body of evidence has been accumulated illustrating temporal increases in the prevalence of obesity across the world. Globally, between 1980 and 2008, obesity prevalence rose from 4.8 to 9.8 percent in men and from 7.9 to 13.8

percent in women (Finucane 2011). For the first time in human history, more overweight than underweight individuals are living on the planet. Over the next two decades, the largest proportional increase in the number of adults who are overweight or obese is expected to occur in low- and middle-income countries (LMICs), where estimates range from increases of 62–205 percent for overweight and 71–263 percent for obesity (Kelly and others 2008).

Although the prevalence of obesity is higher in adults than in children, the incidence of obesity has risen more rapidly among children than among adults in some countries, such as Brazil, China, and the United States (Popkin and others 2006). The worldwide prevalence of childhood overweight and obesity increased from 4.2 to 6.7 percent between 1990 and 2010 (de Onis, Blossner, and Borghi 2010). This increase means that an estimated 43 million children were overweight or obese in 2010, of whom 35 million live in LMICs. The total number of children worldwide who are overweight or obese is expected to reach 60 million (9.1 percent) by 2020 if current trends continue. When interpreting the data on obesity prevalence, it is important to note that for some LMICs major challenges to documenting temporal trends have been both limited sources of data and limited access to high-quality data, due in part to lack of national-level surveillance. This is an important knowledge gap that requires future efforts.

In many LMICs, the percentage of people who are overweight already exceeds the percentage of people who are underweight. However, the percentage of the population who are underweight still remains a major concern in some populations. Undernutrition and obesity can exist side by side within a country, community, or household. Within a given country, obesity tends to be more prevalent in urban than in rural areas. Obesity correlates positively with economic growth and wealth in LMICs, but as a country becomes increasingly wealthy, low-income groups are at greater risk (Malik, Willett, and Hu 2013). Children less than 5 years of age

are most vulnerable to undernutrition due to higher requirements during growth, which might explain the paradox of having overweight adults and underweight children within the same home. Cheap food that is high in energy and low in nutritional quality could adversely affect growth in young children while providing excess calories to older children and adults. Related to this is the increased obesity and metabolic risk observed among children born with low birthweight due to the interplay between in utero fetal programming and an obesogenic environment. Caloric sufficiency and adequate nutrition during pregnancy have been a major focus in many LMICs to ensure good health of both the mother and her offspring. However, excessive weight gain before and during pregnancy has been associated with gestational hyperglycemia and obesity in mothers as well as metabolic complications in offspring (Bellamy and others 2009). These factors pose a particular challenge for implementing obesity prevention policies in many LMICs. Reducing obesity without exacerbating undernutrition, and vice versa, is critical.

Risk Factors for Obesity

Energy imbalance is partially a result of profound sociopolitical and economic changes, including global free trade, economic growth, and urbanization, that have been occurring in high-income countries since the early twentieth century but are now accelerating in LMICs. While these "macro-level" changes are largely beyond the control of the health sector, they influence and interact with numerous modifiable environmental and lifestyle risk factors. At the same time, not all individuals living in obesogenic environments experience the same risk of obesity. Heredity and particular socioeconomic and cultural milieus have also been shown to affect obesity risk even in ostensibly similar obesogenic environments. Body weight regulation is thus a complex interaction between many forces, and personal behaviors in response to these

conditions continue to play a dominant role in obesity prevention **(**figure __.1 **<<insert chapter number>>**). Although the global obesity epidemic has many causes, in this section we summarize the impact of global trade liberalization, economic growth, and urbanization on obesity risk, discuss global changes in major dietary risk factors, physical activity, and sociocultural norms, and consider genetic and epigenetic obesity factors.

<<figure __.1 about here; insert chapter number>>

Global Trade Liberalization

Between the 1970s and 1990s, many countries underwent economic structural adjustments, which included implementation of more market-oriented or liberal agricultural trade policies (Hawkes 2006). These policies have altered the food supply and are thought to have had direct effects on the obesity epidemic, contributing to nutritional transition and changing food choice and availability. At the same time however, it is important to note that some of these changes to the food system have led to improvements in quality of life and food security, and reductions in poverty. Trade liberalization can affect the availability of certain foods by enabling the trade of greater amounts and varieties of food, by removing barriers to foreign investment in food distribution, and by expanding multinational food companies and fast food chains (Kearney 2010). For example, in 1998, transnational food companies based in the United States invested US$5.7 billion in establishing outlets globally (Harris and others 2002). Analysis shows that LMICs that enter free trade agreements with the United States have a 63.4 percent higher consumption of sugar-sweetened beverages per capita than those that do not, after adjusting for a given country's level of gross domestic product (GDP) per capita and urbanization (Stuckler and others 2012). Some scholars have suggested that implementation of the North American Free Trade Agreement (NAFTA) has coincided with the burgeoning obesity epidemic in Mexico

through increased sales of low quality processed and fast foods (Clark and others 2012). . The relationship between economic policies, global trade agreements, and obesity should be investigated as points of intervention, given the potential scale of their impact.

Income and Socioeconomic Status

Over the next three to four decades, global income per capita is projected to rise at a rate of more than 2 percent per year, with more rapid rates expected in LMICs (Kearney 2010). The prevalence of obesity correlates positively with the initial stages of economic growth and development, as populations of rapidly developing LMICs undergo nutritional and lifestyle transitions while having little access to health services and education. An analysis of global patterns of nutritional risks in relation to economic development in 100 countries showed that BMI increased rapidly in relation to national income (Ezzati and others 2005). This association declined as countries achieved upper-middle-income and high-income status, primarily as a result of improved access to health services and education as well as behavioral changes. As average income rises, habits associated with obesity are adopted, such as watching television, purchasing convenience foods at supermarkets, and consuming highly processed fast food. However, access to health care, education, healthy food, and recreational activities that support weight maintenance remain limited.

Within countries, obesity is related to socioeconomic status. In many LMICs, body weight is positively associated with socioeconomic status, which contrasts with general patterns observed in the United States and other high-income countries, where body weight tends to be inversely associated with socioeconomic status. The association between socioeconomic status and body weight is thought to depend on the level of economic development in the country. In a review of nationally representative surveys of women in 37 LMICs, the burden of obesity was

shown to shift toward low-socioeconomic groups as the country's gross national product (GNP) per capita increased to around US$2,500 (Monteiro and others 2004). Countries with GNP per capita greater than US$2,500 include Brazil, Mexico, South Africa, and Turkey.

Urbanization

The proportion of the world's population living in urban areas has increased markedly, from 13 percent in 1900 to almost 50 percent in 2005 (Kearney 2010). This trend is expected to continue, primarily in countries where the vast majority of the population is currently rural. Low to medium density residential areas around urban centers have been associated with obesity in the United States (Hu 2008) and are starting to appear in some LMICs. Globally, 93 percent of urban growth is estimated to occur in LMICs, with 80 percent of growth occurring in Africa and Asia (UN Population Fund 2007). In China, for example, more than 1 billion people are projected to be living in urban centers by 2050, which is nearly twice the size of China's current urban population (UN Department of Economic and Social Affairs 2009).

The consequences of urban living on the development of obesity are numerous and occur largely as a result of changes in the built living environment, range of available food options, and lifestyles related to technological advancement and mechanization. Collectively, these changes have played a role in lowering the quality of urban diets and the expenditure of energy. These trends of positive energy balance are expected to continue as urbanization continues. At the same time, urbanization facilitates greater access to health care and education, which have beneficial effects on obesity. However, many LMICs undergo urbanization at such a rapid pace that the development of essential infrastructure lags behind. It is also important to note that some inhabitants of rural areas have worse diet quality than those of urban areas, especially in terms of diet diversity but it is unclear how this may impact obesity risk, and the trends likely differ

between high income countries and LMIC's and are influenced by socioeconomic status (Darmon and Drewnowski 2008).

Physical Activity

Densely populated areas with little outdoor recreational space have limited opportunities for walking and leisure-time physical activity. Physical activity, including walking and cycling, has modest benefits for weight, with more appreciable effects being seen when lifestyle changes occur in combination with dietary intervention. The combination of increased caloric intake and reduced energy expenditure can have a significant impact on the development of obesity. Lower energy expenditure decreases energy requirements, allowing excess calories to accumulate faster. Current physical activity guidelines for preventing chronic diseases recommend 30 minutes or more of moderate physical activity on most days of the week (Pate and others 1995). Time-trend data from the United States show that leisure-time physical activity has been relatively stable or increased slightly, while activities related to work, transportation, and household chores have declined dramatically and sedentary behaviors such as television viewing and screen time have increased substantially. These changes have led to an overall reduction in total physical activity (Brownson, Boehmer, and Luke 2005).

In many LMICs, a pronounced movement has occurred away from jobs with high energy expenditure such as farming, mining, and forestry and toward jobs in more sedentary sectors of manufacturing, services, and office-based work. This trend is typical of countries experiencing economic growth and urbanization, and these processes will determine the timeframe over which such movement takes place. In addition, computer technology, factories, and mechanization have become widespread in jobs that previously required high energy expenditure. In China, for example, the proportion of the population working in very light-activity jobs increased from 44

to 66 percent between 1989 and 2004 (Popkin 2009). Household chores also have become increasingly mechanized with the emergence of appliances such as washing machines and vacuum cleaners.

Leisure-time activities also have become more sedentary, shifting from outdoor play to indoor entertainment such as television viewing, Internet use, and computer gaming. In China, a study published in 2005 showed that less than 25 percent of adults reported participating in at least 30 minutes of moderate physical activity per day, and television ownership increased from 38 sets per 1,000 persons in 1985 to 155 in 1990 and 270 in 1997 (Wang and others 2007). Data on television viewing and screen time in LMICs are sparse, but many epidemiological studies have shown a link between time spent watching television and weight gain in both children and adults, and reducing sedentary behavior has been shown to have beneficial effects on weight independent of exercise (Munter and others 2005).

Changes to the built living environment include the construction of roads and highways and the implementation of motorized transportation systems that limit the opportunities for walking or bicycling and provide less healthy alternatives. The proportion of journeys made on foot or by bicycle has declined from 37 and 26 percent, respectively, in cities with 100,000–250,000 inhabitants to 28 and 9 percent, respectively, in cities with more than 5 million inhabitants (Singh 2005). Another major shift affecting energy expenditure in LMICs is the displacement of human-propelled modes of transportation, such as bicycles, in favor of motorized transportation, including cars and mopeds. In India, the annual rate of motor vehicle ownership increased 11 percent over the past decade, and in China, new car sales are increasing an estimated 30 percent per year (Kjellstrom, Hakansta, and Hogstedt 2007; Siegel, Narayan, and Kinra 2008).

Behavioral Change and Sociocultural Norms

Certain behavioral changes brought about by urban living could also contribute to the development of obesity in LMICs. Although not formally documented, urbanization is associated with a decrease in sleep duration, as noise pollution, street and domestic lighting, access to television and the Internet, shift work, and night-time social activities are more common in urban than in rural areas. In epidemiological studies, short sleep duration has been associated with weight gain in both children and adults (Berkey, Rockett, and Colditz 2008; Patel and Hu 2008). Similar evidence is starting to emerge from various LMICs, including Brazil, Senegal, Tunisia, and Taiwan, China (Hu 2008). Stress, which has been associated with obesity (Hu 2008), may also be a risk factor in rapidly urbanizing LMICs due to occupational demands and lack of the kind of social support that is available in traditional villages.

Obesity can also be affected by cultural and social norms, with wide variation across LMICs. These include cultural food preferences, societal norms for body shape, cultural practices surrounding the use of leisure-time and physical activity, gender norms, and academic expectations, all of which can interact with other risk factors to contribute to rising rates of obesity. For example, Polynesians, who have one of highest rates of obesity in the world, equate large body size with power, beauty, and affluence (Brewis and others 1998), and in India and many LMICs, there is a general misconception that an obese child is a healthy child (Bhardwaj and others 2008). In contrast, in the United States and some other cultures, some demographics consider being underweight as the epitome of beauty (Low and others 2003). Although cultural and social norms are embedded in society, they are not static. Globalization of the food supply, including multinational supermarkets, fast food chains, mass media, and marketing, has altered consumer preferences and behaviors in many LMICs in a relatively short period of time.

Diet

As many countries experience rapid economic growth and urbanization that have changed the choice and availability of food, concomitant shifts in dietary structure or nutritional transitions occur that promote a positive energy balance. These transitions are also fueled by reductions in the price of low-quality foods that are high in energy and by increases in GDP, which indicate higher family income and enhanced purchasing power. Weight gain and obesity in free-living populations result from the cumulative effects of small changes in daily energy balance. A typical diet is composed of energy-bearing macronutrients, including carbohydrates, protein, and fat, as well as micronutrients, including vitamins and minerals. These dietary factors can directly or indirectly tip the balance in energy intake and expenditure and thus effect changes in body weight. Similar to noncommunicable diseases, weight gain and obesity are complex processes that are caused by perturbations of multiple dietary habits and behaviors rather than by changes in any single dietary factor. This contrasts with deficiency syndromes, which can usually be ascribed to one or a few factors. While dietary patterns vary enormously between and within countries, and limited data are available to document dietary shifts, some broad themes are apparent, such as the global decrease in diet quality—excess consumption of unhealthy and highly processed foods and inadequate consumption of healthful whole foods. Many of the dietary risk factors for weight gain and obesity are covered in chapter 6.

Another major shift contributing to poor diets has been an increase in the consumption of highly refined carbohydrates, such as polished white rice and refined wheat flour. Milling and processing of whole grains to produce refined grains remove the fiber and numerous micronutrients, which have a variety of health benefits. Fiber is largely responsible for the beneficial effects of whole grains on body weight, promoting satiety and leading to decreased

energy intake. Given the number and variety of nutrients, whole grains can also be useful for addressing undernutrition. Temporal data from the United States show an association between intake of refined carbohydrates and risk of obesity and type 2 diabetes mellitus (Gross and others 2004). In urban South India, nearly half of an average individual's daily energy intake comes from refined grains, with polished white rice constituting more than 75 percent of refined grain intake (Mattei and others 2015). In China, white rice accounts for more than 30 percent of an average individual's daily caloric intake (Mattei and others 2015). A meta-analysis of prospective cohort studies in Asian and Western populations found that, for each increment of one serving per day of white rice, the risk of type 2 diabetes increased 11 percent (Hu and others 2012). Associations were stronger in Asian populations than in Western populations because Asian populations consume larger quantities of white rice. The adverse effects of refined grains tend to be more evident in individuals who are overweight or obese and generally more insulin-resistant than individuals who are lean. This finding is of great concern because, as obesity becomes more prevalent globally, more people will be susceptible to the adverse effects of diets high in refined carbohydrates. Although some refined carbohydrates, such as white rice, have been staples in countries such as China for hundreds of years, the negative health effects of refined grains were likely offset by high levels of physical activity.

In addition to the intake of specific foods, certain dietary habits have been associated with body weight. Regular consumption of breakfast has been widely recommended for preventing obesity. Skipping breakfast increases the production of appetite-stimulating hormones, which may lead to overeating throughout the day. In a random control trial (RCT), omitting breakfast led to increased energy intake and adverse effects on blood lipids and glycemic control (Farschi, Taylor, and Macdonald 2005). Data on breakfast consumption and

body weight per se are limited, but some prospective cohort studies have reported inverse associations between breakfast consumption and weight gain in European and U.S. populations (Hu 2008). Increased consumption of fast food is thought to be a major factor contributing to rising rates of obesity, and the intake of fast food is on the rise in many LMICs, as multinational chains seek large new markets. Epidemiological studies from Europe and the United States have shown positive associations between the consumption of fast food and weight gain and adverse metabolic outcomes (Rosenheck 2008). These associations are likely due to a combination of large portion sizes and high calorie content, high amounts of processed meat, refined carbohydrates, sugary beverages, and unhealthy fats, enhanced palatability, and low cost, resulting in overeating and positive energy balance.

From a public health point of view, identifying the dietary determinants of weight gain is critical for reducing the prevalence of obesity since once an individual becomes obese, it is metabolically difficult to lose weight and maintain weight loss. However, numerous short- and long-term studies across a variety of general and clinical populations have attempted to identify the optimal ratio of macronutrients for weight loss. Lowering the proportion of daily calories consumed from fat has been targeted for many reasons, including the high energy density of fat (that is, a single gram of fat contains more than twice the calories of a gram of carbohydrates or protein) and enhanced palatability of high-fat foods. Thus prevailing guidelines for weight loss have recommended reducing the intake of fat, but studies have produced inconsistent findings regarding the benefits of restricting fat for weight loss. One reason for this is the reciprocal relationship between energy from fats and carbohydrates in most diets and, as previously discussed, intake of refined carbohydrates has been positively associated with weight gain. Although the relative influence of macronutrients on body weight remains unclear, accumulating

evidence suggests that low-carbohydrate and Mediterranean-style diets, which are rich in plant-based foods and have a moderate fat content, have benefits for weight loss. These regimens may be more sustainable than other strategies due to the greater diversity and palatability of foods.

Genetic Risk of Obesity

The search for human obesity genes began several decades ago with findings from studies of adopted twins suggesting that obesity and obesity-related traits have a substantial heritable component, although the exact degree of genetic heritability is still debatable. Because the prevalence of obesity in many countries has increased threefold over the last three decades, it is unlikely that genetics are the primary cause of obesity. Compelling evidence indicates that obesity is driven largely by changes in diet and lifestyle. However, ethnic differences in obesity rates cannot be explained by these factors alone. A more probable hypothesis is that obesity is the outcome of an adverse obesogenic environment interacting with a susceptibility genotype. Genetic factors that underlie susceptibility to obesity may be amplified in the presence of certain environmental factors or, given the same diet and lifestyle factors, some individuals may be genetically more prone to obesity than others. Epigenetic mechanisms, in which environmental factors cause changes in the expression of genes but do not involve changes in DNA (deoxyribonucleic acid) sequence, could also help to explain the global increase in obesity prevalence.

Efforts to identify obesity genes have intensified in recent years with advances in genotyping technology and genetic epidemiologic methods. Several genetic factors responsible for rare monogenic forms of obesity have been identified; however, genes for common forms of obesity remain an active area of research. Unlike monogenic obesity, which results from an alteration in a single gene, the genetic profile of common or polygenic obesity is complex and

likely results from the effects of several altered genes. Genome-wide association studies, which determine whether an association between a genetic variation and an obesity-related trait exists by surveying the entire genome for causal genetic variants in a comprehensive and unbiased manner, have identified more than 52 loci associated with obesity traits (Albuquerque and others 2015). Of all the currently identified loci, the fat mass and obesity-associated (FTO) gene has the largest effect on susceptibility to obesity (Albuquerque and others 2015) (1) ((2). However, FTO polymorphism has a modest effect on BMI, explaining only 0.31 percent of the variation in BMI among individuals (Albuquerque and others 2015). These findings have been independently replicated and confirmed in several African, Asian, and European populations in both children and adults, although the functional mechanism underlying the role of FTO in obesity remains unknown.

Identification of gene-environment interactions related to obesity has been challenging because many genetic association studies lack detailed information on diet or other types of exposure. However, some recent observational studies and trials have evaluated gene-diet interactions. For example, the association between sugar-sweetened beverages and obesity was strengthened by an analysis examining whether consumption of sugar-sweetened beverages can modify the genetic risk of obesity, using a genetic predisposition score based on 32 obesity genes identified from genome-wide association studies (Qi and others 2012). Based on data from three large cohorts, greater consumption of sugar-sweetened beverages was associated with a more pronounced genetic effect on elevated BMI and an increased risk of obesity. Individuals who consumed one or more servings of sugar-sweetened beverages per day had genetic effects on BMI and obesity risk that were approximately twice as large as those who consumed less than one serving per month. These data suggest that regular consumers of sugar-sweetened beverages

may be more susceptible to the genetic effects on obesity, implying that a genetic predisposition to obesity can be partly offset by healthier beverage choices. Alternatively, persons with a greater genetic predisposition to obesity may be more susceptible to the deleterious effects of sugar-sweetened drinks on BMI. These findings may partly explain individual differences in the metabolic response to sugar-sweetened beverages. A better understanding of gene-environment interactions and epigenetics can lead to more accurate estimates of the impact of environmental factors on genetically susceptible individuals and identify high-risk populations for targeted prevention and intervention.

Interventions and Policies for Obesity Prevention

Population-based interventions have the potential to shift the distribution of risk factors of an entire population in a favorable direction, making them a cost-effective approach. Policy changes, in particular, have the potential to improve physical and social environments with long-lasting benefits for public health and quality of life. Continued surveillance of obesity and national health outcomes is also necessary to monitor and evaluate programs. In this section, we summarize evidence for the effectiveness of population-level interventions to improve diet and physical activity for preventing obesity in six domains: nutritional and agricultural policies, food labeling, food advertising, mass media campaigns, school and workplace interventions, and urban planning. Strategies to improve diet are also reviewed in chapter 6 and reinforced here given the importance of dietary modification for preventing obesity. Because little data from LMICs are available, much of the evidence summarized is from high-income countries, with the understanding that findings can be translatable to LMICs with appropriate cultural adjustments. In contrast to clinical decision making where the evidence base is dominated by RCTs, we also consider different types of evidence such as observational studies, natural experiments, and

policy changes. Despite the paucity of data and systematic reviews evaluating the effectiveness of some domains, these domains are discussed here because they have great potential for benefit and scalability and represent important knowledge gaps. Lastly, we provide a brief summary of select individual-level interventions for weight loss. Although our emphasis is on preventing obesity, weight loss can improve obesity-related comorbidities among overweight and obese individuals and may have a benefit for mortality.

Nutritional and Agricultural Policies

Combining incentives and deterrents can be an effective strategy to encourage production and consumption of nutritionally beneficial foods. Some governments are considering taxing select foods and beverages, particularly sugar-sweetened beverages, as a means to improve consumer choice and generate revenue. Whether these programs will have the desired effect is yet to be determined. Some studies have suggested that, for such interventions to have an appreciable impact, tax increases of at least 10 percent are needed (Gortmaker and others 2011). In Mexico, a peso-per-liter (roughly US$0.80 per liter) tax on sugar-sweetened beverages resulted in a 10 percent decline in purchases of taxed beverages in the first quarter of 2014 compared to the first quarter of 2013 (INSP 2015). These preliminary results also show roughly a 7 percent increase in purchases of untaxed beverages (such as diet sodas, sparkling and still plain water, 100 percent fruit juices, flavored water with noncaloric sweeteners, and milk without added sugar), including approximately a 13 percent increase in purchases of plain water.[1]

1. For some preliminary results of the effects of a tax on sugar-sweetened beverages and energy-dense nonstaple foods in Mexico, see the website of Mexico's National Institute of Public Health (http://www.insp.mx/epppo/blog/preliminares-bebidas-azucaradas.html).

Removing subsidies on animal-based foods, unhealthy oils, and sugar in exchange for subsidies on fruits, vegetables, legumes, nuts, and whole grains could be an effective strategy for improving diet quality. In 2000 India produced 26.6 million tons of fruits and 96.5 million tons of vegetables (Siegel, Narayan, and Kinra 2008). However, inaccessibility and high costs prohibited consumption of these foods in all but affluent, urban populations. In China, subsidies on fruits, vegetables, and soybeans have increased the production and consumption of these products (Zhai and others 2002). Voluntary actions and regulations made by industry to reduce calories in the food supply are under way in the United Kingdom and the United States (Malik, Willett, and Hu 2013). Translating similar initiatives to other countries represents a promising long-term goal for preventing obesity.

Food Labeling

Nutritional labeling is emerging as a major global initiative, and some LMICs, including Brazil, Chile, China, India, Mexico, and South Africa, are also considering developing systems to identify nutritionally beneficial foods and beverages (Popkin and others 2015). In comparison with nutritional facts panels, which consumers use to draw their own conclusions about how healthy a product is on the basis of the nutrient content of foods, these systems would identify foods that benefit health, such as whole grains, to help consumers to make healthy choices. An increasingly popular strategy being considered by various jurisdictions is calorie labeling on restaurant menus. The U.S. Food and Drug Administration recently finalized two rules requiring that calorie information be listed on menus and menu boards in chain restaurants as well as in similar retail food establishments and vending machines. A systematic review and meta-analysis of 19 studies in the United States found that menu labeling was associated with a reduction of 18.13 kilocalories ordered per meal, but significant heterogeneity between studies limits

interpretation of the results (Long and others 2015). Another small meta-analysis found that labeling menus with calories alone significantly reduced the amount of calories ordered by 31 kilocalories and the amount of calories consumed by 13 kilocalories (Sinclair, Cooper, and Mansfield 2014). In addition, it found that the use of interpretative nutrition information on menus assisted consumers in selecting and consuming foods with fewer calories, saving 0.67 and 81 kilocalories, respectively. These initiatives hold promise for LMICs, where the increasing availability of processed and packaged foods and fast food chains is accompanying increasing rates of urbanization. Educational campaigns must precede or accompany both food package and point-of-purchase nutrition labeling to raise awareness about these initiatives and provide context, so that individuals know to look for the labels and understand why they are important and how to interpret them. Other important caveats include the need to have a consensus on the definition of specific healthy foods such as whole grains and, in the context of LMICs, a system in place to ensure accurate labeling.

Food Advertising

A growing body of evidence indicates that food marketing can influence the food preferences and consumption habits of children (Hawkes 2007). However, evidence from systematic reviews is lacking, and few studies have evaluated the impact of advertising on energy intake or body weight. A systematic review of seven RCTs aiming to assess the effect of television advertising on food intake of children from 4 to 12 years of age concluded that there is a positive association between television and energy intake but that this association is based on a very limited number of trials lacking a solid ground of first-level evidence (Gregori and others 2014). Despite the lack of systematic evidence, regulation of advertising targeted toward children through television, the Internet, or other media is thought to be a potentially effective strategy

that should be adopted globally to reduce the harmful effects of marketing unhealthy high-energy foods. In 2010 the WHO released a set of recommendations on the marketing of foods and nonalcoholic beverages high in fat, sugar, and salt to children in an effort to encourage healthy dietary choices and promote the maintenance of healthy weight (WHO 2010). However, few countries have taken steps to reduce such marketing. In France, marketing of foods high in fat, sugar, and salt is banned unless they are taxed and labeled with a health warning. At the same time, governments can institute zoning laws, if available, that limit the number of fast food restaurants in a given area.

Mass Media Campaigns

The mass media, including national-level social marketing and public service campaigns, have the potential to be very useful tools in delivering public health messages about healthy diets and lifestyles either independently or as part of multicomponent interventions. Careful monitoring and evaluation of these strategies should be done concurrently to gauge their effectiveness. However, very few studies have examined the impact of mass media on diets and lifestyle behaviors or on body weight. This is an important knowledge gap.

School and Workplace Interventions

School-based programs and policies to increase physical activity by requiring physical education classes or breaks and to improve diet by providing healthy school meals and heathier snack options in vending machines and cafeterias are effective strategies to address childhood obesity and should be part of the global obesity prevention agenda. These strategies are likely to be more effective if reinforced through curriculum-based education about healthy diets and active lifestyles and efforts to engage parents and families. A recent systematic review including

115 school-based interventions (mostly in the United States) concluded that moderately strong evidence supports the effectiveness of school-based interventions for preventing childhood obesity (Wang and others 2015). However, more evidence is needed to evaluate programs in other settings or with other types of design, especially interventions oriented toward providing environmental, policy, and consumer health information.

School meal programs, which provide low-cost or free meals to ensure nutritional adequacy among schoolchildren, provide a unique opportunity to encourage healthy eating habits while preventing undernutrition. WHO Europe has a food and nutrition policy, which can be adapted for use in schools in individual countries, that emphasizes the importance of breakfast clubs; intake of fruits, vegetables, and milk; access to water; and removal of vending machines containing snacks and beverages of poor nutritional quality (WHO Europe 2006. Similar to the school setting, worksite-based interventions can overcome barriers to choosing a healthy lifestyle by providing resources and a socially supportive environment for change at a place where individuals spend much of their week and by offering programs at low or no cost. A meta-analysis of worksite-based physical activity programs in high-income countries (mostly the United States) showed significant positive improvements in body weight, cardiometabolic risk factors, physical activity and fitness, and diet quality as well as lower absenteeism and job stress (Conn and others 2009). A systematic review of 17 studies in Europe focusing on promoting a healthy diet in the workplace found limited to moderate evidence of effectiveness for prevention of obesity and obesity-related conditions (Maes and others 2012). Another systematic review of 16 studies mostly in Europe and North America found that diet-based worksite interventions of moderate methodological quality led to positive changes in fruits, vegetables, and total fat intake (Mhurchu, Aston, and Jebb 2010). To improve effectiveness, future programs should aim to

intervene at multiple levels of the worksite environment and ensure stronger adherence to established quality criteria.

Urban Planning

Evidence from various countries supports the relationship between physically active modes of transport and obesity. An analysis of aggregate cross-sectional health and travel data from the United States, 14 comparison high-income countries, and 47 large U.S. cities found significant inverse relationships between active travel and self-reported obesity at all three geographic levels (Pucher and others 2010). A systematic review of 43 incidental physical activity community interventions from high-income economies or regions (Australia, Canada, Europe, Japan, New Zealand, the United Kingdom, the United States, and Hong Kong, China) found that, primarily, active transport (walking, bicycling) interventions and, secondarily, children's play interventions and, to a lesser extent, use of stairs can be effective ways of increasing physical activity (Reynolds and others 2014). Comparisons were control groups who didn't receive the intervention or baseline data in participants were acting as their own control.

Given the potential for benefit, governments should promote and facilitate the use of public transportation and bicycles by providing incentives such as discounted transportation fares, bicycle-sharing programs, cycling safety classes, and secure bicycle parking. Lower health care premiums for active commuting in countries where health care is not state run would also be beneficial. Using public transportation encourages people to be more active generally, by walking and standing, than if they were using cars. Creating a central policy for urban transportation could be a first step for some countries. Governments should also mandate the construction of sidewalks and safe bicycle lanes and the construction of buildings with features that promote fitness, such as accessible staircases. Urban planning initiatives at the national or

regional level should also encourage the development of safe, pedestrian-friendly communities with green spaces and access to public transportation. A systematic review found that physical changes to the built environment can increase urban green space and encourage physical activity (Hunter and others 2015). Careful evaluation of the effectiveness and cost-effectiveness of such policies is needed to support policy strategies.

Popular Weight-Loss Diets

Numerous branded weight-loss programs are broadly available to the general public in many countries, providing structured dietary and lifestyle recommendations via popular books and in-person or online behavioral support. Limited data are available for evaluating the clinical effectiveness of these strategies. However, a recent meta-analysis of trials examining the impact of popular self-administered brand-name diets on body weight compared to no diet found losses in body weight ranging from 4.10 kilograms to 6.55 kilograms after 12 months, with no appreciable difference between diets (Johnston and others 2014). Whether such programs are sustainable is not known.

Pharmacological Strategies

Lifestyle interventions for weight loss are often characterized by high rates of recidivism or weight regain, which may be due in part to complex metabolic processes and biological adaptations that defend against subsequent weight loss and promote weight regain. The primary aim of pharmacological treatment for obesity is to suppress the biological drivers of weight gain or dampen the counterregulatory response to weight loss and thereby enable patients to achieve and sustain clinically meaningful reductions in body weight.

Currently four drugs have been approved by the U.S. Food and Drug Administration for chronic weight management in obese adults: orlistat, lorcaserin, phentermine/topiramate

extended release, and naltrexone/bupropion extended release (Kakkar and Dahiya 2015). Very little data are available regarding the approval, availability, and use of these therapies in LMICs. For countries where these drugs are available, drug safety monitoring systems should be implemented—if not already in existence—to ensure safety of use. A recent report from India documented orlistat abuse in a case of bulimia nervosa and noted that the drug is available over the counter (Deb, Gupta, and Varshney 2014). Use of anti-obesity medications in conjunction with lifestyle modification can lead to weight loss in the range of 5–10 percent (Kakkar and Dahiya 2015). However, further studies are needed to assess the long-term benefits and cost-effectiveness of these new agents as well as potential pharmacological interactions and adverse effects. Several anti-obesity therapies have been taken off the market due to significant side effects (Kakkar and Dahiya 2015), underscoring the importance of close monitoring and evaluation.

Bariatric Surgery

Management of obesity usually begins in primary care, but surgical approaches for weight loss may be considered when initial measures have failed or the patient's degree of obesity and presence of comorbidities are great. The most common types of bariatric surgical procedures include adjustable gastric banding or gastric bypass. Evidence from trials in high-income countries has shown that these strategies are clinically effective for moderately to severely obese patients compared with nonsurgical interventions (Picot and others 2009). However, further research is needed to provide data on patient quality of life, impact of surgeon experience on outcome, late complications leading to reoperation, duration of comorbidity remission, and resource use.

The strength of the evidence for these select interventions has been summarized based on data from the Australian Assessing Cost-Effectiveness (ACE) in Obesity and ACE Prevention studies (Gortmaker and others 2011), assessed the effectiveness and cost-effectiveness of various obesity prevention interventions in Australia (table __.1 **<<insert chapter number>>**). A scale from 1 to 5 was used to rank evidence (with 1 = strongest; 5 = weakest) and assessment was done by a stakeholder's group. Strategies with the greatest strength of evidence included gastric banding in children and adults, pharmacologic therapy (orlistat), combined diet and exercise, weight-loss diets (low-fat, Weight Watchers), and a family-based targeted intervention for obese children. The evidence for unhealthy food and beverage taxes and front-of-package nutrition labeling was considered weak, suggesting a need for additional data.

<<table __.1 about here; insert chapter number>>

Cost-Effectiveness for Select Interventions

The gap between available and required resources to tackle the global burden of obesity is very large and expected to continue growing if measures are not taken to abate current trends. Cost-effective analysis is critical to help policy makers with resource allocation and to identify interventions and policies that could be scaled up in countries at different income levels. Policy makers need to weigh the relative benefits of effective interventions reaching a modest number of people against less effective interventions reaching a wider population. However, few obesity prevention interventions or policy strategies have been subjected to rigorous economic evaluation. In this section, we summarize findings from two studies that have evaluated the cost-effectiveness of select obesity prevention interventions using the cost of disability-adjusted life years (DALYs) averted in Australia (Gortmaker and others 2011) and in six LMICs (Brazil,

China, India, Mexico, the Russian Federation, and South Africa) as part of a joint Organisation for Economic Co-operation (OECD) and WHO analysis (Cecchini and others 2010).

ACE Obesity Study

In the ACE study, a decision threshold of $A 50,000 (US$49,500) per DALY prevented was used to establish whether an intervention was cost-effective or not, which is in line with empirical evidence on what constitutes acceptable value-for-money in Australia. Use of standard methods improves the comparability of results, although lower strength of evidence for many interventions limits the generalizability of findings, and costs can vary.

Of the 20 interventions evaluated, 8 were found to improve health and save costs: unhealthy food and beverage tax, front-of-package nutrition labeling, reduction of advertising of unhealthy foods and beverages to children, school-based education program to reduce television viewing, multifaceted school-based program including nutrition and physical activity, school-based education program to reduce the use of sugar-sweetened beverages, family-based targeted program for obese children, and multifaceted targeted school-based program for overweight and obese children (table __.1 <<**insert chapter number**>>). Gastric banding in adults and adolescents as well as family-based general-practitioner-mediated programs for overweight and obese children were found to be very cost-effective in that they improved health at a cost of less than $A 10,000 per DALY prevented, while multifacted school-based programs without a functioning physical activity component, diet and exercise, and low-fat diets were found to improve health at a cost of between $A 10,000 and $A 50,000 per DALY prevented. The top three cost-saving interventions—food and beverage tax, nutritional labels, and reduction in advertising to children, all of which are environmental—showed modest effects at the individual

level but were highly cost-effective because benefits accrue to the entire population and the cost of implementation is relatively low. However, these interventions vary in their effectiveness and in the likelihood of implementation. In Australia, regulation of advertising is not on the political agenda, which means that reducing advertising to children, one of the most cost-effective interventions, is unlikely. Also, policy makers in Australia considered that the evidence for front-of-package nutrition labeling was insufficient to warrant support, despite plausible outcomes.

Overall, based on assessments made in the ACE study, policy approaches generally showed greater cost-effectiveness than either health promotion or clinical interventions. To prevent obesity, policy makers should consider the strategies found to be cost saving or highly cost-effective. However, the decision about whether to implement a specific obesity prevention strategy in a given country will be based on a combination of factors aside from cost-effectiveness, including the strength and generalizability of the evidence base, feasibility of implementation, impacts on equity, and acceptability to stakeholders. Because the evidence base is constantly evolving, particular emphasis should be given to identifying updated studies in the field. A good example of this pertains to trials examining the effectiveness of low-fat diets on weight loss. While the ACE study found strong evidence that low-fat diets are effective among overweight adults, recent meta-analyses of trials found negligible effects, suggesting that low-fat diets may not be an effective strategy for weight control (Tobias and others 2015). Except for this, data from the ACE study is generally consistent with data from other HICs for the same interventions.

OECD and WHO Study

In the OECD and WHO study, seven interventions aimed at tackling rapidly escalating rates of obesity via healthy dietary habits and increased physical activity—school-based health

promotion, mass media campaigns, counseling of individuals at risk in primary care, fiscal measures affecting the price of fruits and vegetables and foods high in fat, regulation of food advertising to children, and food labeling—were evaluated for their cost-effectiveness for preventing related chronic diseases (stroke, ischemic heart disease, and cancer, including lung, colorectal, and female breast cancer) in two time periods—20 and 50 years—in six LMICs. Additionally, a prevention strategy combining a mass media campaign, fiscal measures, regulation of food advertising, and food labeling was assessed on the basis of the assumption that the effects of the individual interventions, measured in terms of the relative risk of risk factors or chronic diseases, would combine multiplicatively. The analysis was based on a microsimulation model (chronic disease prevention model) that implements a causal web of lifestyle risk factors for selected chronic diseases. Whereas individual-level effectiveness was based mostly on studies from high-income settings, country-specific information was used to establish potential population coverage and to adapt effectiveness to the local distribution of risk factors.

Based on U.S. dollars per DALY averted, relative to a comparator situation of treatment only and no prevention, fiscal measures were consistently cost saving in all LMICs considered and generated the largest (for example, in China) or second largest health effects in both 20 and 50 years (table __.2 **<<insert chapter number>>**). The health effect of fiscal measures was substantially lower in India than in other countries, because Indians consume fewer foods high in fat. Food labeling was also cost saving in many settings, but with smaller health effects than fiscal measures. Regulation of food advertising to children and mass media campaigns had very favorable cost-effectiveness ratios. In 50 years, regulation of food advertising was cost saving in several countries, although its health effect was still very small, compared with other interventions. Worksite health promotion initiatives had favorable cost-effectiveness, with

quicker health returns than regulation of advertising, although returns were lower in some countries over the entire simulation. Physician counseling of individuals at risk in primary care was one of the most effective interventions, but its health effect was greatest and cost-effectiveness was highest in countries where a larger proportion of the population had regular access to primary care physicians and facilities. School-based interventions consistently had unfavorable cost-effectiveness ratios up to 50 years from their initial implementation. However, the cost-effectiveness of interventions targeting young children tends to improve in a longer timeframe (greater than 50 years), as these interventions realize their full potential in improving health. A multiple-intervention strategy would achieve substantially larger health gains than would individual interventions, often with an even more favorable cost-effectiveness profile. Such a strategy would be cost saving in about half the countries examined.

<<table __.2 about here; insert chapter number>>

Taken together, findings from these two studies suggest that the most cost-effective approaches to preventing obesity and downstream chronic disease are price interventions and regulation, such as taxes on unhealthy foods and beverages and subsidies on healthy foods, food labeling, and regulation of advertising of unhealthy foods and beverages. As the OECD study found, fiscal measures are the only interventions likely to pay for themselves since they can generate larger savings in health expenditures than the costs of delivery. What sets these interventions apart from other more targeted strategies is their greater coverage in the population and relatively low cost of implementation. These strategies could feasibly be added to existing measures for preventing chronic disease, such as demand-reduction strategies for tobacco and alcohol (that is, higher excise taxes, advertising bans, and improved labeling) and salt-reduction strategies (via mass media campaigns or regulation of the salt content in manufactured foods). A

strategy of several interventions would generate larger health gains and have a more cost-effective profile than would individual interventions. School-based interventions can be cost-effective strategies for preventing obesity, but their impact on future chronic disease risk may not be realized until many decades later. Regulation of food advertising to children would be a more effective and efficient strategy for targeting children.

Conclusions

Obesity is a major contributor to preventable disease and death across the globe and poses a nearly unprecedented challenge to those tasked with addressing it at the public health, health care provider, and individual level. It is a complex condition resulting from myriad compounding physiological, environmental, behavioral, and sociopolitical factors. Although economic growth and urbanization have reduced food insecurity and improved quality of life for many, they have also provided access to low-cost foods that are low in nutritional value and high in energy and increased the consumption of refined grains, red and processed meat, unhealthy fats, and sugar-sweetened beverages, all of which are associated with weight gain. At the same time, these processes have created environments that promote sedentary lifestyles, reduced physical labor, and increased automated transportation, collectively leading to positive energy balance and weight gain.

Given the scope and complexity of the global increase in obesity, interventions and policies across multiple levels are needed to have a measurable impact on reversing this trend. Such strategies should include coordinated efforts from the international community, governments, food industry, health care providers, schools, urban planners, agriculture and food production and services sectors, media, communities, and individuals.

Based on our summary of epidemiological evidence, various interventions at the population level, including nutritional and agricultural policies, food labeling and advertising, mass media campaigns, school and workplace interventions, and urban planning have the potential to prevent obesity by improving diet, physical activity, or both. Of these approaches, based on limited data from modeling studies in HIC's, the most cost-effective include taxes on unhealthy foods and beverages, subsidies on healthy foods, food labeling, and regulation of advertising of unhealthy foods and beverages, particularly to children. These strategies can achieve wide coverage at a relatively low cost of implementation and could feasibly be added to existing measures for preventing chronic diseases (table __.3 **<<insert chapter number>>**). Although the strength of the evidence for these strategies is weak, particularly from LMICs, implementation should not be discouraged given the potential economic gains.

<<table __.3 about here; insert chapter number>>

School and workplace interventions are also cost-effective and may be useful in LMIC communities that are also managing undernutrition since healthy options that provide adequate nutrition can be provided and outcomes can be monitored carefully. Since many LMICs are experiencing nutrition transitions characterized by high intake of refined grains, poor-quality carbohydrate foods that are high in added sugar, and sugar-sweetened beverages, strategies that encourage the intake of high-quality carbohydrate foods, such as whole grains, fruits, and vegetables, should be made a priority, as should ensuring access to safe drinking water since water is the optimal beverage for hydration. These recommendations would also address nutrient inadequacy.

Regarding interventions to treat obesity, while the evidence is considered strong for the benefits of surgery, pharmacological approaches, and weight-loss diets, the benefits need to be

weighed against cost-effectiveness. Feasibility for use in LMICs would also need to be evaluated. Fewer options exist for managing and treating obesity; given the metabolic challenges in losing weight and high costs associated with obesity, prevention should be the goal of governments. Implementing a strategy of several interventions is recommended since multifaceted interventions would garner larger gains than individual approaches.

The majority of evidence related to obesity risk factors, intervention effectiveness, and cost-effectiveness is from studies conducted in high-income countries, and notable gaps are evident in knowledge from LMICs. Nevertheless, translational approaches should be used to implement evidence-based interventions in these settings rather than waiting for local evidence. Continued surveillance of obesity and national health outcomes is also necessary to monitor and evaluate programs while maintaining awareness among the public and within governments.

Note

<<**unnumbered**>>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. <<**end note**>>

References

Albuquerque, D., E. Stice, R. Rodriguez-Lopez, L. Manco, and others. 2015. "Current Review of Genetics of Human Obesity: From Molecular Mechanisms to an Evolutionary Perspective." *Molecular Genetics and Genomics* 290 (4): 1191–221.

Bellamy, L., J. P. Casas, A. D. Hingorani, and D. Williams. 2009. "Type 2 Diabetes Mellitus after Gestational Diabetes: A Systematic Review and Meta-Analysis." *Lancet* 373 (9677): 1773–79.

Berkey, C. S., H. R. Rockett, and G. A. Colditz. 2008. "Weight Gain in Older Adolescent Females: The Internet, Sleep, Coffee, and Alcohol." *Journal of Pediatriatrics* 153 (5): 635–39.

Bhardwaj, S., A. Misra, L. Khurana, S. Gulati, and others. 2008. "Childhood Obesity in Asian Indians: A Burgeoning Cause of Insulin Resistance, Diabetes, and Sub-Clinical Inflammation." *Asia Pacific Journal of Clinical Nutrition* 17 (Suppl. 1): 172–75.

Brewis, A. A., S. T. McGarvey, J. Jones, and B. A. Swinburn. 1998. "Perceptions of Body Size in Pacific Islanders." *International Journal of Obesity and Related Metabolic Disorders* 22 (2): 185–89.

Brownson, R. C., T. K. Boehmer, and D. A. Luke. 2005. "Declining Rates of Physical Activity in the United States: What Are the Contributors?" *Annual Review of Public Health* 26 (1): 421–43.

Clark, S.E., Hawkes, C., Murphy, S.M., Hansen-Kuhn, K.A., Wallinga, D. (2012). Exporting obesity: US farm and trade policy and the transformation of the Mexican consumer food environment. Int J Occup Environ Health. 18(1):53-65

Carnethon, M. R., P. J. De Chavez, M. L. Biggs, C. E. Lewis, and others. 2012. "Association of Weight Status with Mortality in Adults with Incident Diabetes." *JAMA* 308 (6): 581–90.

Cecchini, M., F. Sassi, J. A. Lauer, Y. Y. Lee, and others. 2010. "Tackling of Unhealthy Diets, Physical Inactivity, and Obesity: Health Effects and Cost-Effectiveness." *Lancet* 376 (9754): 1775–84.

Clark,

Conn, V. S., A. R. Hafdahl, P. S. Cooper, L. M. Brown, and others. 2009. "Meta-Analysis of Workplace Physical Activity Interventions." *American Journal of Preventive Medicine* 37 (4): 330–39.

Danaei, G., E. L. Ding, D. Mozaffarian, B. E. Taylor, and others. 2009. "The Preventable Causes

of Death in the United States: Comparative Risk Assessment of Dietary, Lifestyle, and Metabolic Risk Factors." *PLoS Medicine* 6 (4): e1000058.

Darmon, N., and Drewnowski A. (2008). Does social class predict diet quality? American Journal of Clinical Nutrition. 87 (5): 1107-17.

Deb, K. S., R. Gupta, and M. Varshney. 2014. "Orlistat Abuse in a Case of Bulimia Nervosa: The Changing Indian Society." *General Hospital Psychiatry* 36 (5): 549 e3–e4.

de Onis, M., M. Blossner, and E. Borghi. 2010. "Global Prevalence and Trends of Overweight and Obesity among Preschool Children." *American Journal of Clinical Nutrition* 92 (5): 1257–64.

Ezzati, M., S. Vander Hoorn, C. M. Lawes, R. Leach, and others. 2005. "Rethinking the 'Diseases of Affluence' Paradigm: Global Patterns of Nutritional Risks in Relation to Economic Development." *PLoS Medicine* 2 (5): e133.

Farshchi, H. R, M. A. Taylor, and I. A. Macdonald. 2005. "Deleterious Effects of Omitting Breakfast on Insulin Sensitivity and Fasting Lipid Profiles in Healthy Lean Women." *American Journal of Clinical Nutrition* 81 (2): 388–96.

Finucane, M. M., G. A. Stevens, M. J. Cowan, G. Danaei, and others. 2011. "National, Regional, and Global Trends in Body-Mass Index since 1980: Systematic Analysis of Health Examination Surveys and Epidemiological Studies with 960 Country-Years and 9.1 Million Participants." *Lancet* 377 (9765): 557–67.

Gortmaker, S. L., B. A. Swinburn, D. Levy, R. Carter, and others. 2011. "Changing the Future of Obesity: Science, Policy, and Action." *Lancet* 378 (9793): 838–47.

Gregori, D., S. Ballali, M. G. Vecchio, A. S. Scire, and others. 2014. "Randomized Controlled Trials Evaluating Effect of Television Advertising on Food Intake in Children: Why Such

a Sensitive Topic Is Lacking Top-Level Evidence?" *Ecology of Food and Nutrition* 53 (5): 562–77.

Gross, L. S., L. Li, E. S. Ford, and S. Liu. 2004. "Increased Consumption of Refined Carbohydrates and the Epidemic of Type 2 Diabetes in the United States: An Ecologic Assessment." *American Journal of Clinical Nutrutrition* 79 (5): 774–79.

Harris, J., P. Kaufman, S. Martinez, and C. Price. 2002. *The U.S. Food Marketing System, 2002*. Agricultural Economic Report 811. Washington, DC: U.S. Department of Agriculture Economic Research Service.

Hawkes, C. 2006. "Uneven Dietary Development: Linking the Policies and Processes of Globalization with the Nutrition Transition, Obesity, and Diet-Related Chronic Diseases." *Global Health* 2 (March): 4.

———. 2007. "Regulating and Litigating in the Public Interest: Regulating Food Marketing to Young People Worldwide; Trends and Policy Drivers." *American Journal of Public Health* 97 (11): 1962–73.

Hu, E. A., A. Pan, V. Malik, and Q. Sun. 2012. "White Rice Consumption and Risk of Type 2 Diabetes: Meta-Analysis and Systematic Review." *British Medical Journal* 344 (March 15): e1454.

Hu, F. B. 2008. *Obesity Epidemiology*. New York: Oxford University Press.

Hunter, R. F., H. Christian, J. Veitch, T. Astell-Burt, and others. 2015. "The Impact of Interventions to Promote Physical Activity in Urban Green Space: A Systematic Review and Recommendations for Future Research." *Social Science and Medicine* 124 (January): 246–56.

Johnston, B. C., S. Kanters, K. Bandayrel, P. Wu, and others. 2014. "Comparison of Weight Loss

among Named Diet Programs in Overweight and Obese Adults: A Meta-Analysis." *JAMA* 312 (9): 923–33.

Kakkar, A. K., and N. Dahiya. 2015. "Drug Treatment of Obesity: Current Status and Future Prospects." *European Journal of Internal Medicine* 26 (2): 89–94.

Kearney, J. 2010. "Food Consumption Trends and Drivers." *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences* 365 (1554): 2793–807.

Kelly, T., W. Yang, C. S. Chen, K. Reynolds, and others. 2008. "Global Burden of Obesity in 2005 and Projections to 2030." *International Journal of Obesity* 32 (9): 1431–37.

Kjellstrom T., C. Hakansta, and C. Hogstedt. 2007. "Globalisation and Public Health: Overview and a Swedish Perspective." *Scandinavian Journal of Public Health* 70: 2–68.

Kuczmarski, R. J., C. L. Ogden, L. M. Grummer-Strawn, K. M. Flegal, and others. 2000. "CDC Growth Charts: United States." *Advance Data* 314 (December 4): 1–27.

Lakshmi, S., B. Metcalf, C. Joglekar, C. S. Yajnik, and others. 2012. "Differences in Body Composition and Metabolic Status between White U.K. and Asian Indian Children (EarlyBird 24 and the Pune Maternal Nutrition Study)." *Pediatric Obesity* 7 (5): 347–54.

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, Amann M, Anderson HR, Andrews KG, Aryee M, et al. (2013). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 380(9859):2224-60.

Long, M. W., D. K. Tobias, A. L. Cradock, H. Batchelder, and others. 2015. "Systematic Review and Meta-Analysis of the Impact of Restaurant Menu Calorie Labeling." *American Journal of Public Health* 105 (5): e11–24.

Low, K. G., S. Charanasomboon, C. Brown, G. Hiltunen, and others. 2003. "Internalization of the Thin Ideal, Weight, and Body Image Concerns." *Social Behavior and Personality: An International Journal* 31 (1): 81–89.

Maes, L., E. Van Cauwenberghe, W. Van Lippevelde, H. Spittaels, and others. 2012. "Effectiveness of Workplace Interventions in Europe Promoting Healthy Eating: A Systematic Review." *European Journal of Public Health* 22 (5): 677–83.

Malik, V. S., W. C. Willett, and F. B. Hu. 2013. "Global Obesity: Trends, Risk Factors, and Policy Implications." *Nature Reviews: Endocrinology* 9 (1): 13–27.

Mattei, J., V. Malik, N. M. Wedick, F. Hu, and others. 2015. "Reducing the Global Burden of Type 2 Diabetes by Improving the Quality of Staple Foods: The Global Nutrition and Epidemiologic Transition Initiative." *Global Health* 11 (1): 23.

Mhurchu, C. N., L. M. Aston, and S. A. Jebb. 2010. "Effects of Worksite Health Promotion Interventions on Employee Diets: A Systematic Review." *BMC Public Health* 10: 62.

Misra, A., and L. Khurana. 2008. "Obesity and the Metabolic Syndrome in Developing Countries." *Journal of Clinical Endocrinology and Metabolism* 93 (11, Suppl. 1): S9–S30.

Monteiro, C. A., E. C. Moura, W. L. Conde, and B. M. Popkin. 2004. "Socioeconomic Status and Obesity in Adult Populations of Developing Countries: A Review." *Bulletin of the World Health Organization* 82 (12): 940–46.

Muntner, P., D. Gu, R. P. Wildman, J. Chen, and others. "Prevalence of Physical Activity among Chinese Adults: Results from the International Collaborative Study of Cardiovascular Disease in Asia." *American Journal of Public Health* 95 (9): 1631–36.

Pate, R. R., M. Pratt, S. N. Blair, W. Haskell, and others. 1995. "Physical Activity and Public

Health: A Recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine." *JAMA* 273 (5): 402–07.

Patel, S. R., and F. B. Hu. 2008. "Short Sleep Duration and Weight Gain: A Systematic Review." *Obesity* 16 (3): 643–53.

Picot, J., J. Jones, J. Colquitt, E. Gospodarevskaya, and others. 2009. "The Clinical Effectiveness and Cost-Effectiveness of Bariatric (Weight Loss) Surgery for Obesity: A Systematic Review and Economic Evaluation." *Health Technology Assessment* 13 (41): n.p.

Popkin, B. M. 2009. *The World Is Fat*. New York: Pengiun Group.

Popkin, B. M., L. S. Adair, and S. W. Ng. 2012. "Global Nutrition Transition and the Pandemic of Obesity in Developing Countries." *Nutrition Reviews* 70 (1): 3–21.

Popkin, B. M., W. Conde, N. Hou, and C. Monteiro. 2006. "Is There a Lag Globally in Overweight Trends for Children Compared with Adults?" *Obesity* 14 (10): 1846–53.

Pucher, J., R. Buehler, D. R. Bassett, and A. L. Dannenberg. 2010. "Walking and Cycling to Health: A Comparative Analysis of City, State, and International Data." *American Journal of Public Health* 100 (10): 1986–92.

Qi, Q., A. Y. Chu, J. H. Kang, M. K. Jensen, and others. 2012. "Sugar-Sweetened Beverages and Genetic Risk of Obesity." *New England Journal of Medicine* 367 (15): 138–96.

Reynolds, R., S. McKenzie, S. Allender, K. Brown, and others. 2014. "Systematic Review of Incidental Physical Activity Community Interventions." *Preventive Medicine* 67: 46–64.

Rosenheck, R. 2008. "Fast Food Consumption and Increased Caloric Intake: A Systematic Review of a Trajectory towards Weight Gain and Obesity Risk." *Obesity Reviews* 9 (6): 535–47.

Siegel, K., K. M. Narayan, and S. Kinra. 2008. "Finding a Policy Solution to India's Diabetes

Epidemic." *Health Affairs* 27 (4): 1077–90.

Sinclair, S. E., M. Cooper, and E. D. Mansfield. 2014. "The Influence of Menu Labeling on Calories Selected or Consumed: A Systematic Review and Meta-Analysis." *Journal of the Academy of Nutrition and Dietetics* 114 (9): 1375–88 e15.

Singh, A. 2005. "Review of Urban Transportation in India." *Journal of Public Transportation* 8 (1): 75–97.

Stuckler, D., M. McKee, S. Ebrahim, and S. Basu. 2012. "Manufacturing Epidemics: The Role of Global Producers in Increased Consumption of Unhealthy Commodities Including Processed Foods, Alcohol, and Tobacco." *PLoS Medicine* 9 (6): e1001235.

Tobias, D., A. Pan, and F. B. Hu. 2014. "BMI and Mortality among Adults with Incident Type 2 Diabetes." *New England Journal of Medicine* 370 (14): 1363–64.

Tobias, D., Chen, M., Manson, J.E., Ludwig, D.S., Willett, W., Hu, F.B. (2015). Effect of low-fat diet interventions versus other diet interventions on long-term weight change in adults: a systematic review and meta-analysis.

Lancet Diabetes Endocrinology. 3(12):968-79.

UN (United Nations) Department of Economic and Social Affairs. 2009. *World Urbanization Prospects: The 2009 Revision.* New York: United Nations Population Division.

UN (United Nations) Population Fund. 2007. "Unleashing the Potential of Urban Growth." In *State of the World Population 2007*, ch. 1. New York: United Nations Population Fund.

Wang, Y., L. Cai, Y. Wu, R. F. Wilson, and others. 2015. "What Childhood Obesity Prevention Programmes Work? A Systematic Review and Meta-Analysis." *Obesity Reviews* 16 (7): 547–65.

Wang, Y., J. Mi, X. Y. Shan, Q. J. Wang, and others. 2007. "Is China Facing an Obesity Epidemic and the Consequences? The Trends in Obesity and Chronic Disease in China." *International Journal of Obesity* 31 (1): 177–88.

Whitlock, G., S. Lewington, P. Sherliker, R. Clarke, and others. 2009. "Body-Mass Index and Cause-Specific Mortality in 900,000 Adults: Collaborative Analyses of 57 Prospective Studies." *Lancet* 373 (9669): 1083–96.

WHO (World Health Organization). 1995. "Physical Status: The Use and Interpretation of Anthropometry." Technical Report Series 854, WHO, Geneva.

———. 2000. *Obesity: Preventing and Managing the Global Epidemic.* Report on a WHO Consultation on Obesity, Geneva, 3–5 June, 1997. Geneva: WHO.

———. 2009. *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*. Geneva: WHO.

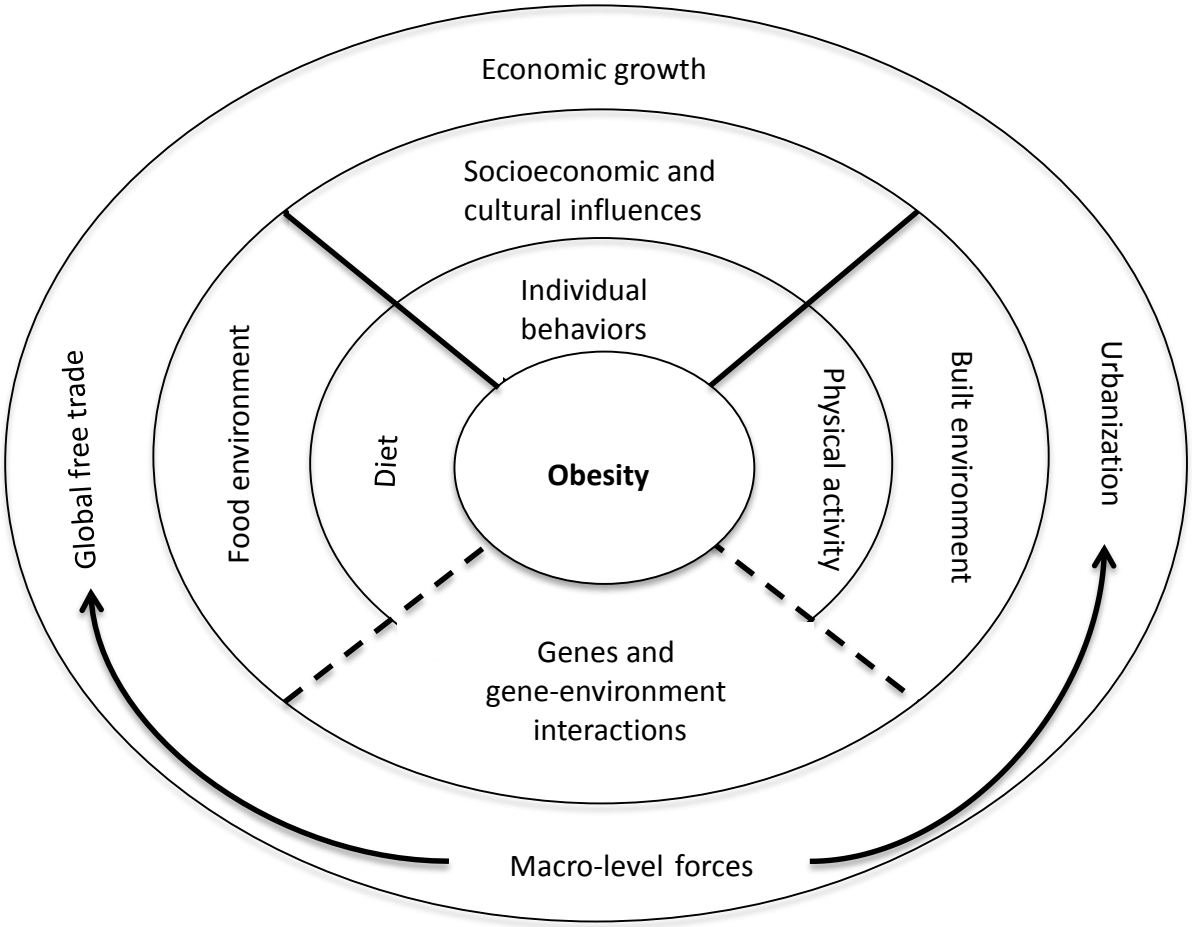
———. 2010. "Set of Recommendations on the Marketing of Foods and Non-Alcoholic Beverages to Children." WHO, Geneva. http://whqlibdoc.who.int/publications/2010/9789241500210_eng.pdf?ua=1.

WHO (World Health Organization) Europe. 2006. "Food and Nutrition Policy for Schools: A Tool for the Development of School Nutrition Programmes in the WHO European Region." WHO Europe, Copenhagen.

WHO (World Health Organization) Expert Consultation. 2004. "Appropriate Body-Mass Index for Asian Populations and Its Implications for Policy and Intervention Strategies." *Lancet* 363 (9403): 157–63.

Zhai, F., D. Fu, S. Du, K. Ge, and others. 2002. "What Is China Doing in Policy-Making to Push Back the Negative Aspects of the Nutrition Transition?" *Public Health Nutrition* 5 (1A): 269–73.

Figure __.1 **<<insert chapter number>>** Determinants of Obesity



Source: Modified from Public Health Systems, Foresight Systems Map, 2007 (https://www.noo.org.uk/NOO_about_obesity/causes).

Note: Macro-level forces are largely beyond our control, but they influence and interact with numerous modifiable environmental and population-level factors. These factors, in turn, can greatly influence diet, physical activity, and individual-level behaviors. Genetic factors that underlie susceptibility to obesity may be amplified in the presence of certain environmental factors. Together, these forces interact in a complex network leading to positive energy balance and obesity.

Table __.1 **<<insert chapter number>>** Effectiveness and Cost-Effectiveness of Select Obesity Prevention Interventions from the Australian Assessing Cost-Effectiveness (ACE) in Obesity and ACE Prevention Studies

Intervention	*Target population*	*Strength of evidence*[a]	*Net cost per DALY saved ($A million)*[b]
Unhealthy food and beverage tax	Adults	4	Cost saving
Front-of-pack nutritional labeling	Adults	5	Cost saving
Reduction of advertising of junk food and beverages to children	Children (0–14 years)	2	Cost saving
School-based education program to reduce television viewing	Primary schoolchildren (8–10 years)	3	Cost saving
Multifaceted school-based program including nutrition and physical activity	Primary schoolchildren (6 years)	3	Cost saving
School-based education program to reduce consumption of sugar-sweetened beverages	Primary schoolchildren (7–11 years)	3	Cost saving
Family-based targeted program for obese children	Obese children (10–11 years)	1	Cost saving
Multifaceted targeted school-based program	Overweight or obese primary schoolchildren (7–10 years)	3	Cost saving
Gastric banding: adolescent	Severely obese adolescents (14–19 years)	1	4,400
Family-based physician-mediated program	Overweight or moderately obese children (5–9 years)	3	4,700
Gastric banding: adults	Adults with BMI > 35 kilograms per square meters	1	5,800
Multifaceted school-based program without a functioning physical activity component	Primary schoolchildren (6 years)	3	21,300
Diet and exercise	Adults with BMI > 25 kilograms per square meters	1	28,000
Low-fat diets	Adults with BMI > 25 kilograms per square meters	1	37,000
Active After Schools Communities Program	Primary schoolchildren (5–11 years)	5	82,000
Weight Watchers	Adults	1	84,000
Lighten up to a healthy lifestyle weight-loss program	Adults	4	94,000
TravelSMART schools	Primary schoolchildren (10–11 years)	4	117,000
Orlistat	Adults with BMI > 30 kilograms per square meters	1	700,000
Walking School Bus Program	Primary schoolchildren (5–7 years)	3	760,000

Source: Gortmaker and others 2011.

a. Strength of evidence is based on criteria adopted in ACE Prevention Study. 1 = sufficient evidence of effectiveness. Effectiveness is shown by sufficient evidence from well-designed research that the effect is unlikely to be due to chance and is unlikely to be a result of bias. 2 = likely to be effective.

Effectiveness results are based on sound theoretical rationale and program logic, indirect or parallel evidence for outcomes, or epidemiological modeling to the desired outcome using a mix of evidence types or levels. The effect is unlikely to be due to chance. 3 = limited evidence of effectiveness. Limited effectiveness is demonstrated by limited evidence from studies of varying quality. 4 = may be effective. Effectiveness is similar to evidence of strength 2, but is potentially not significant and bias cannot be excluded as a possible explanation. 5 = inconclusive or inadequate evidence.

b. Net cost per DALY (disability-adjusted life year) saved = gross costs minus cost offsets divided by number of DALYs saved (costs only for reductions in obesity-related disease and not including unrelated health care costs).

Table __.2 **<<insert chapter number>>** Cost-Effectiveness Ratio of Select Obesity Prevention Interventions after 20 and 50 Years in Seven Countries: Organisation for Economic Co-operation (OECD) and WHO Analysis

Strategy and time period	*Brazil*	*China*	*England*	*India*	*Mexico*	*Russian Federation*	*South Africa*
20 years							
School-based interventions	†	704,863	†	†	†	830,177	†
Worksite interventions	8,270	7,785	45,630	6,151	37,912	6,187	25,409
Mass media campaigns	5,074	7,188	25,897	15,552	6,858	12,911	23,221
Fiscal measures	Cost saving	Cost saving	Cost saving	Cost saving	Cost saving	Cost saving	Cost saving
Physician counseling	8,503	9,390	25,284	6,155	23,811	5,982	23,841
Food advertising regulation	Cost-saving	556	25,672	3,186	11,151	5,718	13,241
Food labeling	9,962	71	12,577	952	3,974	396	7,953
50 years							
School-based interventions	93,350	35,174	152,989	59,665	235,957	26,114	153,233
Worksite interventions	3,541	3,393	20,506	4,491	16,932	2,926	14,561
Mass media campaigns	1,994	3,177	13,796	8,575	2,778	5,822	15,211
Fiscal measures	Cost saving	Cost saving	Cost saving	Cost saving	Cost saving	Cost saving	Cost saving
Physician counseling	5,156	5,718	15,731	5,553	15,108	4,331	16,591
Food advertising regulation	Cost saving	Cost saving	4,278	332	3,415	552	3,352
Food labeling	Cost saving	Cost saving	5,268	776	Cost saving	Cost saving	3,927
Cost-effectiveness threshold (US$ per DALY)[a]	15,000	5,000	50,000	2,500	20,000	15,000	15,000

Source: Cecchini and others 2010.

Note: Cost-effectiveness ratios are expressed in U.S. dollars per DALY averted and represent the net cost of gaining one additional year of healthy life, relative to a no prevention or treatment-only scenario. DALY = disability-adjusted life year.

† Cost-effectiveness ratio is higher than US$1 million per DALY.

a. For countries other than England, the guideline amount of three times GDP per capita (2005 U.S. dollars) is used as a cost-effectiveness threshold. In England, the National Institute for Health and Clinical Excellence uses a threshold of US$50,000 DALY to denote that an intervention is cost-effective.

Table __.3 **<<insert chapter number>>** Recommended Strategies for Obesity Prevention

Strategy	*Description*	*Cost-effectiveness*
Taxation of unhealthy foods and beverages and subsidies for healthy foods	Regulating food consumption and production should be aligned with evidence-based national dietary goals. Taxation, subsidies, and price adjustments can incentivize healthy choices and deter unhealthy choices.	✓✓
Food labeling	Nutritional labeling of foods can guide consumers in making healthy and informed dietary choices. Menu labeling in restaurants can positively influence food choices and intake. Awareness campaigns should precede or accompany labeling initiatives.	✓✓
Regulation of food and beverage advertising to children	Regulation of advertising targeted toward children should be adopted globally to reduce the adverse effects of marketing unhealthy foods and beverages to children.	✓✓
School and workplace interventions	Nutritional and physical activity education and improved standards of school meal programs, including healthy vending policies, should be part of the global childhood obesity prevention agenda. Workplace environments should facilitate access to healthy food options and promote active living.	✓

Note: ✓✓ = most cost-effective; ✓ = cost-effective. Of the six domains (nutritional and agricultural policies, food labeling, food advertising, school and workplace interventions, mass media, and urban planning) considered in our summary of population-level interventions to improve diet and physical activity for obesity prevention, the most cost-effective approaches were taxes on unhealthy foods and beverages or subsidies on healthy foods, food labeling, and regulation of advertising of unhealthy foods and beverages. These strategies can achieve large coverage at a relatively low cost of implementation and could feasibly be added to existing measures for preventing obesity and chronic disease. School and workplace interventions are also cost-effective in the long run and may be particularly useful in communities that are also managing undernutrition since healthy options that provide adequate nutrition can be provided.